REPORT

ON THE

SCIENTIFIC RESULTS

OF THE

VOYAGE OF H.M.S. CHALLENGER

DURING THE YEARS 1873-76

UNDER THE COMMAND OF

CAPTAIN GEORGE S. NARES, R.N., F.R.S.

AND THE LATE

CAPTAIN FRANK TOURLE THOMSON, R.N.

PREPARED UNDER THE SUPERINTENDENCE OF

THE LATE

Sir C. WYVILLE THOMSON, Knt., F.R.S., &c.

REGIUS PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF EDINBURGH
DIRECTOR OF THE CIVILIAN SCIENTIFIC STAFF ON BOARD

AND NOW OF

JOHN MURRAY, LL.D., Ph.D., &c.

ONE OF THE NATURALISTS OF THE EXPEDITION

DEEP-SEA DEPOSITS

Published by Order of Her Majesty's Government

PRINTED FOR HER MAJESTY'S STATIONERY OFFICE

AND SOLD BY

LONDON:—EYRE & SPOTTISWOODE, EAST HARDING STREET, FETTER LANE

EDINBURGH:—JOHN MENZIES & CO.

DUBLIN:—HODGES, FIGGIS, & CO.

1891

Price Forty-two Shillings.

EDITORIAL NOTE.

This Monograph on Deep-Sea Deposits forms the penultimate volume of the Official Reports on the Scientific Results of the Challenger Expedition.

The work connected with the examination and study of the samples of Deep-Sea Deposits, and the preparation of this Report for the press, have occupied a very large part of my time and attention for nearly twenty years, and my colleague, Professor A. F. Renard, has also given much of his time to the same studies during the past fourteen years. We hope the completed work may be regarded as an interesting contribution to our knowledge of the ocean, and prove useful to a large number of scientific men, as it is the first attempt to deal systematically with Deep-Sea Deposits, and the Geology of the sea-bed throughout the whole extent of the ocean.

There are three Appendices to the volume,—the first containing an explanation of the Charts and Diagrams; the second a Report on the Analysis of Manganese Nodules, by John Gibson, Ph.D., of Edinburgh University; and the third Analyses of Deposits and materials from the Deposits, by various Analysts.

The final volume of the Challenger Reports will give a detailed list of the organisms procured at each of the Observing Stations, together with other summary matter dealing with general questions of Oceanography, and will in all probability be published during the course of next year.

John Murray.

Challenger Office, 45 Frederick Street,
Edinburgh, *November* 4, 1891.

REPORT

ON

DEEP-SEA DEPOSITS

BASED ON THE

SPECIMENS COLLECTED DURING THE VOYAGE OF H.M.S. CHALLENGER

IN THE YEARS 1872 TO 1876

BY

JOHN MURRAY, LL.D., Ph.D.
ONE OF THE NATURALISTS OF THE EXPEDITION

AND

REV. A. F. RENARD, LL.D., Ph.D.
PROFESSOR OF GEOLOGY AND MINERALOGY IN THE UNIVERSITY OF GHENT

PREFACE.

During the Voyage of the Challenger, the collection, examination, and preservation of all the samples of deposits were undertaken by Mr. Murray. Mr. Murray had also charge of all the work carried on by means of tow-nets in the surface and sub-surface waters of the ocean, and gave much attention to the part played by pelagic organisms in the formation of marine deposits. During the voyage he submitted the results of his work in this direction to Sir Wyville Thomson, and the results are referred to in several of the Reports of Sir Wyville to the Hydrographer of the Admiralty, published in the Proceedings of the Royal Society of London.[1]

Towards the close of the Cruise a Preliminary Report was prepared by Mr. Murray on the Deposits and Surface Organisms, and published in the Proceedings of the Royal Society of London.[2]

On the return of the Expedition to England, Mr. Murray continued the examination of the large collections that were brought home, and published some papers dealing with the results of his work.[3]

In the year 1878 Professor Renard was invited by Sir Wyville Thomson to assist Mr. Murray in the examination and description of the Challenger collection of marine deposits, especially with reference to the mineralogical and petrographical aspects of the subject. Subsequently it was arranged that a Report on all available samples of Deep-Sea Deposits, whether collected by the Challenger or otherwise, should be published conjointly by Mr. Murray and Professor Renard.

During the years 1881 and 1882 Professor Renard spent several months in Edinburgh, when a large number of the deposits in the collection were examined in great detail, and the methods of examination and the order of

[1] See *Proc. Roy. Soc.*, vol. xxii. p. 423; vol. xxiii. pp. 32 and 245; vol. xxiv. pp. 33, 463, and 623.

[2] *Proc. Roy. Soc.*, vol. xxiv. pp. 471–544, 1876.

[3] "On the Distribution of Volcanic Debris over the Floor of the Ocean," &c., *Proc. Roy. Soc. Edin.*, vol. ix. pp. 247–261, 1876; "On the Structure and Origin of Coral Reefs and Islands, *ibid.*, vol. x. pp. 505–518, 1880.

the proposed publication were arranged. For the past ten years the work has been continuously carried on, and in the interval we have published preliminary papers dealing with our results.[1]

At the outset it was proposed to give a detailed description of every sample of deposit from depths greater than 100 fathoms, together with all that was known of the physical and biological conditions of the waters at the Stations from which the specimens were obtained. Nearly all the Challenger samples, and a very large number of samples collected by other Expeditions, were in fact thus examined and largely prepared for publication, with names of the species of organisms and all other particulars. It, however, became necessary to curtail the descriptions, and to limit them to the Challenger collections, so that the work ultimately assumed its present form.

The details with reference to the various samples of deposits collected by the Expedition are presented in tabular form in Chapter II. The more general conclusions and descriptions are given in a series of chapters dealing with the composition and distribution of the different types of deposits, and in the preparation of these chapters we have made use of all the materials in our possession. Professor Renard thinks it should be stated that Chapter IV., dealing with the materials of organic origin, has been written wholly by Mr. Murray.

We are much indebted to our friends, Sir William Turner and Mr. Robert Irvine, for reading different portions of the proofs, and giving us the benefit of their suggestions, and we have to thank the various analysts and other scientific men for valuable hints during the progress of the work. We desire to acknowledge our indebtedness to all those assistants who have aided us in the practical examination of the deposits, especially to Mr. Frederick Pearcey, who accompanied the Expedition and was afterwards assistant in the Challenger Office, and to Mr. James Chumley, who not only helped in the practical examination of the specimens, but has also rendered great assistance in the preparation of this volume for the press.

[1] "On the Microscopic Characters of Volcanic Ashes and Cosmic Dust, and their Distribution in Deep-Sea Deposits," *Proc. Roy. Soc. Edin.*, vol. xii. pp. 474–495, 1884; "On the Nomenclature, Origin, and Distribution of Deep-Sea Deposits," *ibid.*, pp. 495–529.

CONTENTS.

APPENDICES.

LIST OF ILLUSTRATIONS.

29 Lithographic and Chromo-lithographic Plates, with Explanations.

43 Charts showing the Distribution of Marine Deposits in colour, and the Dredging and Sounding Stations.

22 Diagrams showing the Vertical Distribution of Temperature and the Relations between the Deposits and Depth.

36 Woodcuts in the Text.

INTRODUCTION.

All the notions concerning the sea among ancient peoples were vague and elementary; the few facts known with reference to the phenomena of the ocean were limited to maritime nations like the Phœnicians. Among the learned men of antiquity two doctrines may be said to have prevailed with reference to the distribution of land and water. What may be called the Homeric School—to which Eratosthenes [1] and Strabo [2] belonged—held that the three continents of the old world formed a single island surrounded by the ocean. On the other hand, what may be called the Ptolemaic School regarded the Atlantic and Indian Oceans as enclosed seas like the Mediterranean, and maintained that the east and west points of the known world approached each other so closely that, sailing west from Spain, a ship might easily reach the eastern extremity. Thanks to the influence of Ptolemy,[3] this mistaken notion was perpetuated, and led about fourteen centuries after his time to the discovery of America by Columbus.

The ancients cannot be said to have had any definite conceptions of the deep sea. Experienced mariners, like the Phœnicians and Carthagenians, must necessarily have possessed some knowledge of the depths of the waters with which they were familiar, but this knowledge, whatever its extent, has been wholly lost. In the writings of Aristotle [4] we meet with the first bathymetrical data. He states that the Black Sea has whirlpools so deep that the lead has never reached the bottom; that the Black Sea is deeper than the Sea of Azov, that the Ægean is deeper than the Black Sea, and that the Tyrrhenian and Sardinian Seas are deeper than all the others.[5]

Polybius,[6] in estimating the time it would take for the Sea of Azov and Black Sea to be filled up by the alluvium brought down by the rivers flowing into them, states that the greater part of the Sea of Azov is only 5 to 7 fathoms in depth. Similar depths are shown on modern hydrographic charts.[7]

Posidonius [8] states that the sea about Sardinia had been sounded to a depth of 1000 fathoms—the greatest depth that had ever been attained.[9] This is the first record of a deep-sea sounding, and it would have been interesting had the writer given some information as to the methods employed by the ancients in these bathymetrical measure-

[1] 276–196 B.C. [2] Born about 60 B.C. [3] Lived about the middle of the second century A.D.
[4] 384–322 B.C. [5] Arist., Meteor., 114, § 29. [6] 204–122 B.C. [7] Polyb., iv. 39–42.
[8] Born about 135 B.C. [9] Posidon. ap. Strab., i. 3, § 9, p. 54; see E. H. Bunbury, History of Ancient Geography, vol. ii. p. 98, London, 1883.

ments; before we meet with similar definite statements on deep-sea soundings centuries pass away. Plutarch[1] says:—"The geometers think that no mountain exceeds 10 stadia (6067 feet) in height, and no sea 10 stadia in depth." Cleomedes[2] says:—"Those who doubt the sphericity of the earth on account of the hollows of the sea and the elevation of the mountains are mistaken. There does not in fact exist a mountain higher than 15 stadia (9107 feet), and that is also the depth of the ocean."

The documents of the Middle Ages relative to orography and bathymetry are indefinite and unimportant. The wide-spread opinion among sailors, that the greatest depth of the sea is found near the steepest coasts, appears to be very ancient, and is partly founded on fact. Ibn Khaldoun, who, in the fourteenth century, wrote his famous history of the Berbers, remarks that if the highest mountains are situated near the sea, it must be regarded as a providential arrangement to arrest the invasion of the ocean.[3]

Nicolaus Cusanus, who lived in the first half of the fifteenth century, invented an apparatus consisting of a hollow sphere, to which a weight was attached by means of a hook, intended to carry the sphere down through the water with a certain degree of velocity. On touching the ground the hook became detached, the weight remained at the bottom, the sphere ascended alone, and the depth was calculated by the time it took to return to the surface.[4] This apparatus was afterwards improved by Püchler, Alberti,[5] and Hooke,[6] but the various instruments produced were not satisfactory as regards sounding in the deep sea.

Science, and in a special manner what may be called the Science of the Globe, plays a large part in the intellectual and moral changes which characterise the transitional period known as the Renaissance. The thirty years from 1492 to 1522, through the discoveries of Columbus, Vasco di Gama, and Magellan, added a hemisphere to the chart of the world. Not only did these voyages double at a single bound all that was previously known of the surface of the earth, but by creating new ideas, enlarging the field of research, observations, and studies, they contributed more than anything else to the progress of the past four hundred years, and the rapid development of modern civilisation. The existence of the Antipodes, and the sphericity of the earth, were no longer scientific theories, but practically demonstrated facts; the fundamental principles of all scientific geography were for ever established.

During his voyage across the Pacific, Magellan[7] attempted, for the first time, to sound in the open ocean. Navigators at that time had sounding lines of only 100 and 200 fathoms in length. With these Magellan did not reach bottom between the coral islands of St. Paul's and Los Tiburones, and he somewhat naïvely concluded that this was

[1] Flourished towards the end of the first century A.D.
[2] Flourished probably in the second century A.D.
[3] Ibn Khaldoun, Histoire des Berbers, trad. de l'Arabe par M. le Slane, tom. i. p. 194, Paris, 1852.
[4] For description of this apparatus see Poggendorf, Geschichte der Physik, p. 116, Leipzig, 1879.
[5] 1404–1472 A.D. [6] 1635–1703 A.D. [7] 1470–1521 A.D.

the deepest part of the ocean.[1] Although the oceanic phenomena revealed at the surface of the sea were eagerly studied during, and immediately after, the time of the great discoveries to which we have just referred, the phenomena of the deep sea cannot be said to have engaged the attention of navigators and scientific men till after the lapse of several centuries.

In the first half of the seventeenth century Kircher reviews the doctrines as to the depth of the sea accepted in his time. He says:—"In the same manner as the highest mountains are grouped in the centre of the land, so also should the greatest depths be found in the middle of the largest oceans: near the coasts with but slight elevations the depth will gradually diminish towards the shore. I say coasts with but slight elevations, for if the shores are surrounded by high rocks, then greater depths are found. This is proved by experience on the shores of Norway, Iceland, and the Islands of Flanders."[2]

The first attempt to represent the bottom of the sea by isobathic curves is to be found in a map by Philippe Buache in 1737. These curves are intended to show that certain elevations of the sea-bottom correspond with the orography of the neighbouring land. In an essay on physical geography, published in 1752, he develops his ideas on this subject.[3]

Unsuccessful attempts were made by Captain Ellis in 1749, by Lord Mulgrave in 1773, and by Scoresby in 1817, to sound the ocean. Sir John Ross was more fortunate in 1818. During his first Arctic expedition he brought up 6 lbs. of mud from 1050 fathoms in Baffin's Bay. Soundings were correctly obtained in 1000 fathoms in Possession Bay, and worms and other animals were found in the mud procured. Sir James Clark Ross, during his Antarctic expedition,[4] after a number of unsuccessful attempts with the sounding lines in use, made a new line on board his ship, 3600 fathoms in length. With this a satisfactory sounding was obtained in 2425 fathoms in the South Atlantic, and another off the Cape of Good Hope in 2677 fathoms. On two occasions no bottom could be found with over 4000 fathoms of line. He also dredged successfully in depths of 400 fathoms. Some beautiful specimens of Corals, Corallines, *Flustra*, and a few Crustaceous animals were obtained.

A great impulse was given to deep-sea soundings when Lieut. Brooke, an officer in the United States Navy, invented his sounding machine in 1854, by which, applying Cusanus' idea of a detaching weight to the sounding line, the sinker was detached when the weight struck the bottom. This instrument was modified and improved by Commander Dayman, who employed it while sounding across the Atlantic in the region through which the Atlantic cable would require to pass. The introduction of steel wire

[1] Pigaffetta, Premier voyage autour du Monde, p. 53, Paris, l'an ix.
[2] Kircher, Mundus Subterraneus, p. 97.
[3] Buache, "Essai de géographie physique," &c., Hist. de l'Acad. des Sciences, 1752, p. 399.
[4] From 1839 to 1843.

by Sir William Thomson in 1870 was a still further improvement, and, indeed, since the commencement of submarine telegraphy, the process of taking deep-sea soundings has been rapidly perfected. Many submarine telegraph ships, surveying vessels, and even private yachts, have now been fitted with the most improved apparatus for sounding; so that, when it is desired to know the depth only, this can be ascertained expeditiously and with great accuracy.

During the past thirty years the ocean has been sounded in all directions, and we have in consequence a very correct notion of the general form and relief of all the great ocean basins and enclosed seas. Not only in a knowledge of the bathymetry of the ocean, but in an acquaintance with all the other conditions of the deep sea, there has been a rapid and important development, thanks to the investigations of the Challenger Expedition, as well as the previous and subsequent expeditions of this and other countries.

This Report being limited to a consideration of the sedimentary deposits of the deep sea, it seems desirable to indicate the views that have at different times been held with reference to marine sedimentation.

Herodotus[1] discussed the formation of alluvium at the entrance of the Nile, and the relations subsisting between land and sea, but on these it is unnecessary to dwell.

Plato,[2] in the myth of Atlantis, supposes a great extent of land situated in the external sea to have disappeared in one day and one night beneath the water of the ocean. Since that time, he adds, the Atlantic Sea has ceased to be navigable; its waters have become muddy and charged with clay derived from the engulfed land.[3]

Skylax of Coryanda,[4] in speaking of the sea which bathes the west of Europe, limits his remarks to saying:—"Beyond the Pillars of Hercules there are many Carthagenian commercial stations, much muddy water, high tides, and open seas."[5]

Aristotle[6] has no new views with regard to the great external ocean, which, he states, in accordance with the ideas generally admitted in his time, is muddy and little agitated by the winds.

Polybius[7] points out that in the Sea of Azov the rivers bring down considerable quantities of sediment. He estimates the time it will take for this fluviatile alluvium to fill up, not only the Sea of Azov, but also the Euxinus or Black Sea. The ideas of Polybius, from a geological point of view, are most reasonable, but the rate of encroachment has been much slower than he supposed during the 2000 years which separate us from the time when he wrote. The modifications in these seas have not been very appreciable.

Strabo[8] says: Running water works profound modifications on the surface of the

[1] 484–408 B.C.
[2] Born 429 B.C.
[3] Plato, Timæus, c. 5, 6, and Critiæs, c. 3, 8.
[4] Flourished in the middle of the fourth century B.C.
[5] Skylax, Periplus, 1.
[6] 384–322 B.C.
[7] 204–122 B.C.
[8] Born about 60 B.C.

land, and these changes are subordinate to the nature of the country through which streams and rivers pass. Torrents descending from mountains have a great erosive power, and the same is the case with rivers which flow over soft or sandy ground; both spread out on the plains and transport to the sea immense quantities of alluvial matter. The sediment from rivers is not transported to great distances, for matters in suspension are arrested by the movements of the sea; the bed of the ocean is not in consequence filled up so rapidly as one would think, but the places near the coasts are loaded with sandy materials, and it is here that the greatest modifications take place. He rejects the view that the sediment brought to the Black Sea by rivers could have had any considerable effect in filling up that sea and causing it to overflow. Strabo likewise attributed an active part to the winds in all the changes taking place at the surface of the globe. To the combination of all these forces he attributes what has, since his time, been called the sculpturing of the continents.[1]

Seneca[2] says: In virtue especially of its persistence and continuity, water acts on the solid bodies which constitute the land by dissolving and disintegrating them, and even transporting them, sometimes far from their place of origin. All rocks, even the hardest, are penetrated by water, which dissolves them at least partially. Seneca attributes the solvent action to the presence of a gas (spiritus); thermal springs possess the power of dissolving minerals in the highest degree. Among those which resist the least, he enumerates salt, sulphur, nitre, alum, bitumen, and lime. The matters dissolved by water are deposited again, and this precipitation is especially abundant when the waters are thermal and gaseous. He likewise explains the formation of calcareous tufas. He points out that the saline substances, held in solution by the aqueous element, may be absorbed by earthy layers, which in a way serve as a natural filter. What has just been said upon the chemical action of water shows that Seneca had clearly recognised those hydrothermic phenomena which play so important a role in geology.

Seneca's ideas regarding the mechanical action of water are not less just. The hardest rocks are not able to resist the repeated force exercised by a drop of water, and the erosive effects of water are most pronounced when the forces in play are those of rivers and the currents and waves of the sea, as may be observed in the beds of rivers and on bold coasts; everywhere on the land, water is to be seen victoriously attacking and destroying rocks. Its chemical effects often precede the mechanical action; this last finds its work half completed. Streams and rivers transport at all times, but especially during floods, clay, sand, and rocks picked up from the layers which they traverse. The erosive power of waves is, however, even

[1] See H. Fischer, Ueber einige Gegenstände der physischen Geographie bei Strab, als Beitrag zur Geschichte der alten Geographie, Wernigerode, 1879.

[2] Born a few years B.C.

greater than that of running water: cliffs broken and smashed into ruins are unquestioned witnesses of the work of destruction effected by the sea on coasts. Running waters deposit at their mouths the matters which they carry in suspension, thus forming the deltas of rivers. In their turn the mineral particles in suspension in marine waters are deposited at the bottom of the sea, often at considerable distances from the coasts. Among the factors which play a part in marine sedimentation, tides and currents are enumerated. Seneca points out, besides, that all waters, and especially those of the ocean, possess the power of cleansing themselves from all impurities; they may be said to wash the coasts and lay down near them all matters in suspension. During a series of centuries the lines of coasts undergo sensible modifications.[1]

A few notions regarding the geological action of water, the sediments carried into the sea and then solidified, are met with in the works of Kazwini,[2] and other Arab writers.

We find in Maçoudi[3] examples of the carriage of fluviatile sediments, whose accumulation causes the sea to retire. He had been profoundly impressed by the sanding up produced by the Tigris and Euphrates; he cites the case of the city of Hiza, formerly a sea-port, which, after the lapse of 300 years, was situated far in the interior.[4]

Albirouni[5] embraced the idea, previously expressed by Megasthenes, according to which Bengal has been formed by the accumulation of sediment deposited by the Ganges. The writings of this author also show that he had observed the distribution of materials transported by water; he points out that the larger fragments are deposited at the upper parts of rivers, that gravel is found lower down in their course, and finally, that sand and the finest particles are carried into the ocean.

In Italy, in the fifteenth century, Leonardo da Vinci wrote that the sea changes the equilibrium of the earth, that the shells accumulated in various layers have necessarily lived on the spot which the sea occupied. The great rivers, he says, carry into the ocean the waste of the land, and the deposits thus formed have been successively covered by others of various thicknesses, and finally the bottom of the sea has become the top of mountains.[6]

The Dane, Steno[7], endeavours to show that the carapaces of Crustacea are formed of matter secreted by the animal's body; he establishes the connection existing between fossils and the sedimentary layers which contain them, and the true origin of both. He was the first to distinguish the layers formed in the sea from those deposited in fresh water, and to notice the character of the shells in both instances. He concludes, from

[1] See A. Nehring, Die geologischen Anschauungen des Philosophen Seneca, Wolfenbüttel, 1873 and 1876.

[2] Flourished about 1263 A.D.

[3] Flourished about 915 A.D.

[4] Maçoudi, Les Prairies d'Or, texte et traduct. par MM. Meynard et Courteille, Paris 1861; see in particular the anecdote of Kaled and Abd-el-Meçih, tom. i. c. ix. pp. 216, 222.

[5] Flourished about 1000 A.D.

[6] See Venturi, Essai sur les ouvrages physico-mathématiques de Léonard da Vinci, Paris, 1797.

[7] De solido intra solidum naturaliter contento dissertationis prodromus, Florence, 1669.

his observations on the original character of these deposits, that the layers now found perpendicular, or inclined to the horizon, were horizontal at the time of their formation.

In 1740 Ant. Lazzaro Moro developed a system in which he attributes to frequently recurring submarine explosions the formation of mountains, plains, and islands. According to him the globe was primitively covered with water; on the third day of creation the crust which formed the bottom of the sea was raised. The mountains resulting from this upheaval are the primitive rocks, in which no fossils are found. At a later period there arose from the interior of the earth lava and other substances which accumulated on the bottom of the sea, and were upheaved in their turn through the same agency. With this second phenomenon were introduced diverse substances, such as salt, sulphur, and bitumen. As a natural consequence the water became salt, animals were developed in it, the earth became peopled about the same time, and the eruptions continuing produced an alternation of sedimentary and eruptive deposits.[1]

Arduino divided the Paduan, the Vicentin, and the Veronese mountains into primitive, secondary, and tertiary. The secondary mountains are for the most part formed of compact limestone in continuous strata, and contain petrified organised bodies. These strata vary in hardness, fineness of grain, composition, colour, and in the species of marine bodies they contain, since, according to him, there is but one kind in each stratum.[2]

Marsilli[3] makes a few observations on the bathymetric knowledge then possessed concerning the nature of the bottom of the sea; he admits that the basin of the sea was excavated "at the time of the creation out of the same stone which we see in the strata of the earth, with the same interstices of clay to bind them together." He adds that we should not judge of the nature of the bottom of the basins by the materials which seamen bring up in their soundings. They dredge almost always on a muddy bottom, and very rarely on a rocky one, because the latter is covered with slime, sand, sandy, earthy, and calcareous concretions, and organic matter. These substances, he says, conceal the real bottom of the sea, and have been brought there by the action of the water. These substances always cover stony masses. "Lastly," he adds, "to explain myself briefly, I may compare the bed of the sea to a cask, which, having long held wine, seems from the inside to be made of dregs of tartar, though it is really of wood." In the profiles which accompany his work, he has marked with dotted lines the stony parts of the bottom. In sea-bottoms of great extent, he distinguishes those which are covered with fine sand, or with a sandy conglutination; the part covered with fine sand is always that exposed to the flow of rivers.

[1] De crostacei e degli altri marini corpi, che si trovano sui monti, Venice, 1740.

[2] Di varie minere di metalli e d'altre specie di fossili delle montane provincie Venetae, &c., *Mem. Soc. Ital.*, tom. iv. 1788.

[3] Histoire physique de la mer, par L. F. comte de Marsilli, traduit par Boerhaave, Amsterdam, 1725.

The observations of Donati[1] on the bottom of the Adriatic led him to think that it is hardly different from the surface of the land, and is but a prolongation of the superposed strata in the neighbouring continent, the strata themselves being in the same order. They contain marble, stone, metals, and in some places sand, gravel, or clayey soil. He attributes to the nature of the sea-bottom the presence of certain substances in one place and their absence in another, and adds that he thinks this observation will explain why the earth has mountains and plains entirely destitute of marine bodies, whilst in other parts a great many are found, and why in some spots many varieties are found, and only one in others. Among the rocks formed in the Adriatic, Donati mentions marble, breccia, and calcareous tufa. The bottom of the Adriatic is covered with a layer formed by crustaceans, testaceans, and polyps, mixed with sand, and to a great extent petrified. This crust may be 7 to 8 feet deep, and he attributes to this deposit, bound together with the remains of organisms and sedimentary mineral matter, the rising of the bottom of the sea, and the encroachment of the water on the coasts.

In the great works of Wolfgang, Knorr, and Walet (1755–1773) we already find a distinction established between the fossil remains of pelagic animals and those of animals found on the sea-coast, and they express an opinion that the existing analogues of those that have not been found must exist in the deep seas as yet unexplored.

Beccari, towards 1729, created a new branch of conchology by the discovery of a small kind of polythalamous shell of nautiloid shape (*Nautilus beccarii*, Linn.). The coils of the helix and its transverse divisions give it a great resemblance to the ammonite—a term of comparison which was long adopted for all the other analogous Foraminifera, so plentiful in the marls of North Italy. Beccari counted more than 1500 in two ounces of this micaceous silico-calcareous sand.[2]

Ten years later G. Bianchi (better known by the name of J. Plancus) announced that he had found on the shore of Rimini the living analogue of the small fossil ammonite, and that its dimensions were such that it required 130 of them to equal the weight of a grain of wheat. He found a great many other species, which he still classed along with the nautilus and ammonite, on account of their internal divisions. His work[3] contributed much to increase our knowledge on this subject, and at a later period he pointed out, within a mile of Sienna, a bed of microscopic shells analogous to those found on the shores of Rimini.

Later on Soldani examined the clay of the tufa and sands of North Italy, and produced his work on the nautili and ammonites of Tuscany,[4] enriching science with a

[1] Essai sur l'histoire naturelle de la mer Adriatique, par le Dr. Vitaliano Donati, avec une lettre du Dr. L. Sesler, traduit de l'Italien, à la Haye, chez Pierre de Hondt, 1757, p. 6.

[2] Comm. Bonon., vol. i. p. 62.

[3] De conchis minus notis in littore Ariminiensi, Venice, 1730.

[4] Saggio orittografico ed osservazioni sopra le terre nautiliche ed ammonitiche di Toscana, with 25 plates, Sienna, 1780.

multitude of shells belonging to very small marine animals, then considered as nautili and ammonites—an error which lasted till 1835. As he assigned no particular names to the diverse forms, which he described and figured with care, and even grouped according to certain analogies, Soldani did not advance the knowledge of them as much as he might have done had he applied the then well-known nomenclature of Linnæus. In 1789–1797 he produced another very considerable work[1] on the microscopic shells found on the shores of the islands of Giglio, Elba, Massa, &c. He observes in this work that these small bodies are not young specimens which grow with age, but are perfect adults. The various species occupy various depths, and this explains, he adds, why those in a fossil state are not found mixed indifferently in all the strata.

In 1836 Professor C. G. Ehrenberg produced his first works. His name will ever remain inseparably connected with the discoveries relating to the microscopic organisms of the sea. It would be impossible to enumerate here the numerous memoirs and important publications of this micrographer, who devoted his whole life, with extraordinary activity, to microscopic organisms, to atmospheric dust, to the examination of material brought up from deep soundings, and to all questions appertaining to the sea. We must touch on one salient point, viz., the connection he established between certain classes of living microscopic organisms, and the part they played in geological times. As early as 1836 he showed that the siliceous strata, known as "Tripoli," found in various parts of the globe, especially at Bilin in Bohemia, were but an accumulation of the skeletons of Diatoms, Sponges, and Radiolaria; he pointed out that similar strata were formed now-a-days by Diatoms in the subsoil of Berlin. In 1839 his observations at Cuxhaven revealed the presence of living Diatoms and Radiolarians on the surface of the Baltic, of the same species as those found fossil in the Tertiary deposits of Sicily and Oran. He showed, moreover, that in the Diatom layers of Bilin the siliceous deposit had, under the influence of infiltrated water, been transformed into compact opaline masses. Starting from these facts, he concluded that rocks similar to those which play so important a part in the terrestrial crust are still being formed on the bottom of the sea.

Humboldt addressed a letter to Lord Minto, First Lord of the Admiralty, with reference to Sir J. C. Ross's Antarctic Expedition, calling attention to the importance of studying the microscopic organisms, which Ehrenberg had shown played so important a role in the constitution of terrestrial strata. Dr. Joseph Hooker, who was attached as naturalist to the expedition, observed[2] that the waters and ice of the Antarctic regions swarm with Diatoms to such an extent that they give the water a brown tint. Between lat. 50° and 70° S. prodigious quantities of them were found, and in 80° S. lat. all the surface ice, the sides of the icebergs, and the base of the great Victoria Barrier within the limit of the waves, were coloured brown by these organisms. He remarks that the siliceous

[1] Testaceographia et zoophytographia parva et microscopica, with 179 plates.
[2] *Brit. Ass. Report* for 1847.

skeletons must, after the death of the organisms, form siliceous deposits of considerable extent around all coasts bordered with ice, at depths between 80 and 400 fathoms. Opposite Victoria Barrier the bottom was covered with a white or greenish mud, consisting principally of Diatom frustules. In very deep water, opposite Victoria and Graham's Land, the mud was very pure and fine grained, but in shallow water, near the coast, it was mixed with sandy and gravelly particles. Hooker considered that these microscopic plants were intended to maintain in the south Polar regions the balance between the animal and vegetable kingdom, and also to purify the vitiated atmosphere, performing in Antarctic latitudes the part of vegetation in other regions. He states that Diatoms exist in every latitude from Spitzbergen to Victoria Land, Iceland, Great Britain, the Mediterranean, North and South America, and the islands of the South Sea, and that the frustules of species living in the Antarctic have contributed to the formation of various strata during geological periods. He estimates that the deposit formed principally of Diatom frustules extends continuously for more than 400 miles off Victoria Land, at depths of about 300 fathoms. The existence of remains of Diatoms, including a few Antarctic species, in volcanic ashes, pumice, and scoriæ, led him to suppose that organic substances covering the bases of active volcanoes, like Mount Erebus and Vesuvius, might be ejected from the craters along with volcanic products.

In 1840 Edward Forbes joined, as naturalist, the surveying ship "Beacon" while in the Mediterranean, and for eighteen months he studied the Ægean Sea and its shores, taking more than one hundred dredgings at different depths down to 130 fathoms. Before Forbes' time the bathymetrical distribution of marine animals had been investigated to a certain extent, but the works of Audouin and Milne-Edwards (1830), Sars (1835), and Oersted (1844), applied only to the more superficial waters of the sea. Forbes studied the question with regard to animals inhabiting deep water, and in 1844 published his memoir, "On the Light thrown on Geology by Submarine Researches."[1] He maintains that the dredgings show the existence of distinct regions at successive depths, having each a special association of species. He remarks that the species found at the greatest depths are also found on the coasts of England, and he concludes, therefore, that such species have a wider geographical distribution. Forbes divided the area occupied by marine animals into eight zones of depth, in which animal life gradually diminished with increase of depth, until a zero was reached at about 300 fathoms. He shows that in Cretaceous and Tertiary layers similar zones may be distinguished, and that depth must have been in former times, as it is now, one of the factors in the distribution of marine organisms. He found fewer species in the deep zones than in the shallow ones, and supposes that plants, like animals, disappeared at a certain depth, the zero of vegetable life being at a less depth than that of animal life. Forbes concluded that, as nearly all marine basins are over 300 fathoms in depth, most of the sedimentary beds must be void

[1] *Edinburgh New Phil. Journ.*, vol. xxxvi. p. 318.

of organic remains, and the absence of organisms in certain strata convinced him that they had been formed at great depths or deposited prior to the existence of organisms. He observed that the number of organisms belonging to colder regions increased with the depth of water, and in the deeper zones of warm latitudes species are noticed which are inhabitants of the littoral zones of the highest latitudes. Forbes also showed that all sea-bottoms are not equally fit for the development of life, for in all the zones he found areas less peopled than others, these areas being mostly formed of ooze and sand, and inhabited only by creatures whose remains were not likely to be met with in a fossil condition. He explains the alternation of layers with and without fossils by changes in the level of the sea-bottom of the time. The science of Oceanography was greatly advanced by the researches of Forbes, more especially with regard to the distribution of marine animals,[1] and in this respect Lovén also materially contributed to the science.

In 1845 Professor W. C. Williamson described some Foraminifera, Diatoms and Sponge spicules from some Mediterranean muds, and, in discussing the origin of limestone strata in shallow and deep waters, he suggests that the whole of the calcareous organisms may be removed by carbonated waters.[2]

In 1846 Captain Spratt, R.N., dredged from 310 fathoms, 40 miles east of Malta, eight species of Mollusca, and he expressed the opinion that life exists at much more considerable depths; later, when surveying the Mediterranean between Malta and Crete, he obtained fragments of shells from a depth of 1620 fathoms. Both Spratt and Lovén arrived at conclusions which proved the influence of temperature on the distribution of marine animals.

In 1851 Professor J. W. Bailey applied himself to the microscopic study of the soundings collected by the U.S. Coast Survey within 100 fathoms,[3] and he showed the important part played by Foraminifera in the deposits some distance off the coast of New Jersey. Owing to the abundance of these calcareous organisms the deeper deposits differed considerably from the shore deposits, in which mineral particles, especially quartz, predominated. In 1856 he made known the nature of the soundings collected by Brooke in the Sea of Kamchatka in depths of 900 to 2700 fathoms.[4] He remarks that in all the samples mineral matters diminished with increase of depth, and that while the mineral particles decreased the organic remains increased. Of organic remains Diatoms predominated,

[1] In 1850 Forbes presented his first general Report on the Marine Zoology of the British Islands to the British Association. This Report was of great importance to science, and in it he indicated the desirability of prosecuting further researches in the North Atlantic, opposite the Hebrides, around the Shetlands, and between the Shetland and Faroe Islands, thus pointing to a field of exploration which twenty years later became the scene of the investigations of Carpenter, Thomson, and Gwyn Jeffreys, and still more recently of Murray and Tizard.

[2] "On some of the Microscopical Objects found in the Mud of the Levant and other Deposits," &c., *Mem. Lit. and Phil. Soc., Manchester*, vol. viii. pp. 1–128, 1847.

[3] "Microscopical Examination of Soundings made by the U.S. Coast Survey off the Atlantic coast of the United States," *Smithsonian Contributions to Knowledge*, vol. ii., article iii. pp. 1–15.

[4] *Amer. Journ. Sci.*, ser. 2, vol. xxi. pp. 284–285, 1856.

Sponge spicules and Radiolarians being also present, while the calcareous tests of Foraminifera were absent. These deposits of microscopic organisms, in their richness, extent, and high latitude, resemble the siliceous deposits of the Antarctic already noticed by Hooker. Bailey's researches proved that localised deposits were formed in the high seas, in which not calcareous, but siliceous, remains predominated. The excellent state of preservation of these siliceous organisms, and the fact that many of them still retained the soft parts, led him to conclude that they must have been living up to a very recent period, not necessarily at the great depths where they were found, but probably drifted from shallower deposits.

About the same time Bailey published his work on the origin of greensand and its formation on the bottom of modern seas.[1] Ehrenberg had long before observed a pseudomorphism of the calcareous shells of Foraminifera in the Chalk into silica. As early as 1845 Bailey had called attention to the casts of Foraminifera in the Eocene marls of Fort Washington.[2] Mantell stated in 1846[3] that casts of Foraminifera and their soft parts were preserved in flint and limestone, and that the chambers of the Foraminifera were often filled with calcite, silica, or silicate of lime. But Ehrenberg was the first to show the connection between greensand and the Foraminifera, and to throw light on a point which had long puzzled geologists. In 1855 he says that, in all the examples he had examined up to that time, greensand must be considered as due to the filling up of organic cells of Foraminifera, like a lithoid mould.[4] Bailey verified Ehrenberg's results from the examination of a number of Cretaceous and Tertiary rocks of North America.

Pourtalès in 1853 announced that he had obtained from a depth of 150 fathoms, in lat. 31° N., long. 79° W., a deposit formed of almost equal parts of *Globigerinæ* and black sand, probably greensand.[5] Bache showed these and similar samples, taken in the region of the Gulf Stream, to Bailey, who found in them casts of organisms, some of which were "well-defined greensand, others reddish, brownish, or almost white."[6] He concludes that these glauconitic casts have not been transported from ancient formations, but have been formed where they were found in the same manner as in geological formations. He states that his own and Ehrenberg's researches prove that other organisms, besides Foraminifera, may serve as moulds for the greensand, and he notices that with the well-defined casts are associated green grains less regular in form, "having merely a rounded, cracked, lobed, or even coprolitic appearance."[7] The phenomena accompanying the decomposition of organic substances, he says, are closely connected with the formation of this mineral—a green or red silicate of iron or almost pure silica.

In 1856 Lieut. Berryman, in the steamer "Arctic," sounded across the North Atlantic, and obtained samples of the deposit from thirty-four points between St. John's, New-

[1] *Proc. Boston Soc. Nat. Hist.*, vol. v. pp. 364–368, 1856.
[2] *Amer. Journ. Sci.*, vol. xlviii. p. 341.
[3] *Phil. Trans.*, p. 466, 1846.
[4] *Monatsb. d. k. Akad. Wiss. Berlin*, 1855, p. 172.
[5] Report U.S. Coast Survey for 1853, App., p. 83.
[6] *Loc. cit.*, p. 367.
[7] *Loc. cit.*, p. 368.

foundland, and Valentia. These deposits were described by Bailey,[1] who, from the fact that the mineral particles were angular, concluded that there is little movement at the bottom in deep water, otherwise the mineral fragments would be rounded. He observed the abundance of calcareous matter due to the accumulation of microscopic shells, which fall to the bottom after the death of the organisms. Bailey also observed the presence of volcanic ashes in the deposits, and remarked that the Gulf Stream had spread these "plutonic tallies" over thousands of miles. Some doubt having arisen as to whether these ashes might not have been thrown overboard from passing steamers, Bailey compared the two, and arrived at the conclusion that the substances found on the bottom of the Atlantic were really of volcanic origin; Maury supposed that this dust might have been carried by the wind from volcanoes in Central America or from extinct volcanoes in the Western Islands. By treating the deposits with acid, Bailey showed that there is always a small quantity of mineral particles in organic calcareous sediments, though veiled by the preponderance of the calcareous element, and that the calcareous organisms increase in abundance as the Gulf Stream is approached. He found only imperfect casts of Foraminifera in the deposits off the northern coasts, the green casts being generally met with in the more southerly soundings.

Lieut. Maury, in the latest (9th) edition of his "Sailing Directions," 1858, gives an abstract of the knowledge of marine deposits possessed up to that time. He estimated the part taken by calcareous or siliceous microscopic organisms in pelagic deposits, based upon Bailey's observations. He agrees with Bailey that the animalculæ, whose remains are found at the bottom of the sea, lived in the surface waters; but he carries the idea too far when he asserts that the absence of light, low temperature, and pressure preclude the possibility of life in very deep water. Ehrenberg held the opposite opinion regarding the habitat of these microscopic organisms, based upon the presence of organic substances in the shells dredged from the bottom of the sea, and argued that he distinguished forms in the deposits to be found nowhere else; but tow-net observations have since proved that forms identical with the most abundant of these shells from the bottom live in the surface waters.

In 1857 Captain Dayman sounded across the North Atlantic in H.M.S. "Cyclops," along the great circle between Valentia and Trinity Bay, Newfoundland, a little to the north of Berryman's line of soundings. He states that in his deepest sounding the deposit consisted of a plastic floury substance or ooze, which stuck to the line when drawn up.[2] Dayman's soundings were examined and reported on by Professor Huxley,[3] who found the samples obtained between 1700 and 2400 fathoms to be remarkable for their uniformity; in the bottles containing them Huxley observed a viscous substance, and

[1] *Amer. Journ. Sci.*, ser. 2, vol. xxi. pp. 284–285.

[2] Deep-Sea Soundings in the North Atlantic, made in H.M.S. "Cyclops," in June and July 1857, London, published by the Admiralty, 1858.

[3] Appendix to Dayman's Report.

small round corpuscles soluble in acid, which he called Coccoliths, and which he regarded as the skeletal parts of a supposed gigantic Monera—*Bathybius*—wide-spread over the sea-bottom. When dry the deposit looked like chalk, and he observed that the calcareous organisms formed the principal part, *Globigerina* shells making up 85 per cent. of the mass; siliceous organisms were also present, including *Coscinodiscus* and other Diatoms. He considers the Globigerina Ooze to be of high scientific interest on account of its extent, depth, and resemblance to the Chalk, and discusses the question of the habitat of the Foraminiferous shells constituting the major part of the deposit. He does not express a decided opinion as to whether the shells have been transported from shallower water, whether the animals lived in the surface waters, from whence, after death, they subsided to the bottom, or whether they actually lived at the bottom in deep water, but seems to prefer the last hypothesis, concluding by saying: "I abstain at present from drawing any positive conclusion, preferring rather to await the result of more extended observations."

Dr. Wallich, in 1860, accompanied H.M.S. "Bulldog" as naturalist when surveying in the North Atlantic for the American cable. In discussing the results of his examination of the deposits obtained[1] he endeavours to trace a connection between the Globigerina Ooze and the Gulf Stream, pointing out that the shells are abundant in the deposits between the Faroe Islands and the east coast of Greenland, and in a large portion of the direct line between Cape Farewell and Rockall, but are absent or rare in the deposits between Greenland and Labrador. In the southern hemisphere calcareous deposits had been found on the Agulhas Bank at a depth of 90 fathoms, in which the *Globigerina* shells made up 75 per cent. of the sediment; he suggested that the area covered by this deposit depended on the current flowing round the Cape from the east. Wallich came to the conclusion that many of the fossiliferous strata, hitherto regarded as having been deposited in shallow water, may possibly have been deposited at a great distance from the surface.

A considerable quantity of mud from the North Atlantic, 2500 fathoms, was handed by Huxley to Professor Gümbel,[2] who found it to consist of Foraminifera, with Radiolarians, Diatoms, Sponge spicules, Ostracodes, and mineral particles. Gümbel expresses the opinion that these mineral particles were transported by currents, and concludes that if such heavy materials could have been conveyed so far from the coasts, clayey matters would have been transported at the same time, and that the clayey deposits of ancient formations might have a similar origin. He confirmed Huxley's observations on Coccoliths, and found similar bodies in numerous geological strata; he also agrees with Huxley as to the existence of the Monera, *Bathybius*.[3]

[1] The North Atlantic Sea-bed, London, 1862.

[2] See *Nature*, vol. iii. pp. 16, 17, 1870.

[3] *Bathybius* was believed to be a gigantic Monera, covering with a network of organic matter the whole of the sea-bottom in the greater depths of the Indian and Atlantic Oceans (see Huxley, *Quart. Journ. Micros. Sci.*, N. S., vol. viii. p. 203, 1868; *Proc. Roy. Geogr. Soc.*, vol. xiii. p. 110, 1869). Mr. Murray has shown that what was supposed to be a gigantic Monera (*Bathybius*) consisted of the gelatinous sulphate of lime thrown down from the sea-water, with which the specimens of the ooze were impregnated, by the alcohol used in the preservation of the samples (see Narr. Chall. Exp., vol. i. p. 939).

The dredgings and soundings along the coast of America, taken by the U.S. Coast Survey in 1867, were subsequently examined by Pourtalès. He found among the deposits two well-marked varieties, siliceous and calcareous; the siliceous deposits extended along the coast as far as Cape Florida. The calcareous deposits are divided into Coral and Foraminiferous formations, the latter found in the greatest depths. He also distinguished a muddy deposit, which he considered quite subordinate and related to the Tertiary formations.[1]

Pourtalès also gives a description of the different stages in the formation of glauconite. He says :—"We find, side by side, the tests perfectly fresh, others still entire, but filled with a rusty-coloured mass, which permeates the finest canals of the shells like an injection. In others, again, the shell is partly broken away, and the filling is turning greenish; and finally we find the casts without trace of shell, sometimes perfectly reproducing the internal form of the chambers; sometimes, particularly in the larger ones, cracks of the surface or conglomeration with other grains obliterates all the characters. They even coalesce into pebbles, in which the casts can only be recognised after grinding and polishing."[2] Pourtalès observes that these glauconitic grains are deposited in depths of 50 to 100 fathoms near the coasts of Georgia and South Carolina.

L. Agassiz discussed the results of Pourtalès' observations, and states that what he had seen of deep-sea deposits seemed to indicate that no recent or ancient formation ever occurred in very deep water. He concludes that the present continental areas within the 200-fathom line, as well as the oceans, have preserved their outlines and positions from the earliest times.[3]

In the Reports of Carpenter, Wyville Thomson, and Gwyn Jeffreys, on the cruises of H.M.SS. "Lightning," "Porcupine," and "Shearwater,"[4] there are many references to the marine deposits collected in the sounding tube and dredges. A comparison is especially drawn between the White Chalk and the Atlantic mud or ooze; in the earlier Reports it was suggested that "we are still living in the Cretaceous epoch," and in later ones that the Atlantic mud "might have been accumulating continuously from the Cretaceous or even earlier periods to the present day."[5]

In 1871 Delesse published his work "Lithologie du Fond des Mers," treating more particularly of coast sediments from the seas of France; it forms an important contribution to our knowledge of marine deposits, and contains lithological charts founded upon the official charts published by the European and American Governments.

The Challenger Expedition left England in 1872, and during the cruise, which lasted nearly three and a half years, many preliminary notices were published by Wyville

[1] Report of the Superintendent of the United States Coast Survey for 1869, pp. 220–225, Washington, 1872.

[2] *Loc. cit.*, p. 224.

[3] *Bull. Mus. Comp. Zoöl.*, vol. i. pp. 368, 369, 1869.

[4] From 1868 to 1870; published in *Proc. Roy. Soc.*

[5] Thomson, The Depths of the Sea, p. 470, London, 1874.

Thomson, Murray, and Buchanan,[1] dealing with the nature and origin of the marine deposits procured in the various sounding and dredging operations.

Since the return of the Challenger Expedition very many samples of marine deposits have been collected from nearly all regions of the ocean basins by the surveying vessels of the British Navy, by the telegraph ships belonging to the India-rubber, Gutta-percha, and Telegraph Works Company, and to the Telegraph Construction and Maintenance Company, and by Norwegian, Italian, French, German, and American Expeditions. The great majority of these samples have passed through our hands, and have, along with the Challenger collections, formed the material for our investigations.

In the present work we have endeavoured to point out the composition and mode of formation of marine deposits in general, as well as the distribution of the different types over the floor of the ocean. In many cases we have indicated the resemblances and differences between these deposits and certain geological formations, but we have not discussed in detail the wider geological bearings of the results arrived at from these researches. If it be remembered that, previous to the recent scientific explorations of the great ocean basins, we possessed no positive knowledge concerning the organic and mineralogical components of the deposits now forming over more than one-half of the earth's surface, the importance of the Challenger's discoveries, as to the nature of the sea-bed, on all inquiries regarding the past history of our globe will be readily appreciated.

The large amount of material at our command has enabled us to divide marine deposits into two great categories—Terrigenous Deposits and Pelagic Deposits.

The Terrigenous Deposits include those now forming along the littoral zone, in shallow water, and on the continental slopes beyond the 100-fathom line. They are, for the most part, composed of materials washed down from emerged land, the various components exhibit abundant traces of mechanical action, and the accumulation is relatively rapid. Among these terrigenous deposits it is possible to recognise an accumulation of materials analogous to those forming certain schistose rocks, shales, marls, greensands, chalks,[2] phosphatic and other limestones,[3] volcanic grits, quartzites, and sandstones of geological formations.[4]

[1] See *Proc. Roy. Soc.*, vol. xxiv., 1876

[2] The nature of the mineral particles and pebbles of the chalk, the evidences of mechanical action, the variability of the residue of the chalk, the chemical analysis, the character of the organic remains, and the position of the Cretaceous sea, all point to the white chalk being formed near shore, and not in the abysmal regions of a deep ocean like a typical Globigerina Ooze (see L. Cayeux, "La Craie du Nord de la France et la Boue a Globigérines," *Ann. Soc. géol. du Nord*, tom. xix. pp. 95–102, 1891, and other papers by the same author). The same remarks are applicable to certain calcareous and siliceous rocks of the Alps (see F. Wähner, "Aus der Urzeit unserer Kalkalpen," *Zeitschr. d. Deutschen und Oesterr. Alpenvereins*, Bd. xxii. pp. 87–124, 1891).

[3] In some terrigenous deposits there appears to be distinct evidence of the commencement of dolomitisation.

[4] The area covered by terrigenous deposits (from the coast line seaward to an average distance of about 200 miles, and down to an average depth of about two miles) has been called by Mr. Murray the Transitional Area. It covers about one-seventh, while the land surface occupies two-sevenths, and the pelagic deposits four-sevenths of the earth's surface. Mr. Murray holds that all the marine stratified rocks of the continents have in past times been laid down in regions corresponding to the Transitional Area.

The Pelagic Deposits are formed in the deep water of the central regions of the great ocean basins, and consist of organic oozes and a reddish clay. They are chiefly made up of the calcareous and siliceous remains of organisms that have fallen to the bottom from the surface waters, along with clay and volcanic debris in a more or less advanced state of decomposition. There is little or no trace of mechanical action on the components of these Pelagic Deposits, their accumulation is relatively slow, and among them there do not appear to be any accumulations of materials identical with the marine stratified rocks of the continental areas. It seems doubtful if the deposits of the abysmal areas have in the past taken any part in the formation of the existing continental masses.[1]

An inspection of Chart 1, showing the horizontal distribution of deposits, and an examination of the accompanying descriptions, will show that the various types of deposits pass insensibly the one into the other, and that a slight alteration in the depth is frequently sufficient to produce a marked difference in the character of the deposit, the other conditions remaining unchanged. So slow does the growth of the deposit in some red clay areas appear to have been that not more than a few inches have accumulated since the Tertiary period. The various components have consequently undergone much alteration, and numerous new secondary products have been formed. In these abysmal deposits, as well as in those close to the coasts, it will be seen that synchronous deposits may thus differ widely in their mineralogical and biological composition, even when the conditions at the surface of the ocean are almost identical.

[1] We have examined hand specimens of Tertiary or recent rocks from the Barbados, the Solomon Islands and other oceanic islands of the Pacific, which approach closely in character to Pteropod Ooze, Globigerina Ooze, Red Clay, and Radiolarian Ooze (see Harrison and Jukes-Browne, "The Geology of Barbados," published by authority of the Barbadian Legislature, 1890; H. B. Guppy, "Observations on the recent calcareous formations of the Solomon group made during 1882–84," *Trans. Roy. Soc. Edin.*, vol. xxxii. pp. 545–581, 1885).

CHAPTER I.

ON THE VARIOUS METHODS OF OBTAINING, EXAMINING, AND DESCRIBING DEEP-SEA DEPOSITS.

a. Methods employed on board Ship.

The various instruments employed on board ship for the purpose of obtaining information with reference to the deposits now forming on the floor of the ocean have been described in detail in the Narrative of the Cruise.[1] In this place it is, however, proposed to refer briefly to these instruments with the view of pointing out the quantity of these deposits procured by the different methods, under various conditions as to depth, locality, and nature of the bottom.

The ordinary deep-sea sounding lead, from 12 to 14 lbs.[2] in weight, armed with lard, often gives valuable and reliable information concerning the deposits in all depths under 100 fathoms.[3] This is especially the case where the bottom is hard, sandy, or rough, and if the lead be used frequently over a considerable area, and the particles be examined by the microscope after being freed from the grease by means of turpentine or naphtha.

The Cup Lead (Fig. 1) is a modification of the ordinary deep-sea lead (A), with an iron spike (C) driven into its lower end; at the bottom of this spike is an inverted hollow iron cone (B), and above the cone is a sliding iron disc (D) movable up and down the spike between the bottom of the lead and top of the cone, and just large enough to cover the opening of the cone when resting upon it. During the descent of the lead the disc is raised off the cone by the friction of the water, so that on reaching the bottom the cone is forced into the mud, and is filled with the mud or other loose material forming the deposit. On the lead being drawn up through the water, the friction of the water forces down the sliding disc (D) on the top of the cone (B), and thus prevents the contents from being washed out.

The Valve Lead (Fig. 2) is another modification of the deep-sea lead, fitted at its base with an iron cylinder (A) having a common butterfly valve (B) at the bottom. This form of lead was found in practice to be the best for all ordinary soundings in depths under 300 fathoms.[4] The cylinder being made to unscrew, the contents can be collected expeditiously, and usually without much loss. Even when the cylinder contained no specimen from the bottom, an examination of the lower edges would often

[1] Narr. Chall. Exp., vol. i. pp. 56 *et seq.*
[2] 5·5 to 6·4 kilogrammes.
[3] 183 metres.
[4] 549 metres.

indicate the nature of the rock or other hard substance upon which the instrument had struck. In sounding in enclosed arms of the sea, such as the lochs of the west of Scotland, where the deposit is a soft mud, although the depths are usually under 100

FIG. 1.—The Cup Lead.
A, ordinary deep-sea lead; B, inverted hollow iron cone; C, iron spike; D, sliding iron disc.

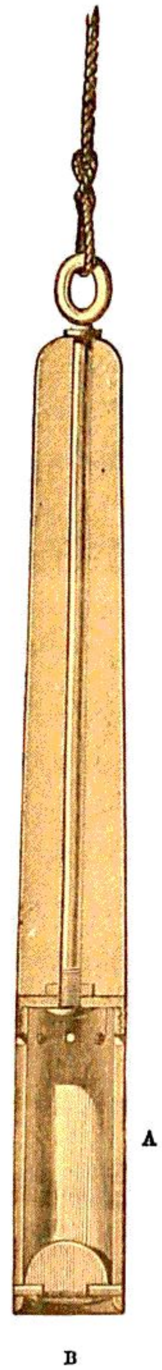
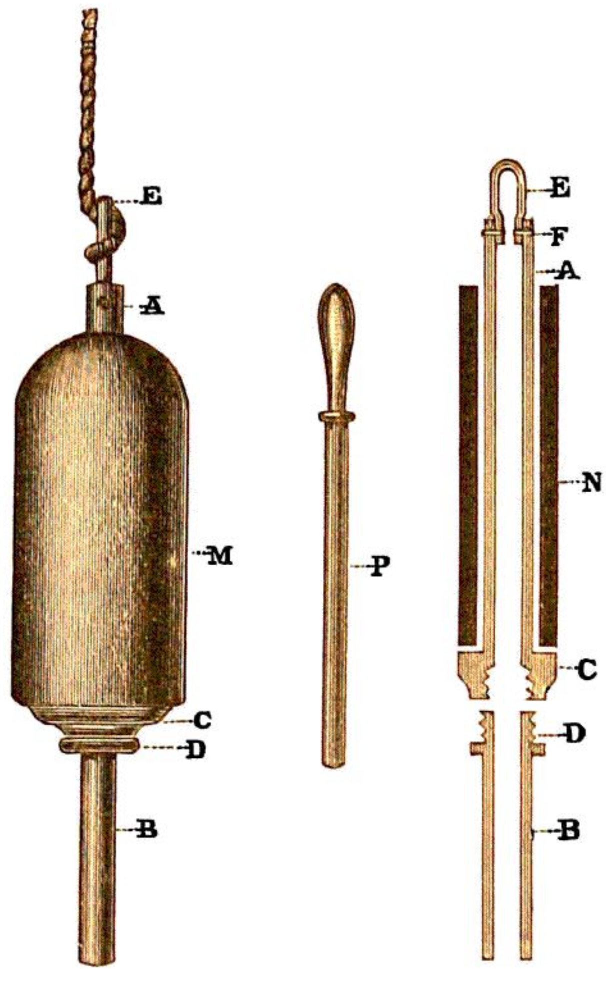


FIG. 2.—The Valve Sounding Lead.
A, iron cylinder; B, butterfly valve.



FIGS. 3, 4.—Buchanan's Improved Sounding Lead.
A and B, brass tube 1 inch (25·4 mm.) in diameter in two pieces, at lower end of the upper piece a shoulder C, with a thread screw, receives the corresponding shoulder D of the lower piece. The leaden weight M or N rests on the shoulder C. When used, tube B is filled with a plug or cylinder of the mud, the upper part containing water. The plunger P is used to push out the plug of mud from B when the latter is unscrewed at D. The weight M is 14 lbs. (6·4 kilogrammes), the weight N, 3 lbs. (1·4 kilogrammes). A comb valve may be fitted at the lower end of the tube if necessary (see L, Fig. 7).

fathoms, a modification of this tube is desirable, so as to procure a section of the mud by plunging the tube deep into the deposit. Such a modification was devised by Mr. Buchanan and is represented in Figs. 3 and 4.

The Hydra Sounding Machine, or the *Baillie Sounding Machine*, represented in the cuts Figs. 5 and 6, were always used on board the Challenger for the deeper soundings, the latter being exclusively employed during the last two years of the cruise. In these the iron

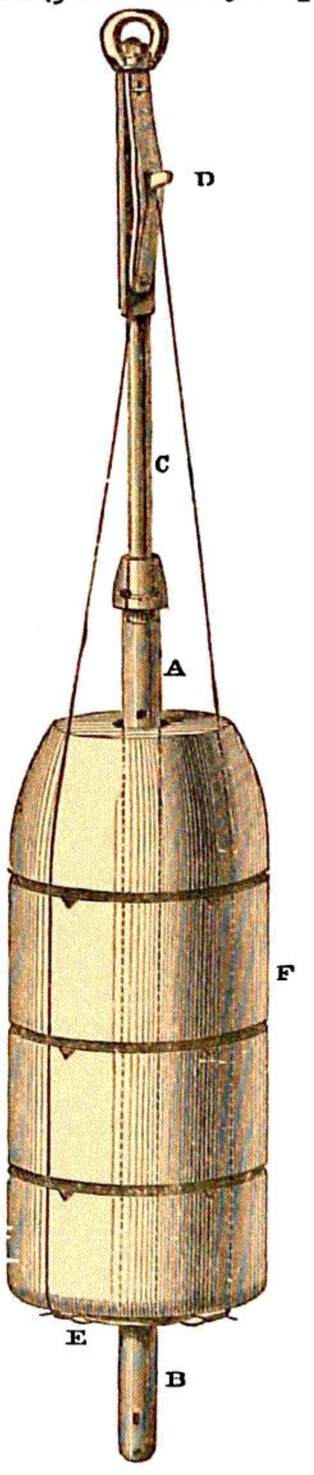


FIG. 5.—Hydra Sounding Machine.

A, brass cylinder with butterfly valve B at the bottom and a sliding iron rod C at the top; D, stud over which the wire attached to the washer E, and thus supporting the weights or sinkers F, is passed.

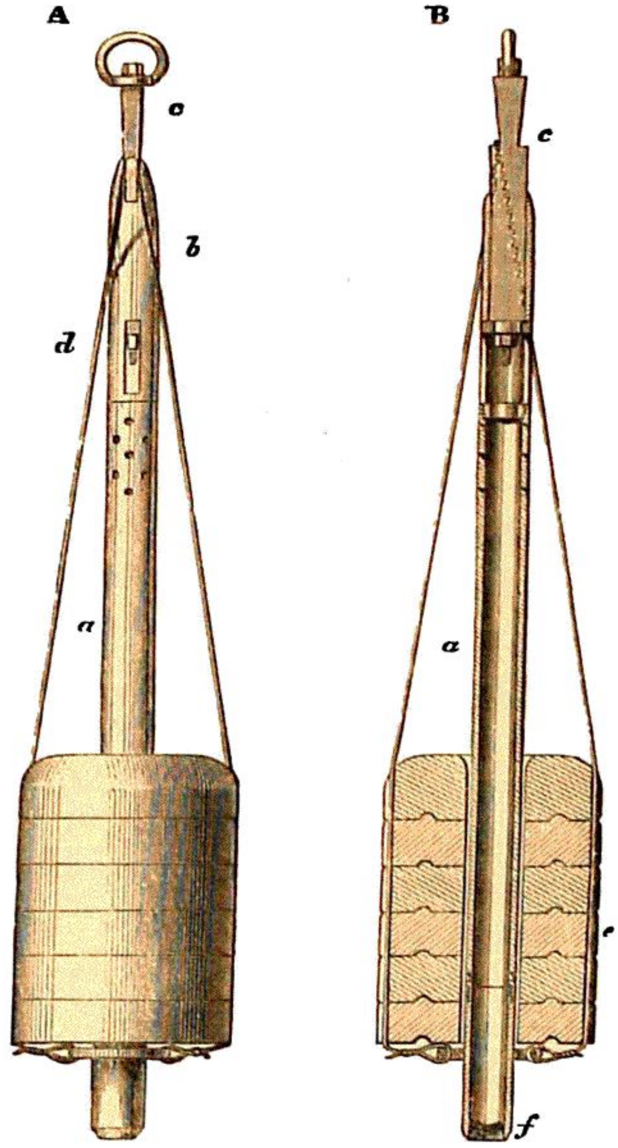


FIG. 6.—Baillie Sounding Machine.

a, iron cylinder with butterfly valve *f* at the bottom and brass tube *b* at the top; *c*, cylindrical iron weight sliding backwards and forwards in *b*, regulated by the slit *d*; *e*, iron weights.

weights or sinkers (F) which surround the iron cylinder serve to carry the line down and to force the tube into the deposit, but being detached on striking the bottom, these sinkers are left at the bottom of the sea, while the tube containing a specimen of the deposit is hauled to the surface and on board ship. During the first months of the cruise the diameter of the tube was not more than 1 inch,[1] but this was replaced by one having a diameter of $2\frac{1}{2}$ inches,[2] and latterly the tube was made to project fully 18 inches[3] below the weights. When there was reason to suppose that the bottom would be a tenacious clay, no butterfly valve was used at the lower end of the tube, as this valve is a great impediment to the entrance of the deposit into the tube. In these cases the tube sometimes sank 18 inches or 2 feet[4] into the clay, and brought up a section to that depth and over a quart[5] bottle full of the clay. It not being always possible to know beforehand the nature of the bottom, it was found by experience best to have the tube always fitted with the butterfly valve when sounding, for a Globigerina Ooze or other less tenacious deposit was not retained in the tube without the valve. To facilitate collecting the mud or other deposit brought up by the tube, the lower half was made to unscrew, and this was then taken into the laboratory, the butterfly valve removed, and the roll of mud or other deposit taken out at the upper end, or allowed to slip out by its own weight, on jerking or on striking it gently on the table. The arrangement, colour, and general appearance of the different layers, if any, were then carefully noted. Even when the whole of a more or less granular deposit appeared to have been wholly washed out of the tube on its way up through the water, still a small quantity of the deposit or a few shells or stones would usually be found inside behind the valves. The method of sounding with these machines is very satisfactory from the point of view of the study of Deep-Sea Deposits, for the largest specimens of the deposit are thus obtained; the method of sounding with wire, now chiefly employed, where the weights and tubes are very much less, is less satisfactory in this respect.

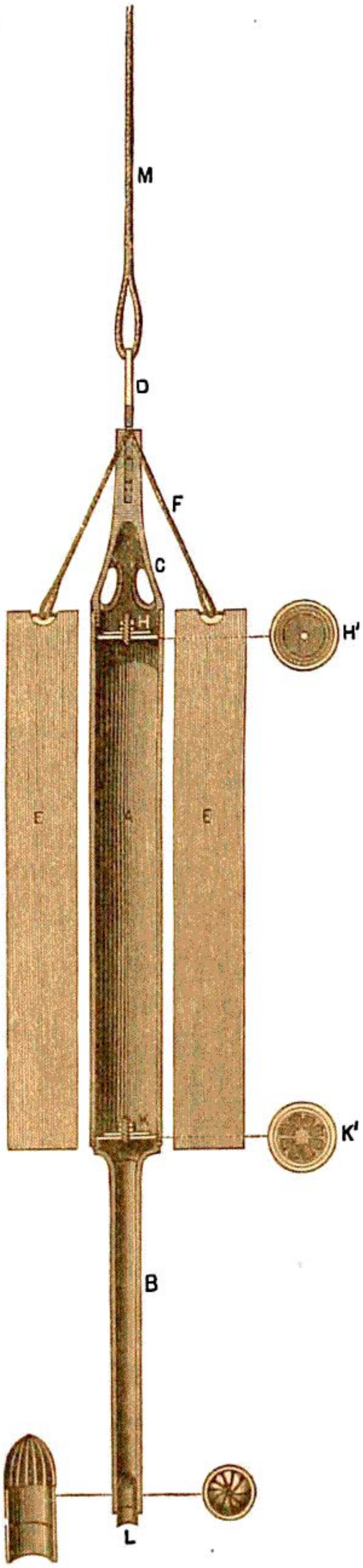


Fig. 7.—Buchanan's Combined Sounding Tube and Water-Bottle.

Buchanan's combined sounding tube and water-bottle, as used by Mr. Buchanan with success on board the telegraph ships, is represented in Figs. 7, 8, 9, and 10, and has the advantage of utilising the weights in pushing the tube into the ground, with the

[1] 25·4 mm. [2] 63·7 mm. [3] 45·7 centimetres. [4] 61 centimetres. [5] 1·1 litres.

view of procuring specimens of the deposits below the superficial layers. With it good samples of the mud and of the bottom water are obtained without trouble. The instrument consists of the "water-bottle" A, a tube about 18 inches[1] long and $2\frac{1}{4}$ inches[2] in diameter, of about one litre capacity. It has at each end a valve, H, K, made of india-rubber, on a metal seating, opening upwards. Above the upper valve H, the shank C is screwed into the tube A, and below the lower one K, the mud tube B, which is 12 inches[3] long and 1 inch[4] in diameter, is screwed to A. Into the lower end of the mud tube B can be inserted the valve L, which consists of a piece of thin sheet brass, cut out like a comb, and bent round into a cylindrical shape. It is soldered to a stouter piece of brass tube, which fits into the end of B and is retained by a bayonet joint. At the upper end of the shank C the tumbler D supports the weight E by the sling F, and is in its turn supported by the sounding line M.

The details of the tumbler are shown in Figs. 8, 9, 10. It will be seen that at its

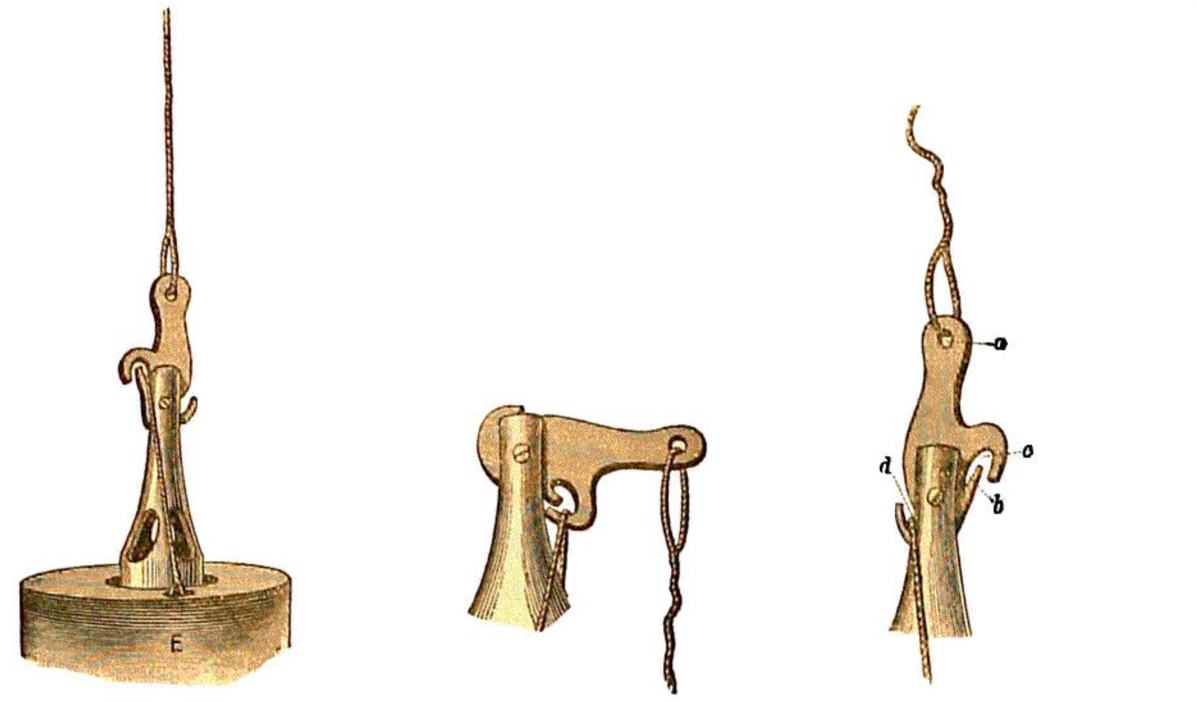


Fig. 8. Fig. 9. Fig. 10.

Disengaging Apparatus for Buchanan's Sounding Tube and Water-Bottle.

upper end it has the hole *a*, into which the eye of the sounding line is spliced. At the lower end it has three notches, *b*, *c*, and *d*. If it is not wished to detach the weight, the sling supporting it is hooked into the notch *d*, which is considerably below the suspending axis. Consequently, when the tube reaches the bottom and the sounding line above slackens, the tumbler still preserves its upright attitude, and on heaving up, the sinker is recovered along with the tube. If the sinker is not to be recovered, the sling is hooked in the notch *b*, which is above the axis. When the tube reaches the bottom and the sounding line slackens, the pressure of the sling upsets the tumbler, which falls

[1] 45·7 centimetres. [2] 57·35 mm. [3] 30·48 centimetres. [4] 25·4 mm.

over into the position Fig. 9. In getting into this position the weight drags the sling out of the notch *b*, and it falls into the notch *c*. Here it remains as long as the tube is at the bottom, exerting all its weight in pushing it into the ground. On heaving in, the tumbler is drawn into an upright position, when the sling slips free and the tube is brought up without the sinker. When it has been brought to the surface, it is found that the mud tube B is filled with a compact cylinder of mud, which by its weight has kept the india-rubber valves closed by drawing them tight down on their seats, and has therefore insured that the water enclosed at the bottom has not been contaminated by admixture with other water on the way up.

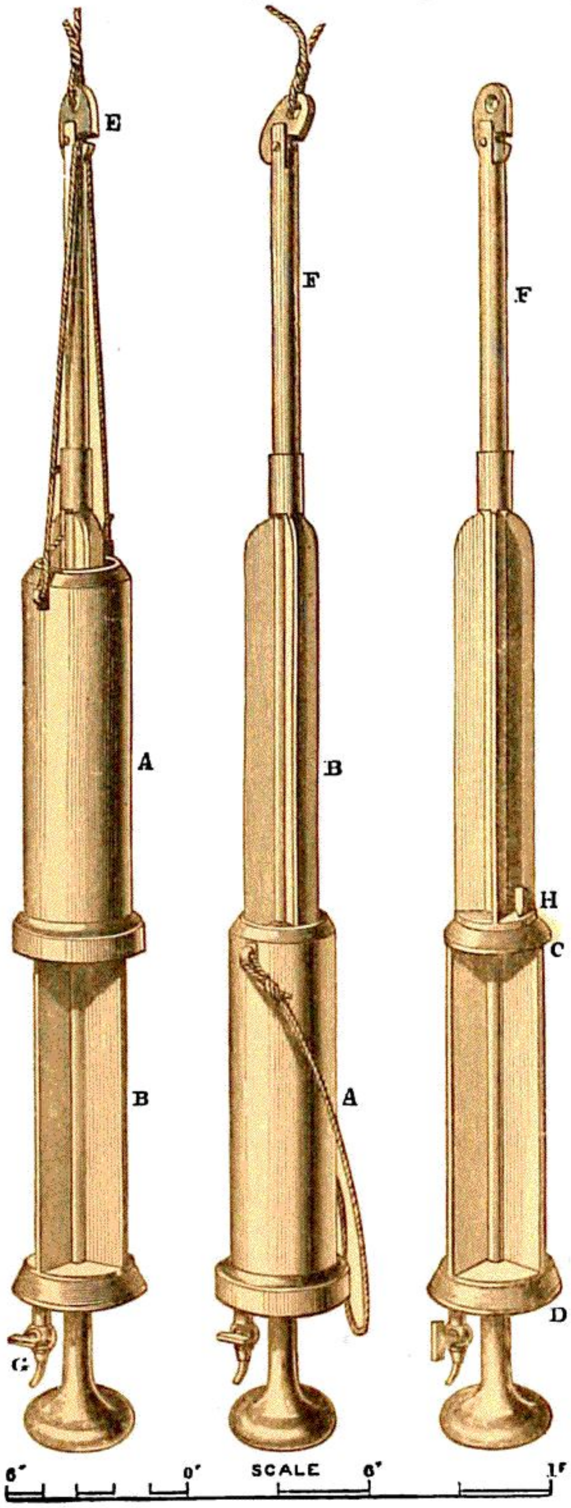


Fig. 11.—The Slip Water-Bottle.

A, brass cylinder sliding up and down the metal shank B, attached by a wire to the slipping arrangement E, fixed to the end of the rod F. When the apparatus reaches the bottom the cylinder is released and falls down to the lower part, where it rests on the lower of two accurately ground valves C and D; the water enclosed is removed by the tap G.

The localities, even in mid ocean, where the bottom is "hard ground," are by no means rare, and if the tube just described be dropped on it with a 50 lb.[1] sinker, the mud tube will be much disfigured; but if there be any loose material at all, such as gravel or coral, a little of it will probably be entangled behind the comb valve. In the absence, however, of a mud plug, the bottom water will be valueless. As a rule, the bottom of the deep sea consists of mud sufficiently soft and tenacious to fill the mud tube throughout the greater part of its length with a compact plug, and if the tube B be screwed water-tight into the lower part of the tube A, it is retained in it just as a liquid is retained in a pipette. In soft ground, clays and most Globigerina Oozes, it is better to discard altogether the comb valve L, because it always offers some resistance to the entrance of the mud, and is not wanted to keep it in. The instruments are fitted with mud tubes of two sizes, namely, the smaller 1 inch[2] in diameter, and the larger $1\frac{3}{4}$ inches[3] in diameter. In the ordinary routine work of running a line of soundings the smaller size should be used and without

[1] 22·8 kilogrammes. [2] 25·4 mm. [3] 44·45 mm.

the comb valve. It is screwed into A on the top of a thin leather washer to make the

FIG. 12.—The Dredge.

A, A, arms of the dredge, connected together with iron screw bolts B, B, B, and between them an iron tongue C, with a swivel-ring D at its upper end, to which the dredge-chain is fastened; E, E, E, two knife-edged pieces of iron on the long sides of the framework, having an outward inclination of about 10° from the perpendicular; F, sack of the dredge made of network of soft line, and lined inside with cotton cloth; G, G, iron bar, suspended by the ropes H, H, to the framework, and supporting the flat-headed swabs K, K, K, K, K.

joint tight. At each sounding a sample of the mud and of the bottom water will be obtained. When the tube is brought on board, the mud tube is unscrewed, any water that may be on the top of the mud cylinder is poured off, and the mud cylinder itself pushed out by a metal plunger, which just fits the tube. The water is simply poured out of the bottle into any convenient vessel. If the gases dissolved in the water are to be examined, then it must be drawn off by a siphon passed through the upper valve and down to the bottom of the tube.

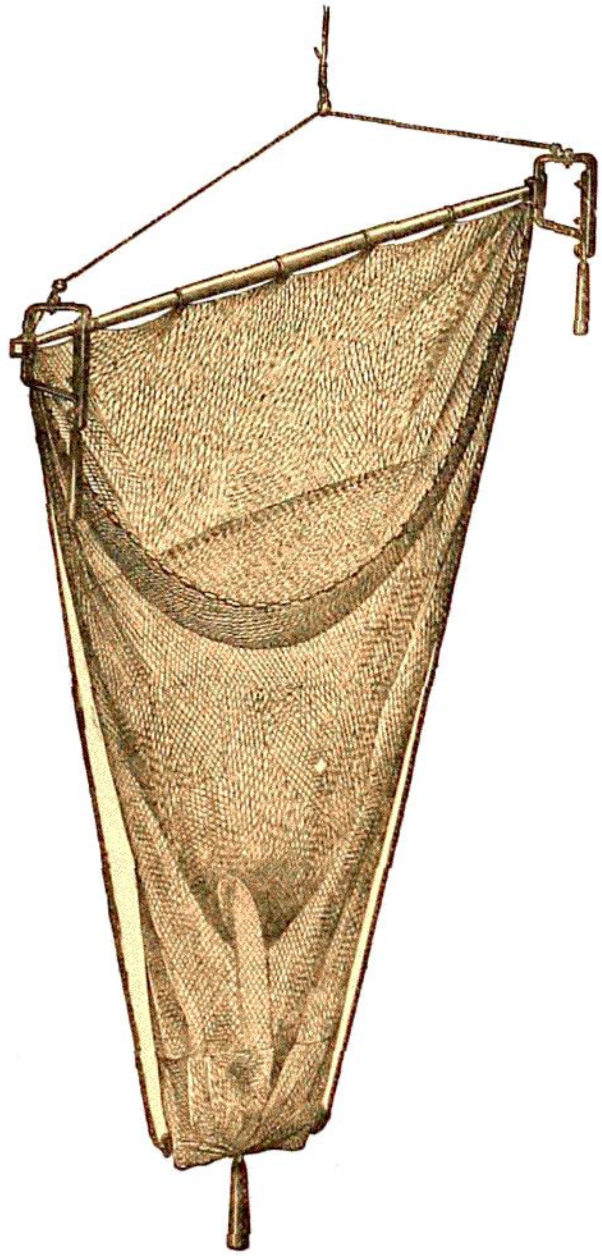


FIG. 13.—The Beam-Trawl used in deep-sea work.

This sounding tube has been very successfully used on board the ships "Dacia" and "International," belonging to the India-rubber, Gutta-percha, and Telegraph Works Company, while surveying the route for the cable from Cadiz to the Canary Islands. It has the advantage that on board such ships, where rapidity of work is of the greatest importance, good samples of mud and of bottom water are obtained in the course of the ordinary routine work, and without having to use any extra instruments. The weight of the sinkers used was 60 lbs.,[1] but 50 lbs.[2] is quite heavy enough. When the sinker is to be recovered, its weight should not exceed 30 lbs.[3]

In some of the telegraph ships four small tubes were at one time fitted to the lower part of the sounding instrument, and brought up four little rolls of the deposit. Other slight modifications have been introduced in the form and size of the tube and valve for retaining a specimen of the deposit, but these do not differ widely from those which have been noticed above.

A water-bottle, called the *slip water-bottle* (Fig. 11), was almost always attached to the line when sounding on board the Challenger; this bottle closes on striking the bottom, and it frequently happened that it was partly filled with mud or ooze, thus giving, in addition to the sounding tube, indications as to the nature of the deposit.

In the *dredges and trawls* (Figs. 12 and 13) used on board the Challenger, a large quantity of deposit was frequently brought up from the greatest depths of the ocean.

[1] 27·2 kilogrammes. [2] 22·7 kilogrammes. [3] 13·6 kilogrammes.

The iron framework of the largest dredge was 5 feet[1] in length, 1 foot 3 inches[2] in breadth—its weight being 137 lbs.;[3] the next size, which was made much stronger, was 4 feet[4] in length, 9 inches[5] in breadth, and weighed 259 lbs.;[6] the smallest was 3 feet[7] in length, 1 foot[8] in breadth, and weighed 85 lbs.[9] The smallest was generally used in great depths, and with it a successful haul was obtained in 3875 fathoms.[10]

The trawls were of the kind known as beam-trawls, the length of the beams being 17, 13, and 10 feet;[11] the smallest was used in very deep water. Into the bottom of the bag of the dredge and into the bottom of the net of the trawl fine cloth was usually sewn, so as to retain some of the fine ooze or mud, as well as to capture very small animals. It frequently happened that many hundredweights of Globigerina Ooze, Diatom Ooze, or other deposit were brought up in the dredge and trawl, especially when a fine cloth was placed in the bottom of the bag or net. On the other hand, the greatest hauls of manganese nodules, sharks' teeth, bones of whales, fragments of rocks, mixed with red or chocolate-coloured clay occurred when no cloth was placed in the bag or net; on these occasions the fine clay evidently passed through the meshes, while the larger fragments were retained in the netting; there was occasionally a sufficient quantity of the above materials in the trawl to fill a 30-gallon cask.[12]

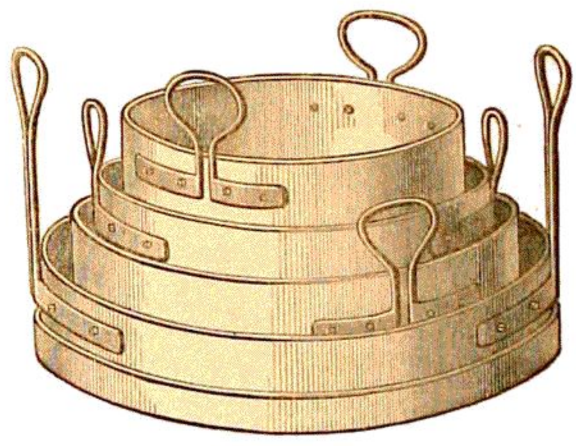


FIG. 14.—The Sieves.

When a large quantity was procured, the ooze or clay was passed through sieves of various sizes (Fig. 14), by working them up and down in large tubs of clean sea water; all the larger particles from these sieves were then carefully collected and placed in bottles with spirit, and labelled "coarse" and "fine washings."[13] A quantity of the deposit, just as it was taken from the dredge or trawl, was also preserved in bottles for examination at home. The operation of sifting the deposits took place on the dredging bridge immediately after the trawl or dredge was landed on board; the more detailed examinations were carried on in the laboratory on the upper deck.

The ordinary surface tow-net (Fig. 15), used for catching pelagic animals, made of coarse cloth of various kinds, the iron hoop having a diameter of 1 foot or 18 inches,[14]

[1] 1·524 metres. [2] 38·1 centimetres. [3] 62·1 kilogrammes. [4] 1·219 metres.
[5] 22·9 centimetres. [6] 117·4 kilogrammes. [7] 9·14 decimetres. [8] 30·48 centimetres.
[9] 38·6 kilogrammes. [10] 7088 metres. [11] 5·184, 3·964, and 3·05 metres. [12] 136 litres.

[13] The ooze which had been passed through sieves was sometimes sent home from the "Porcupine" and earlier expeditions without being properly labelled, or without a statement that all the finer particles had been washed away, hence some samples were described as *Orbulina ooze*, some of the siftings consisting largely of these Foraminifera.

[14] 30·48 or 45·7 centimetres.

was frequently attached to the beam of the trawl and iron frame of the dredge, and gave in most cases information of the immediate surface-layers of the bottom that could not be obtained by the trawl, dredge, or sounding tube. A tow-net was in like manner

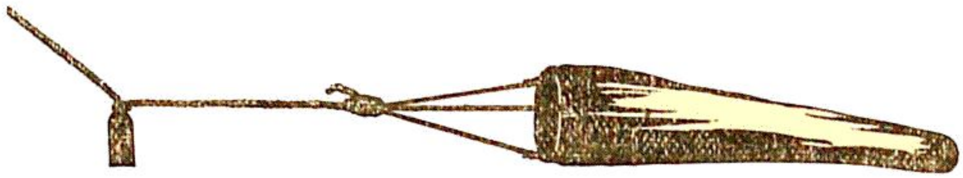


FIG. 15.—Ordinary method of using the Tow-Net.

sometimes fixed to the weights that were placed on the trawling line, some 200 to 500 fathoms[1] in front of the dredge or trawl. This net occasionally came up filled with mud or ooze.

In another way, however, the surface-nets gave still more valuable information. During almost every day of the cruise these nets were dragged at the surface and in depths of 10, 20, 50, and 100 fathoms,[2] either from the ship or from small boats lowered for the purpose. Occasionally they were sent down to and dragged at depths of 500, 1000, and 1500 fathoms.[3] The contents of the deeper nets were carefully compared with the contents of those dragged at the surface and in shallow water. Again, the organic remains found in the deposits at the bottom were carefully compared with the animals captured in the tow-nets on the same day or in the same region. Hundreds of observations of this kind, repeated day after day, led to a very accurate conception of the part played by surface organisms in determining the nature of the deposits now forming on the floor of the ocean at different depths and in different latitudes throughout all parts of the world.

On every occasion during the cruise when the anchor was heaved on board, it was carefully inspected, and specimens of the mud which came up on it were examined and preserved. Recently Mr. Buchanan anchored one of the telegraph ships in 1600 fathoms[4] with an anchor specially arranged to bring up a specimen of the deposit (see Fig. 16). This was a Tropman anchor, weighing 5 cwts.,[5] the flukes being connected by a frame to which a canvas bag was laced; with this he obtained over 1 cwt.[6] of Globigerina Ooze.

The various contrivances have now been indicated by which information is obtained concerning the deposits now forming on the floor of the great oceans and inclosed seas. Although there are many modifications in the trawls and dredges not here referred to, these are not of any essential importance as regards the information furnished about the

[1] 366 to 914 metres.
[2] 18·3, 36·6, 91·5, and 183 metres.
[3] 914, 1828, and 2742 metres.
[4] 2926 metres.
[5] 253·7 kilogrammes.
[6] 50·7 kilogrammes.

deposits.[1] The specimen of a deposit brought up at any particular spot may be very small, yet when studied with the light thrown on the subject at other stations where a large quantity was procured by the dredge or trawl in addition to that taken in the sounding tube, a very correct idea of the nature of a deposit can be formed even from the examination of such a small sample.

FIG. 16.—The Anchor Dredge.

As soon as a specimen of a deep-sea deposit was procured, it was examined on board by Mr. Murray, and notes of the quantity, colour, and the general physical characters were entered in a journal. A small quantity of the deposit was then shaken up in pure sea water and separated by three decantations, each of which was examined in the wet and dry state by the microscope;[2] the organisms, minerals, and other substances present were then noted so far as possible. The carbonate of lime in the specimen was subsequently removed by dilute hydrochloric acid and the residue examined with the microscope. In order to examine specimens of the deposit and the various decantations in the dry state, it was found to be a great saving of time to saturate these with spirit of wine and then burn this off. The appearance of the manganese nodules, teeth, bones, and other materials were also carefully noted on being taken from the dredge. Mr. Murray's notes, as well as the large number of specimens brought home with so much care, were all available in the more detailed examination which has since been carried on at home during the past fourteen years.

b. Methods adopted for the Study and Description of the Deposits in the Laboratory after the Return of the Expedition.

In the preceding section the various contrivances for raising specimens of marine deposits from the bottom of the sea, together with the methods employed in

[1] For an account of more recent modifications in deep-sea apparatus, see Alexander Agassiz, Three Cruises of the United States Steamer 'Blake,' Boston and New York, 1888; Sigsbee, Deep-Sea Sounding and Dredging, Washington, 1880; Prince Albert de Monaco, Recherche des Animaux Marins, Compte-Rendu des Scéances du Congrès International de Zoologie, p. 133, Paris, 1889; Thoulet, Océanographie (Statique), Paris, 1890.

[2] The microscopes used most frequently by Mr. Murray were a Ross binocular with low powers and a Hartnack with high powers; these were firmly clasped to a small table, fixed securely into the deck of the ship. The seat again was firmly fixed between this table and the wall of the cabin. By this arrangement he could work with advantage even in rough weather when the motion of the ship was considerable.

the first sorting and examination of the materials on board ship, have been indicated.

It is now proposed to explain in detail the plan adopted in the subsequent detailed examination and description of these deposits,—to point out the chemical manipulations

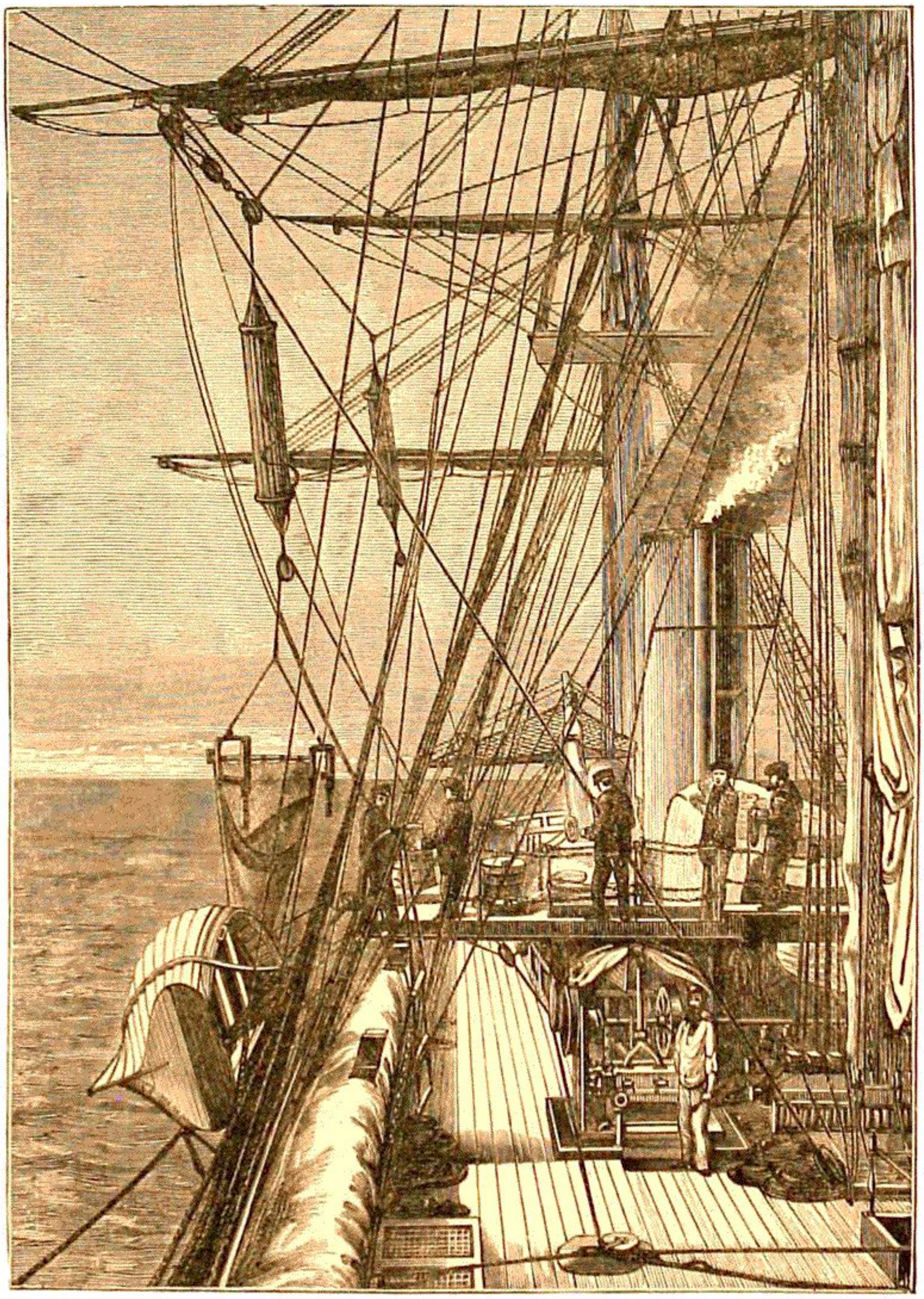


FIG. 17.—Dredging and Sounding arrangements on board the Challenger.

and microscopic analyses by means of which the biological and mineralogical nature of the deposits was determined.

The history of a marine deposit is in general very complex, comprising as it does an account of the origin of the deposit, the causes which have brought the varied elements to the spot, and the modifications, physical and chemical, which these have undergone in the course of time. Each of the constituent elements, whether organic or inorganic, has, again, its own history, and this we have endeavoured to trace by studying their nature, form, dimensions, and their relations to each other at the spot from which they have been collected by the dredge or sounding tube. For this purpose the chemical and microscopical methods recently introduced into the study of geology have been largely made use of. A knowledge of the various particles forming a deposit led to a rational classification of marine deposits and to a definite nomenclature, of which we will have to speak further on.

At the outset, the difficulties which surround this kind of study may be pointed out. In the first instance the quantity of a deposit procured in the sounding tube may be very small, and this, especially whenever of an incoherent nature, has undergone a kind of sorting in the tube itself, owing to some of the finer or coarser particles being washed out while being hauled up through the water. Again, the specimens preserved in spirit or water have undergone sorting by being shaken up during the voyage, so that the contents of the bottles are often arranged in layers, the heavier portions being at the bottom and the lighter on the top. The specimens artificially dried, when not first washed in distilled water, often contained crystals of sulphate of lime and other sea salts. In the case of samples from the dredge or trawl there had been, it was evident, much washing away while the apparatus was being hauled up through the water; indeed often all the deposit was washed away, and only manganese nodules, teeth, bones, and rock fragments remained in the net. It is thus apparent that considerable care was necessary to ensure that, in making analyses or in choosing a sample for determining the percentage of carbonate of lime or other elements present, we were working with an average sample. As a rule we took for this purpose the specimens collected in the sounding tube and dried on board ship. When a difference was noted in the upper and lower layers in the sounding tube, these were preserved and examined separately. The results of an examination of the specimen from the sounding tube, frequently small in quantity, were compared with those obtained from an examination of a very large quantity procured in the trawl or dredge at the same spot, often amounting to several hundredweights.

It is evident, then, that to make the descriptions as clear as possible, it became necessary to follow a systematic plan and not to deviate from it. The method finally adopted was chosen, after many attempts, as the best, and the one most likely to be followed by others in describing deposits that may be hereafter obtained from the ocean's bed. This method will now be referred to in detail, and will be at once rendered intelligible by reference to the Tables in Chapter II., where the particulars regarding each of the Challenger specimens are presented in synoptical form.

In commencing the examination of a deposit, attention was first given to the *macroscopic characters*. By means of the naked eye or a hand lens, the substance was inspected in the wet and dried condition, and its general aspect, colour, grain, and greater or less plasticity in the former state, and its brittleness, cohesion, colour, grain, and the streak of the clayey matter in the latter state, were noted. It seemed necessary to distinguish the differences in the characters of the substance in the wet and dry condition, as these are often considerable, the colour being often deeper in the wet material, the condition in which it is usually seen by seamen when brought on board ship. Macroscopic examination itself permits a classification of deposits into certain well-defined categories, in accordance with their mode of formation and composition. It shows in a general way the composition of the deposit, and especially the part taken in its composition by organic and inorganic elements. Colour in this relation is important, as it frequently enables us to distinguish at once an organic ooze from a mud or clay made up chiefly of inorganic materials, especially when taken in combination with the grain and other physical peculiarities.

The colour and other physical characters of the Residue left after the removal of the carbonate of lime are likewise important, for they frequently enable us to trace the connection between a typical Red Clay and the residue present in a Globigerina Ooze, the colour of the residue in such an ooze being often entirely masked by the abundance of the calcareous shells; the colour of this residue is noted, in the tables, in the same column as the name and physical characters. *Plasticity* points out the greater or less abundance of clayey matter; the *farinaceous aspect* indicates abundance of Diatom frustules; the *grain* tells as a rule whether the deposit comes from near a coast, from the open sea, or from a region affected by floating ice.

The fundamental characters of a deposit revealed by a macroscopic examination become much more definite and precise when followed by a detailed examination of its component particles, commencing with a microscopic examination of the calcareous organisms, which were separated by decantations into finer and coarser portions, and examined in the wet and dried conditions. This was accomplished by placing the wet substance in long clear glass wash bottles, and shaking up with abundance of clean water, so as to separate the particles one from another and free them of amorphous matter. Subsequently the various products of decantation, when dry, were passed through sieves with very fine meshes. The genera and species of the organisms could in this way be determined with great accuracy, and their relative abundance could be estimated. In over a hundred of the deposits all the calcareous organisms were carefully picked out by means of a moistened camel-hair pencil from under the microscope, and then mounted on separate slides when the species were determined; this was a work requiring great care and patience, and was latterly most successfully and expeditiously performed by Mr. Frederick Pearcey, who accompanied the Expedition, and was subsequently assistant in the Challenger Office. In this way the Molluscs, Foraminifera, fragments of Polyzoa, Annelid tubes, Corals, otoliths of fish, and other calcareous fragments underwent careful examination. The smaller fragments, which could not thus be picked out and examined separately, were searched for under high powers, and the presence or relative abundance of Coccospheres, Coccoliths, Rhabdoliths, and amorphous and other particles was noted.[1]

Under the heading CARBONATE OF CALCIUM in the Tables, Chapter II., the general character of these organisms is indicated in two columns. In the first of these the Foraminifera are named, beginning with the pelagic Foraminifera, which make up the greater part of the carbonate of lime present in most deep-sea deposits. These organisms live on the surface of the ocean in vast numbers, and the dead shells accumulate at the bottom, forming, when in great abundance, the well-known Globigerina Ooze; the proportion which these make of the whole deposit is estimated after inspection, and the figures indicating this proportion are placed in brackets ( ). In like manner, the percentage of the shells of those Foraminifera which live at the bottom of the sea is estimated and placed beneath in the same column. In the second column the kind and percentage of other calcareous organisms present in the deposit are indicated in the same way.

In front of the two columns giving the names and estimated quantities of the different carbonate of lime organisms, is another smaller column under the general heading CARBONATE OF CALCIUM, which gives the total percentage of carbonate of calcium present in the deposit. This is obtained by a quantitative determination of the carbonic acid by attacking the sediment with dilute hydrochloric acid. What is considered as a fair representative sample of the deposit is taken, finely ground, and dried thoroughly in an air or water oven at a temperature (in the case of the air-oven) of 100°–110° C., and transferred to a sample tube. A portion, about 0·5 to 1 gramme, is weighed directly but quickly, and transferred to the large bulb of the carbonic acid apparatus (see Fig. 18).

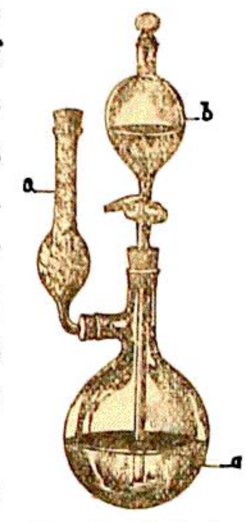


FIG. 18.—Carbonic Acid Apparatus.

This apparatus consists of a bulb (*a*) of about 3 ozs. (100 c.c.) capacity, an acid bulb (*b*), and a calcium chloride tube (*c*). The bulb is provided with two openings, one as ordinarily is the case, and another smaller one blown in the side of the neck. Into the larger opening is fitted an india-rubber stopper, through which passes the limb or delivery-tube of the acid bulb. This acid bulb is fitted with a ground stop-cock, and holds about half an ounce of dilute hydrochloric acid, 1 in 3. Into the smaller opening is fitted another india-rubber stopper, into which is fixed an upwardly-inclined calcium chloride tube, filled with fragments of fused calcium chloride, to dry the evolved carbonic acid gas. The calcium

[1] The minute organisms and amorphous calcareous matters here referred to are not, of course, included in the term "fine washings" (p. 23), which we use exclusively to indicate the finer portions of the deposit *after the removal of the carbonate of lime.*

chloride is first subjected to a stream of dry CO_2, so that, when used in the estimation of the CO_2, no error may be introduced by the absorption of the gas. The calcium chloride tube is fitted with an india-rubber stopper, in order to exclude the outside air when cooling and during the process of weighing.

The weighed sample is placed in the large bulb, a little water added, the different parts adjusted and finally wiped dry, and then the whole is weighed by suspending from the beam of the balance by a fine platinum wire. The acid is then run in little by little, until all effervescence has ceased; the contents of the bulb are heated with constant shaking to near the boiling point, cooled, and finally weighed, and from the loss in weight (weight before experiment minus weight after) the percentage of calcium carbonate is calculated. When these analyses were first made, Ludwig's apparatus was used, but this was modified to the present form by the substitution of an ordinary calcium chloride tube for the circular basal one, as there was a certain amount of inconvenience experienced in heating.

It may be urged that the determination by carbonic acid, unaided by the oxide of calcium test, indicates but approximately the quantity of carbonate of calcium, for the deposit may contain carbonates of magnesia and iron. It is sufficient to observe that these bodies are only present in very small quantities. Besides, the composition of a deposit at the same station and even in the same sample varies sometimes by a quantity greater than the error committed. It is true that small quantities of iron, alumina, phosphates, &c., are always dissolved in the above process, but this partial dissolution has no marked influence on the biological or mineralogical determinations that require to be made. This method was then sufficiently exact for our purpose. Complete quantitative analyses were made of many of the deposits, but the length of time required to do this for all samples was not compensated by any real utility in the investigation, while in many cases the quantity of a deposit was insufficient for such an analysis.

By thus removing the carbonate of lime with dilute hydrochloric acid from each deposit, our descriptions are conveniently divided into two parts, one dealing almost exclusively with materials of organic origin—the shells and skeletons of carbonate of lime secreting organisms,—and another referring to the part in which the mineral element predominates in the great majority of cases; in some localities, however, there are associated with the minerals properly so called, the remains of siliceous organisms, together with the silicified casts of calcareous organisms, and these may together or separately make up the greater part of the deposit after the removal of the carbonate of lime.

That part of the deposit which remains in the vessel after the removal of the carbonate of lime is called in the descriptions Residue. In the examination of this residue the heavier particles were separated by decantation and examined by reflected light in the wet and dried states, and subsequently mounted on microscopic slides for examination by transmitted light. As a rule the residue from about 1 gramme of the substance was taken for examination, so that the evaluations of the various elements present might be comparable in different deposits, but often very large quantities of a deposit were taken and the carbonate of lime all removed, in order to have a considerable quantity of residue for more thorough examination and study.

The processes made use of in lithology for isolating mineral species by means of strong acids, by the action of electro-magnets, by liquids of high density, by sifting, &c., have all been used by us with varying success, especially when we desired to get a sufficient quantity of a substance for quantitative examination.

Liquids of high density, such as the compounds of mercury and potassium, and borotungstate of cadmium, were useful when dealing with a coarse deposit, but not so in dealing with an ordinary deep-sea deposit, where the grains are exceedingly fine, so much so, that as a rule it appears to the naked eye as a homogeneous mass. With an ordinary magnet and an electro-magnet we were most successful in extracting from a mud or ooze all the magnetic particles, such as magnetite, fragments of meteorites, with particles of magnetic metals. This was accomplished by placing the magnet, covered with thin "iron" paper, in a porcelain basin, in which the mud or ooze had been well mixed up with water, and moving it slowly about, keeping the magnet as near to the bottom of the vessel as possible without touching it; it was then removed into another basin, the paper taken carefully off, and the particles washed into a clean basin to clear them from extrancous matter, then re-collected on a slide for examination under the microscope.

The deposit was, after great dilution with clean water, also passed over fixed electro-magnets, to collect the magnetic particles, but this was not so convenient in practice as the above method with movable electro and permanent magnets.

The very simple process of fractional decantations, practised often and after a regular system, proved to be in the end the most useful and expeditious way of preparing the residue for microscopic analysis, and it was this process that we followed in all our examinations. In this way we were usually able to separate sufficiently the Residue into the three portions noted in the table under the headings: 1. **Siliceous Organisms**; 2. **Minerals**; 3. **Fine Washings.** The decantations were performed with glass or porcelain vessels and abundance of water. The whole was kept in motion for some time, and then the finer particles were poured off carefully, after continued stirring and shaking. The first of these decantations gave us the fine washings, in the second the siliceous organisms predominated, while the heavier mineral particles remained behind. Each of these were mounted on microscopic slides for further examination.

The figures in the first column of the tables under Residue give the percentage in the whole deposit, and is found by subtracting from 100 the quantity of carbonate of calcium as determined by analysis. The numbers within brackets in each of the other columns before *siliceous organisms*, *minerals*, and *fine washings*, give the estimated abundance of these in the deposit, as in the case of the relative abundance of the various carbonate of lime organisms under the heading carbonate of calcium; in short, all the numbers in the tables within brackets ( ) represent the estimated quantity present after examination, in contradistinction to those numbers without brackets, which are the result of quantitative determination.

1. **Siliceous Organisms.**—These consist generally of Diatoms, Radiolaria, and Sponge spicules of various kinds. The enumeration of the genera of these would much exceed the limits necessarily imposed by the style of the table, but full particulars are given in the special reports, to which the reader is referred. Under this heading are also grouped those Foraminifera, the tests of which are for the most part made up of the inorganic particles found in a deposit, like the Astrorhizidæ, Lituolidæ, &c. There are also placed under this heading the glauconitic and other casts of marine organisms which are occasionally found in considerable quantity in some deposits, and remain in the residue after the removal of the carbonate of calcium; these cannot, of course, be classed among siliceous organisms in the same sense as Diatoms, Radiolarians, and Sponge spicules, but their mineralogical characters are indistinct, and for descriptive purposes this appears the best place to note their occurrence. These casts bear distinctly the impress of the calcareous organisms, but their chemical composition has not been in all cases determined, though in many instances they are probably either a silicate corresponding to glauconite, or of a phosphatic nature. When glauconite is present with well-defined characters, it is placed among the mineral particles.

2. **Minerals.**—The fragments of minerals and rocks were examined on slides, first by reflected light, dry, and then by transmitted light, under the mineralogical microscope. Sometimes preparations were mounted in Canada balsam, or the particles were cemented together by gum copal, and then rubbed down till thin and transparent, by a process analogous to that used in making thin sections of rocks.[1] But this was possible only in certain cases, and generally we had to examine the mineral fragments on a slide with water, this mode of observation allowing the particles to remain free, and rendering easy chemical reactions under the microscope. The mean diameter and form of the mineral fragments are stated in all cases, as this is a matter of considerable importance in giving a clue as to the agents at work during the formation of the sediment under consideration. The order in which the species are mentioned in the tables is, generally speaking, that of their importance or abundance in the deposits. The characters which have guided us in diagnosing the mineral species most commonly met with in the deep-sea deposits are briefly stated below; the characters noted under the various species refer

[1] See F. G. Pearcey, Method of Consolidating and Preparing Thin Sections of Friable and Decomposed Rocks, Sands, Clays, Oozes, and other Granulated Substances, *Proc. Roy. Phys. Soc. Edin.*, vol. viii. pp. 295–300, pl. xi., 1884.

always to the examination of isolated crystals or fragments of minerals such as are found in the deep-sea deposits. There are many characters which are passed over in silence, though no less important than the others, but these properties are only shown when the minerals are cut into numerous sections in various directions, and therefore but rarely seen in such isolated grains. It should also be remembered that the determination is much more difficult because these particles are of very small dimensions, are mixed with a large quantity of amorphous substances, are generally decomposed and altered by chemical or physical agencies, and in this isolated state do not present the associations which are met with in crystalline rocks. Only those mineral species that are well defined and individualised are mentioned, and their characters given in the following short descriptions. When speaking of the "fine washings" we shall indicate some of the principal characters of the amorphous matters which are present in the deposits, such as clayey matters, oxides of iron and manganese, organic substances, phosphatic grains, &c.

AMPHIBOLE.—*Hornblende.*—Although minerals of the amphibolic group are more or less frequent in the deposits it is rather difficult, except in the case of glaucophane, to distinguish the varieties owing to the minuteness of the grains and to their clastic nature. We have generally to deal with common or with basaltic hornblende. The fragments of these two varieties are generally prismatic, with a perfect cleavage of 124° parallel to the prism, high relief and interference colours, the greatest extinction angle rarely exceeding 20°. *Common hornblende*, more or less distinctly prismatic individuals, generally greenish, rarely brownish, colours of pleochroism green. Associated with quartz, epidote, felspar, and other debris of older crystalline rocks. In some cases fragments of actinolite are found as columnar or fibrous aggregates with debris of crystalline or actinolite schists. *Basaltic hornblende*, fragments of well-crystallised individuals, sometimes regularly bounded crystals coated with volcanic glass, well-marked cleavage, high lustre on the planes of cleavage, black by reflected and brown by transmitted light, strong pleochroism and absorption, small angles of extinction, vitreous inclusions, in some cases coating of magnetite and characteristic corrosion.

Glaucophane.—This mineral is somewhat rare in the deposits; it is observed in the form of small prismatic fragments and is distinguished by its highly-pronounced violet-blue colour, and by the angle of the prismatic cleavage, which is the same as for amphibole. The extinction angle on the klinopinakoid does not exceed 7°. Strong pleochroism: blue, bluish violet, yellowish grey. Occurs with land debris and fragments of mica-schists and gneissic rocks.

APATITE.—This mineral, rarely found in the deposits, is observed in the form of hexagonal columnar fragments, sometimes in elongated or rounded grains. The surface is corroded and full of small cavities, extinction parallel to the length, colourless, or but slightly coloured, in this case pleochroic, high index of refraction, considerable relief. Readily soluble in acids, tested by microchemical reaction with molybdate of ammonium and by sulphuric acid. These microchemical reactions were also used in the determination of small phosphatic concretions and of grains of the same nature. Apatite was found with fragments of older crystalline rocks (see chapter on phosphatic nodules).

CALCITE.—Besides the great number of the remains of organisms or skeletons formed of calcite or of aragonite, this mineral is often observed in the deposits bounded by the cleavage planes or as radiated or fibrous aggregations. These fragments or concretions of calcite are generally characterised by the twinning parallel to $-\frac{1}{2}$ R, or by the cleavage parallel to R, colourless, sometimes coloured with limonite, bluish, yellowish, and occasionally milky or almost opaque. Small relief, between crossed nicols presents characteristic irisation, high interference colours, stronger absorption of the ordinary ray; is distinguished by the facility with which it is attacked by cold hydrochloric acid. Calcite of organic origin can almost always be distinguished by its form and microstructure; sometimes, as in the case of otoliths of fish, Foraminifera, and Mollusc shells, one observes between crossed nicols the black cross of spherulitic aggregation.

CHLORITE.—Under this name are included all the minerals of the chlorite group. Lamellæ or scales more or less curved, with irregular outlines, often with parallel structure, sometimes forming fibro-radiated aggregates. Also observed in the form of minute amorphous particles attached to various minerals or coating rock fragments; perfect cleavage parallel to the basal plane; colour green, more or less dark, index of refraction low. The lamellæ parallel to the cleavage are isotropic, extinction parallel to the cleavage, interference colours bluish, pleochroic, fibro-radiated aggregates give the interference cross of spherulites, easily acted upon by acids, microchemical reaction of magnesia, iron, and alumina; becomes opaque, brown, or blackish when heated on a platinum foil. Generally found with debris of schistose and of older crystalline rocks, principally amphibolic or gneissic, also as coating of some specimens of continental rocks and minerals.

CHROMITE.—Often in small octahedral crystals, more usually as irregular grains; fine splinters are transparent, reddish brown, or brown. In reflected light black metallic lustre, not magnetic, not attacked by acids, reaction of chrome before blowpipe. Found with debris of crystalline rocks, especially of olivine rocks.

DELESSITE.—Fibrous or fibro-radiated aggregates, often zonary structure, green, yellowish green, brownish, double refraction weak, slightly pleochroic. Often observed on fragments of basaltic rocks, of tachylite, or of palagonite. Easily acted upon by acids, when heated becomes black or brownish.

DOLOMITE.—Sometimes found as aggregations of crystals, which have almost always the outlines of the fundamental rhombohedron R, forming small rock fragments, with saccharoidal structure; colourless or brownish, not acted upon by acetic acid or cold dilute hydrochloric acid, microchemical reaction of magnesia. Occurs in the deposits as fragments of dolomitic rocks associated with blocks or gravel of older crystalline and sedimentary rocks transported by icebergs.

EPIDOTE.—Generally occurs as fragments of crystals, mostly prismatic, rarely with sharp crystallographic faces, elongated parallel to the axis of symmetry, cleavage cracks following M. Several crystals often found attached parallelly, sometimes more or less radiated aggregates or grains. Yellowish green colour, sometimes almost colourless, uneven surface and strong relief, high interference colours, strong pleochroism: yellow, brown, green; extinction parallel to the cleavage, unattacked by cold acids. Occurs with debris of eruptive or schistose rocks.

FELSPARS.—(*a*) *Monoclinic.*—Generally fragments bounded by the cleavage planes, following P and M, intersecting at right angles, colourless or coloured by interpositions, dull or sometimes opaque, in other cases glassy. Weak double refraction, low interference colours, no pleochroism nor differences in absorption, extinctions of the monoclinic system, twins following the Carlsbad, Baveno, or Manebach laws. *Sanidine*, often in crystals more or less fragmentary, with glassy habit, colourless and transparent, presenting the ordinary crystallographic form, tabular parallel to M or prismatic parallel to the edge P/M, separation-planes parallel to the orthopinakoid, glass inclusions often regularly disposed. Associated with recent volcanic products, often covered entirely or partly with a glassy coating. *Orthoclase*, fragments bounded by cleavage planes, often irregular grains, no glassy habit, dull and milky, no glass inclusions, intergrowth with quartz or with triclinic felspar, decomposition into kaolin or muscovite, microchemical reaction of potash. Associated in the deposits with debris of crystalline schists and of older eruptive rocks.

(*b*) *Triclinic.*—*Microcline*, colourless or dull grains or fragments often bounded by the cleavage planes parallel to P and M, polysynthetic lamellæ following the albite and pericline laws. In parallel polarised light characteristic cross-hatched appearance produced by twin lamellæ parallel and perpendicular to P/M. Extinction of 15° 30' on P, alterations as for orthoclase. Associated with debris of older eruptive and schisto-crystalline rocks. *Plagioclase*, under this designation are included all the triclinic felspars with the exception of microcline. As a rule, in the deposits, the specification of plagioclase by optical determination is difficult or uncertain; when a specification of the plagioclases has been made it is stated in the descriptions. They occur in deep-sea deposits in most cases as fragments of crystals often bounded by the cleavage planes; when they are imbedded in glassy or palagonitic matter, as is frequently the case in the true pelagic deposits, they present the ordinary crystallographic forms or are crystallised in very thin tables parallel to M. Polysynthetic twinning following the albite law with frequent repetition, and following the pericline law, sometimes Carlsbad twinning together with the twinning according to the albite and pericline laws. Extinctions of triclinic minerals, zonary structure. The plagioclastic fragments present two kinds of habit: dull and cloudy with the debris of older eruptive rocks, glassy and colourless with those of more recent eruption and in volcanic ashes; alteration into zeolitic matter, kaolin, mica, and saussurite; microchemical reaction of lime and soda. When it was altogether impossible, on account of the alteration or of their minuteness, to determine whether the felspathic fragments were to be referred to the monoclinic or the triclinic felspars we use the general term *felspar*.

GARNET.—Often in rhombododecahedral crystals or in grains either quite round or angular, irregular fracture without cleavage, numerous inclusions of various minerals, occasionally coated with green chloritic or serpentinous substance or with phyllitic matter. Generally little altered, isotropic, reddish by transmitted light, unacted upon by acid, high index of refraction, strong dispersion. The most frequent varieties in the deep-sea deposits are common garnet, almandin, and pyrope; they occur generally with debris of older crystalline and schisto-crystalline rocks.

GLAUCONITE.—Grains more or less rounded, sometimes split, often retaining the form of Foraminifera or other organisms in which the glauconite has been moulded. The colour by reflected light is yellow, more or less dark green, black or reddish; by transmitted light it shows greenish or reddish tints. Between crossed nicols aggregate polarisation spotted with bluish and yellowish tints, in some cases appears isotropic, numerous inclusions, reaction of potash (see description of glauconitic deposits).

GYPSUM.—Generally regularly-bounded crystals, sometimes rounded, perfect cleavage following the klinopinakoid, transparent, colourless, greyish or brownish from numerous inclusions of clayey and other substances from the bottom. Double refraction strong; axial plane in the plane of symmetry. In some cases, if not in all, these crystals were formed in the bottles containing the deposits preserved in alcohol.

HEMATITE.—Generally found as *red hematite*, as flakes or small granules coating or colouring other mineral particles, sometimes isolated in the deposits. Often transparent, red to yellowish. Soluble in strong hydrochloric acid. In the deposits this earthy red hematite is very difficult to distinguish from *brown hematite* or *limonite*, the former being frequently altered. Brown hematite, often associated with manganese, is the most frequent in the deposits as brownish amorphous colouring matter, easily soluble in hydrochloric acid.

MAGNETITE.—Readily extracted with a weak magnet, angular grains frequently in the form of octahedral crystals, sometimes twinned following the spinel law, frequent skeleton crystals and groups of irregular grains, opaque, black, with a characteristic bluish metallic lustre. Occasionally a zone of limonite covers the surface of these magnetic particles; often imbedded in volcanic glass, and associated in the same fragment with other volcanic minerals such as felspar, augite, hornblende, &c., more rarely with debris of older schisto-crystalline rocks and cosmic spherules. Titaniferous magnetite or ilmenite is often found in irregular jagged grains; it is distinguished in some cases from true magnetite by a coating of leucoxene. Acted upon by hydrochloric acid, it is slowly dissolved, giving a yellowish green solution.

MICA.—The minerals of this group are generally distinguished by the naked eye in the deposits; they are seen as shining flakes, particularly when the water is being decanted. As it is difficult, or almost impossible, to distinguish the various species of the micas in the deep-sea deposits, we have taken into account for a broad distinction the following characters. The particles of mica do not show crystallographic outlines, except on the cleavage plane, which is shining; they are perfectly cleavable in thin lamellæ parallel to the basal plane. More or less transparent in various colours from light yellowish or almost colourless to green, brown, or almost opaque, showing brilliant interference colours, optically negative, extinction parallel to the cleavage. We divide all the micas into: (*a*) *Black mica*, flakes parallel to the cleavage deep brown or green, also red or almost black, in convergent light biaxial character scarcely determinable, very strongly pleochroic, the rays vibrating parallel to the cleavage strongly absorbed. Associated with debris of schisto-crystalline and metamorphic rocks, and of old and recent eruptive rocks. This subdivision comprises biotite, and probably anomite and phlogopite in some cases. (*b*) *White mica*, with a silvery lustre, transparent, colourless, light yellowish or greenish; no pleochroism, but absorption of the rays parallel to the cleavage. Intense coloration between crossed nicols, large axial angle. In some cases *sericite* is met with in the soundings associated with fragments of porphyroids or phyllites; it is observed as irregularly-bounded flakes, bent and twisted; the lamellæ are irregular. The other characters are the same as for white mica. The white mica is commonly found with debris of altered sedimentary or gneissic rocks or with minerals derived from the disintegration of granite. It is possible that under the name of white mica not only muscovite and sericite, but other varieties, and also altered black mica, are included. Generally speaking, the micas are the less altered of the silicates of the deep-sea deposits.

OLIVINE.—Almost always irregularly-bounded grains, except when coated with volcanic glass; in this case olivine has the crystallographic forms of this mineral in recent eruptive rocks; often skeleton crystals. Imperfect cleavage following the brachypinakoid and cracks following the macropinakoid. Transparent, colourless, greenish or reddish by alteration, without pleochroism, and with feeble absorption, high relief; colours of polarisation very bright green and red, even for the smallest fragments. Numerous inclusions of fluid, of vitreous grains, of magnetite and picotite. Decomposes into serpentinous matter, but generally the alteration of olivine in deep-sea deposits is accompanied with a deposition of ferric oxide or hydrous oxide of iron. Gelatinises with sulphuric acid. Olivine is found in some exceptional cases with debris of crystalline schists or older eruptive rocks, but generally with clastic volcanic minerals and fragments of basalts, limburgite, tachylite, and in volcanic ashes.

PYRITES.—Sometimes observed in cubic crystals or in the form of pentagonal dodecahedrons, sometimes with the characteristic striæ of oscillatory combination, sometimes in irregular grains, opaque, yellowish metallic lustre or bluish black in reflected light. Occasionally transformed into limonite.

PYROXENE.—(*a*) *Rhombic*, lamellar aggregates, generally large fragments, are found with older eruptive rock debris, short prismatic fragments with products of more recent eruptions. Cleavage following the prism of about 90°, in some cases also another cleavage parallel to the brachypinakoid. Index of refraction high, low interference colours. Extinction parallel to the pinakoidal cleavage. *Enstatite*, colourless to grey, yellowish, not pleochroic. *Bronzite*, often fibrous, yellowish to greenish, pleochroic, greyish green, yellowish. These two pyroxenes often contain metallic inclusions, intergrowth with monoclinic pyroxene. Associated with older rock debris, principally with peridotic rocks, and with volcanic ashes of andesitic or trachytic nature. In this case the fragments or crystals have often glass inclusions, but do not show intergrowth with monoclinic pyroxene. This or the previous variety found also in cosmic spherules. *Hypersthene*, greenish, red or brownish fragments bounded by cleavage planes, prismatic when associated with the debris of more recent eruptive rocks, intergrowth with monoclinic pyroxene. In the massive variety characteristic tabular inclusions, strong pleochroism. Found rarely with debris of older eruptive rocks, in some cases with lapilli or minerals of andesitic or trachytic eruptions.

(*b*) *Monoclinic.*—*Augite*, fragments irregularly bounded or with cleavage planes, often crystals of the ordinary form, coated with volcanic glass, twinning parallel to the orthopinakoid, cleavage parallel to the prism of 87° 6′, greenish, yellowish, brownish, purplish, high index of refraction, strong double refraction, oblique extinction of 36° 54′. Weak pleochroism: green, yellow, brown; in some cases not pleochroic. Gaseous or glassy inclusions frequent, encloses also crystals and grains of magnetite. Found frequently in the deposits with debris of basalts, andesites, &c., in volcanic ashes. *Diallage*, grains bounded by cleavage faces, cleavage parallel to the orthopinakoid, fibrous structure; greenish or brownish, tabular inclusions, double refraction strong, maximum extinction angle of about 40°, cleavage plates show one of the systems of polar rings. Associated with debris of older eruptive rocks.

QUARTZ.—It is generally in the form of quartz that free inorganic silicic acid is found in the deposits; particles of jasper, chalcedony, &c., are relatively rare. Only in exceptional instances was quartz observed as small crystals bounded by the planes of the hexagonal prism and pyramid. As a general rule the grains of this mineral are without any crystallographic outlines; they are angular or rounded, massive, without cleavage planes, with a characteristic conchoidal fracture. After cleaning with acid, the grains are transparent and colourless; some are clouded with inclusions, no traces of alteration, not attacked by acids. The latter characters: absence of cleavage planes, conchoidal fracture, rounded or angular form, without crystallographic faces, absence of any decomposition, distinguish at first sight this mineral from felspar. Interference figure of monaxial crystals, positive double refraction, in parallel polarised light bright colour, when the fragments attain, as they do in some deposits, a certain thickness. In many cases this mineral is characterised by its inclusions, sometimes arranged in planes or irregularly disposed, by liquid inclusions, some with carbonic acid or with small cubic crystals; sometimes these quartz grains contain needles of tourmaline, rutile, scales of hematite, chlorite, &c. The minerals associated with the quartz grains give a clue as to the matrix rock: quartz fragments derived from granite are generally characterised by numerous liquid inclusions, some with cubic crystals, the grains have not crystallographic outlines. The same may be said of quartz derived from crystalline schists. Quartz of porphyritic rocks, which is very rare, is distinguished in some rare cases by its more or less regular outlines, corrosion, and by glassy geometrical inclusions; moreover, liquid inclusions are not so often met with as in granitic quartz. The quartz of clastic rocks is angular or rounded, the micro-structure of the grains being the same as that of the same mineral in the rocks in which it was originally formed. *Vein quartz* presents irregular grains or aggregations of grains containing numerous liquid inclusions, sometimes fibrous or milky. Fragments of *chalcedony* are fibrous with a radiated structure, the fibres being very thin; double refraction negative, aggregate polarisation or spherulitic interference cross.

The silica derived from organic remains, which, like quartz, plays a very important part in marine deposits, behaves, between crossed nicols, like an isotropic body; to this character must be added the property which this variety of silica possesses of preserving, notwithstanding its tenuity or disaggregation, a special organic structure (Radiolaria, Diatoms, Sponge spicules). This structure enables us in numerous cases to determine the organisms from which the siliceous particles are derived. This variety of silica is soluble in caustic potash.

RUTILE.—This mineral is very rarely found in isolated prismatic crystals or in small grains, it is generally imbedded in fragments of rocks. In some shore deposits rutile is observed in the form of fine needles, or fragments of microscopic prismatic crystals often twinned as in the slates. Sometimes these small crystals are arranged in groups (*sagenite*), brown or reddish in colour. Double refraction very strong, high relief and brilliant polarisation colours for the smallest particles, not acted upon by acids. Associated with debris of older schisto-crystalline rocks, slates, &c.

SERPENTINE.—Compact or fibrous grains, in some cases mesh- or lattice-structure, yellowish, greenish, or brownish; in the veins, secondary deposition of metallic oxides; remains of the primitive mineral imbedded in the serpentine, birefrangent, colours of chromatic polarisation generally weak; in polarised light the fibrous or special structure appears most distinctly. Attacked by hot hydrochloric acid, and by sulphuric acid, with separation of gelatinous silica.

TOURMALINE.—Often found in small prismatic fragments or hemimorphic crystals. Transparent, brownish, bluish grey, reddish or greenish. Strong pleochroism, the ordinary ray very much absorbed, extinction parallel to the length, no cleavage but cracks somewhat parallel to the base, tolerably numerous inclusions often grouped together. Unattacked by ordinary acids. Almost always associated with debris of crystalline schists, granitic rocks, slates, &c.

ZEOLITES.—Sometimes granular aggregations, isotropic (*analcim*), or with rhombohedric cleavage (*chabasite*), more frequently divergent or radiated aggregations of small prismatic crystals, exceptionally isolated crystals or fragments of crystals bounded by prismatic and pyramidal faces, generally attached to fragments of rocks or of volcanic glass; colourless, transparent, low polarisation colours. Easily acted upon by hydrochloric acid, with formation of gelatinous silica. It was only possible in some exceptional cases to give a specification of the various zeolites, by microscopical examination or by microchemical reactions (see chapter on formation of zeolites in the deep-sea deposits).

ZIRCON.—Small quadratic crystals more or less rounded, prismatic but generally short, with indications of pyramidal faces. Colourless, yellowish, reddish, strong double refraction, relief very marked, colours of polarisation bright red and green, no pleochroism. Sometimes zonary structure, liquid and other inclusions. Reaction for zirconia by fusing with bicarbonate of soda. Found with debris of crystalline schists and of older and recent eruptive rocks, associated also with quartz grains, and other minerals derived from the disintegration of sedimentary rocks.

The above are the minerals most frequently met with in the deposits, and the microscopical characters on which we rely for their determination. It is true that all the characters used in lithological investigations are not indicated in the foregoing short descriptions, but, as already stated, the nature itself of the deep-sea deposits does not allow us to make a practical application of all the resources of microscopical analysis. Some other mineral particles composed of lapilli and fragments of rocks, manganese and iron concretions, phosphatic nodules, cosmic spherules, &c., will be described at length in the following chapters.

3. **Fine Washings.**—It remains now to point out the characteristics of the third part of the residue, that denominated "fine washings." This portion comes away with the first decantations; although in these decantations the substances composing the deposit are separated, as a rule, according to their specific gravity some particles of a higher density are always carried away with the lighter substances on account of their form and their very small size. Hence it may be expected that the fine washings obtained in this way will be a mixture of various substances in which predominate nevertheless the lightest and the smallest particles of the deposit. The somewhat vague term of *fine washings* appears to be preferable for this part of the residue to a mineralogical name, such as clay, for instance. The fine washings are connected intimately with the two other groups of materials composing the residue—the siliceous organisms, and the mineral particles; but the small size of these siliceous remains and of the fragments of minerals do not, as a rule, permit them to be classed with determinable species, and, on the other hand, in this part of the residue the amorphous matter predominates, forming, to the naked eye, a kind of homogeneous mass of a decidedly clayey character. Under the high powers of the microscope one observes that infinitesimal particles of organic and inorganic nature are imbedded in this argillaceous substance, which forms, so to speak, the substratum of the whole. Hence in this heterogeneous aggregation, which comes under the name of fine washings, may be distinguished :—

a. Argillaceous matter, forming small lumps with indefinite outlines, not reacting between crossed nicols, coloured or slightly tinted by other substances, reddish grey, brownish, &c., no gelatinisation with cold acids, after treatment with hydrochloric acid becomes more or less colourless, soluble after ebullition in sulphuric acid, heated on a platinum foil becomes red, yellowish, brownish, through the decomposition of the organic substances and dehydration and oxidation of the iron. Reaction of alumina with cobalt solution. The microstructure of this clayey matter is very indefinite, having, in wet preparations, a more or less gelatinous aspect in many instances. The colouring substances are manganese and iron, or one of them. The hydrated peroxide of manganese, in small microscopic concretions or as a pigment, is brownish, transparent, and dissolves in strong hydrochloric acid setting chlorine free. With the manganese are generally associated, as the colouring matter of the amorphous substances, oxides of iron, chiefly limonite, which are dissolved in cold dilute hydrochloric acid. When this iron is not combined with the clay, it appears as small lamellæ, as confused aggregations, giving to the clayey substance an ochreous or yellowish brown colour. With reflected light, limonite is reddish or deep brown; after heating these particles become black, opaque, and magnetic. Although we can rarely distinguish limonite from red hematite, it seems probable that in some cases the latter is represented in the deposits. The distinctive characters are that hematite is not at all so soluble in acids; it is red in reflected light and in transmitted light slightly transparent with a reddish tinge. These argillaceous matters are mixed up with :—

b. Organic substances, heated on a platinum foil they disappear or leave cinders, not decomposed by hydrochloric acid; soluble in caustic potash. Generally no organic structure is to be seen; amorphous, colour greenish, yellowish, brown, or grey, between crossed nicols behaving as isotropic bodies; in some cases when exhibiting an organic structure they are birefrangent.

c. Siliceous organisms, owing to their low specific weight (1·9 to 2·3), and their small size, these are carried away with the fine washings, and are fragments of the siliceous organisms found in the deposit.

d. Mineral particles, fragments of the same species as mentioned under "minerals."

We see thus that what goes by the name of deep-sea clay has no complete analogy with what should be included under the name of pure clay. It is not chemically or physically similar to kaolin, but is more nearly allied to bole-clay, rich in iron and manganese, and the clayey matter in the fine washings plays a much less important part than might be suspected before microscopical examination. Further on it will be shown that the proportion of silica in these clays, and therefore the proportion of silica in the fine washings, indicates generally free silica. This is to be attributed to the presence of remains of siliceous organisms, or small quartz particles. The fragments of minerals which pass away in the first decantations are always less than 0·02 mm. in diameter; their diminutiveness thus makes them float suspended in the water for some time, when the latter is agitated by shaking. Particles of this size might perhaps be determined in a rock section under the mineralogical microscope, but this is not possible with minute, isolated, irregular, chemically and physically altered, fragments, generally without any crystallographic outlines. There is, however, one exception in the case of splinters from pumice stone and vitreous volcanic rocks. The structure and form of these glassy particles makes them much more readily distinguishable than other mineral particles, so that particles even 0·002 mm. in diameter can be recognised. This can easily be tested by grinding a piece of pumice to powder in an agate mortar, when it will be found that the abundance of gaseous bubbles, the filamentous structure, curvilinear outline and jagged appearance due to the presence of the bubbles, enable the minutest fragments to be detected. The fragments from basic and acid pumice can even be detected in some cases; the latter yields elongated and nearly colourless fragments, while the former shows darker particles, and some of the bubbles are of a circular form rather than elongated.

To sum up, then, with reference to any one of the examples taken from the Tables in Chapter II., it will be observed that the number of the station is first given, then follow the date, the position, the depth from which the specimen was obtained, and the temperature of the water at the surface and bottom of the sea, when these are known.

The name given to the deposit is then stated, with the general physical characters, and the colour of the residue after the removal of the carbonate of calcium is also noted in the same column. The footnotes in the tables give the numbers of the analyses of substances from each station; these analyses will be found tabulated in the subsequent chapters. References to the specimens figured in the plates are also given in the footnotes.

Under the heading CARBONATE OF CALCIUM there are three columns, the first giving the percentage of this substance in the whole deposit, the figures having been obtained by quantitative analysis. In the second column the general designations of the Foraminifera which secrete lime are given in two groups, the first including those which live on the surface of the ocean and whose dead shells accumulate at the bottom of the sea and form by far the largest part of the carbonate of lime in oceanic deposits; the second group includes those lime-secreting Foraminifera that pass the whole of their lives at the bottom of the sea. Before each of these groups will be found numbers within brackets, giving an estimated percentage of the part each plays in making up the whole deposit. In the third column will be found an indication of the remains of other lime-secreting organisms observed in the deposit, such as pelagic and other Molluscs, otoliths of fish, fragments of Echinoderms, calcareous spicules of Alcyonaria, Corals, Ostracodes, calcareous Algæ, &c., and the number before this group gives the estimated amount of these in the whole deposit. Except when the shells of pelagic Molluscs are present, this group does not make up a large part of any deposit in water over 200 fathoms[1] in depth.

Under the heading RESIDUE the first column gives the percentage of the residue in the whole deposit, the figures here being obtained by subtracting the weight of carbonate of calcium found by analysis in 100 parts of the deposit. In the following column is given the general designation of the siliceous organisms or their fragments, and the estimated percentage of these in the whole deposit. Under this head are included those Foraminifera which build their tests by cementing together the mineral particles of the deposit, as well as those internal casts of calcareous organisms which have usually more or less of a glauconitic character. In the next column is given the mineral and crystalline fragments, with their mean diameter in millimetres, and the estimated part these as a whole take in the formation of the deposit. As a rule, the order in which the various species of minerals are stated gives an index to their abundance in the deposit, the most numerous being stated first, the least numerous last. In the fourth column, under this heading, will be found a statement as to the bulk and character of the fine washings of the residue. The constitution of these is very complex, but is fundamentally of an

[1] 366 metres.

amorphous clayey character, with exceedingly minute fragments of all the mineral particles and siliceous organisms with oxides of iron and manganese.

In the last column of the table will be found additional observations with reference to the nature of the bottom at the place where the deposits were collected, with other brief details. For more easy reference there is placed along the edges of the tables a statement as to the regions of the ocean to which the descriptions refer, and at the upper left-hand corner of each table there is a reference to the charts and sections in which the stations are represented.

c. Chemical Analyses of the Deposits.

During the cruise of the Challenger, Mr. J. Y. Buchanan frequently made qualitative tests of the deposits and of some of the substances found in them, but no detailed quantitative analyses could be attempted. In the foregoing sections it has been stated that we have not always had recourse to complete and elementary chemical analysis, preferring as a general rule microscopic analysis, for these deposits not having a constant and well-defined composition, did not require for their classification the long operations of quantitative analysis. As previously stated, the quantity of carbonate of calcium has in every case been determined, as this afforded a ready and certain means of classing the various kinds of deposits. In a great number of cases we have applied quantitative methods of chemical analysis with a definite end in view while engaged in the examination of the various samples, and in typical examples of all the deposits complete qualitative and quantitative analyses have been undertaken by ourselves or other chemists acting under our directions. The plan adopted by MM. Renard, Sipöcz, Hornung, and Klement, in the laboratory of Professor Ludwig of Vienna, or in M. Renard's laboratory at Brussels, may be here referred to in order to prevent repetition.

Following the method generally adopted at present for the analysis of silicates, three samples of the substance were taken. The first served to determine the water, silica, alumina, oxide of iron, manganese, magnesia, lime, and eventually cobalt and nickel.

With reference to the direct determination of water, this has always been effected after the method which we owe to Dr. Sipöcz. The substance is dried at 110° C., weighed, mixed with three times its weight of alkaline carbonates, and placed in a small platinum boat; the latter is then introduced into a porcelain tube and exposed to the action of a heated stove, all the precautions prescribed by Sipöcz being taken during the operation.[1] Under the influence of the heat of the furnace, the solvents act at the same time as the water frees itself; this latter is driven off by a current of dry air and collected in a U-tube containing pumice stone saturated with sulphuric acid, previously weighed. When the disengagement of the water ceases, the increased weight

[1] Sipöcz, *Sitzungsberichte der Wiener Akademie der Wissenschaften*, Bd. lxxvi. p. 51, 1877.

of the tube shows the quantity of water collected directly, and the solvent process is now complete. The boat is withdrawn from the tube and contains a vitreous mass. The silica is separated in the usual way after the evaporation to dryness of an acid solution. The iron and alumina are precipitated in the form of hydroxides by ammonia. Ebullition is maintained until the complete disappearance of the excess of free ammonia, so as to keep the manganese in solution; when the latter body was present in rather considerable quantities, the separation was effected by means of succinate of ammonia.

The oxides of iron and alumina weighed together are redissolved in hydrochloric acid; the small quantity of silica which is left undissolved in the acid is then treated apart, and the weight of it added to that of the silica obtained before. The iron is separated from the alumina by potassium hydrate; to the filtrate, after the separation of the iron and alumina, the direct addition of sulphide of ammonium gives a precipitate of sulphide of manganese, which is weighed after calcination in the form of mangano-manganic oxide. The calcium is afterwards precipitated in the form of oxalate of calcium, and weighed as oxide of calcium. In the filtrate separated from the precipitate of oxalate of calcium, the addition of phosphate of ammonium and ammonia produces a precipitate of ammonio-magnesia phosphate. Finally, the sulphuric acid is treated in the form of sulphate of barium in the last filtrate.

The second portion of the substance was destined for the determination of the protoxide of iron. The substance, dried and weighed, is introduced into a hard glass tube in an atmosphere of carbonic acid gas, and mixed with hydrofluoric acid and sulphuric acid. The sealed tube is submitted to a temperature of about 100° C. until the substance is entirely decomposed; the solution is then titrated with permanganate of potash.

The third and last portion of the substance is used for the determination of the alkalies. This part, weighed and dried, is submitted to the action of sulphuric and hydrofluoric acids in a platinum capsule; after evaporation with acids and calcination, the substance is treated with hydrochloric acid. The manganese is precipitated by baryta, and the excess of baryta by ammonia and carbonate of ammonia. A solution is thus obtained, containing the alkaline chlorides and excess of carbonate of ammonia; the latter is got rid of by calcination. The last traces of magnesia are eliminated by oxide of mercury; the chlorides are weighed together. To the solution containing the chlorides of sodium and potassium is added chloride of platinum, in order to separate the potassium as chloro-platinate, which is weighed in a glass filter after dessication. From the weight of the chloro-platinate of potassium, the quantity of chloride of potassium is deduced. The weight of chloride of sodium is obtained by difference.

In certain cases, when it became necessary to estimate quantitatively the various substances forming the residue, a large quantity of the deposit was treated with very dilute hydrochloric acid, taking care that the operation should take place without exceeding a weak acid reaction; after the elimination of the carbonates, phosphates, and sulphates, the residue was analysed as described above.

A considerable number of sharks' teeth, bones of Cetaceans, and manganese nodules were selected by Mr. Murray and sent to Professor Dittmar, F.R.S., for analysis. This able chemist has himself given an account of the methods he has employed, and these will be stated in the various places where his results are discussed, throughout the body of this Report. The same chemist also made, at the request of the editor of the reports, experiments to establish the state of oxidation of the manganese in the deposits, and gives a full account of his methods.

Soon after the return of the Expedition, Mr. Murray selected, at the request of the late Sir C. Wyville Thomson, a rather extensive series of typical deposits, rocks, manganese nodules, and other substances, which were all sent to the late Professor Brazier of the University of Aberdeen for analysis. These will be found interpolated throughout the body of this work. These various deposits and concretions were analysed by submitting the substances to the hydrochloric acid test; the part dissolved in the acid was analysed separately, and the residue of this experiment was afterwards treated by solvents.[1]

d. Materials available and made use of during the Investigation.

It seems desirable, in concluding this introduction on the methods we have employed in this research on the nature and distribution of deep-sea deposits, to say a few words on the specimens and collections at our disposal during the investigation. While many thousands of samples of deposits have been examined by us from nearly every part of the great ocean basins, only those collected during the voyage of H.M.S. Challenger have been described in detail in the following tables. After much reflection it was deemed advisable to limit the descriptions to the Challenger collections, as they formed the basis of the whole inquiry. All the specimens were collected and labelled with great care immediately after they were brought up from the bottom of the ocean, and the conditions under which they were found were carefully noted. The quantity of the deposit procured at each station by the sounding tube, the trawl, and the dredge was as

[1] Professor Brazier says:—"The deposits in these analyses were treated as earths by me, and after digestion in hydrochloric acid, were evaporated to dryness and subsequently re-dissolved as far as possible; the insoluble residue, after weighing, was treated with boiling caustic potash, and so much of the residue as was then dissolved was looked upon as silica of easy combination, and classed along with the bodies soluble originally in hydrochloric acid. Where Diatoms and other siliceous organisms were present, I was puzzled to know in what state the silica existed at the bottom of the ocean, for in the analyses of these deposits there was little for it to be combined with. In such cases the silica dissolved by caustic potash must very closely represent the siliceous organic matter present. I need not mention that the silica, with alumina and iron remaining insoluble in the potash, was simply rocky grit. Apparently, some allowance should be made for small portions of silica derived from easily decomposed minerals yielding sesquioxide of iron and alumina."

a rule much larger than in the case of any other collection of deep-sea deposits, and they covered such a wide area in all the principal ocean basins that they must be regarded as fairly representative of all the deposits now forming on the floor of the ocean. The detailed study of these large samples has thrown so much light on the subject that it has been possible to interpret with great certainty the nature of the deposit in those regions where only a relatively small quantity of the mud, ooze, or clay has been obtained by other expeditions. Indeed, the number of samples of deposits that have been sent to us from British and foreign ships and expeditions, which we have examined in the manner set forth in the following tables, greatly exceed those collected by the Challenger; in all, these have amounted to many thousands, and will be made use of in verifying all general conclusions.[1] In this way we have had an opportunity of examining personally deposits from nearly every region of the great ocean basins, and from nearly all the enclosed or partially enclosed seas. An investigation, extending over so wide a field and occupying so long a time, necessarily involved a great amount of labour and patience, but led in the long run to a great familiarity with and knowledge of deep-sea deposits as a whole, and their distribution in existing seas.

e. Leading Characteristics of Deposits from different Localities.

After a careful examination of a deep-sea deposit, following the method explained in the foregoing pages, it is even possible to state with a very considerable degree of certainty the region of the ocean in which it was formed, as well as to state approximately the depth and distance from land at which it was procured by the sounding tube, dredge, or trawl. Indeed, we frequently requested our assistants to select for us a sample

[1] In addition to the Challenger collections, the following among other collections have passed through our hands:—The very large and important collection made by the U.S.S. "Tuscarora" throughout the basin of the great Pacific Ocean in 1873–78; a collection by the U.S.S. "Gettysburg" in the Atlantic in 1876; a large and important collection made by the U.S.S. "Blake" in the Caribbean Sea, Gulf of Mexico, and along the eastern coasts of America, 1877–82; a very extensive collection from the steamships "Silvertown," "International," "Dacia," and "Buccaneer," belonging to the India-rubber, Gutta-percha, and Telegraph Works' Company, Silvertown, 1884–86, along the western coasts of Africa, around the Cape Verde and Canary Islands, and about the West Indies; several large collections from the ships of the Telegraph Construction and Maintenance Company in 1879–85, along the eastern coasts of Africa, in the Indian Ocean, and in the Pacific Eastern Seas, and in the South and North Atlantic; many valuable and important collections received through the Hydrographer of the Admiralty, from Her Majesty's surveying ships "Sylvia," Red Sea, 1886; "Seine," Indian Ocean, 1885; "Egeria," Indian Ocean, 1887, and South Pacific, 1887–89; "Myrmidon," Coral Sea, 1887; "Rambler," Indian and Pacific Oceans, 1888–90; "Valorous," North Atlantic, 1870–75; "Investigator," Bay of Bengal and Indian Ocean, 1886–89; "Alert," South Pacific, 1880; "Flying Fish," Indian Ocean, 1887; "Stork," Indian Ocean, 1888; "Triton," Faroe Channel and North Sea, 1882–84; "Bulldog," North Atlantic, 1860; "Porcupine," North Atlantic, 1869–70; "Lightning," North Atlantic, 1868; "Nassau," Indian Ocean, 1876; "Argus," North Atlantic, 1879; "Swallow" and "Dove," Yellow Sea, 1865–66; "Dart," Pacific Ocean, 1857. We have also received specimens, or have been permitted to examine them at different times, from the Norwegian North Atlantic Expedition, Nares' North Polar Expedition, Ross's Antarctic Expedition, "Talisman" Expedition, "Gazelle" Expedition, "Hassler" Expedition, and the U.S. Fish Commission, as well as from other sources.

from among several thousands, but not to give us the slightest indication of the ocean or depth from which the specimen was obtained. After examination, we have then marked regions on the chart in which we believed it was collected, stating at the same time the probable depth. In the great majority of cases, in about nine out of ten trials, the position could be stated within a few hundred miles and the depth within a few hundred fathoms. A few of the considerations on which we relied in making such determinations may fitly terminate this chapter on the methods of study.

The presence of large numbers of Pteropod and Heteropod shells indicates tropical or subtropical regions, and relatively shallow depths. Abundance of the shells of pelagic Foraminifera indicates the same regions, but when found without the shells of pelagic Molluscs they indicate a greater depth than when these latter are present. A very few fragments of these pelagic organisms, and consequently a low percentage of carbonate of lime, with abundance of the red and yellow oxides of iron and the black oxide of manganese, point out again still greater depths in the tropical regions. The presence or absence, and the size, of Rhabdoliths, Coccoliths, and Coccospheres give important indications as to latitude and depth—the first predominating in tropical regions, the two latter being better developed in temperate regions, and all disappear from the deposits as the polar waters are approached. Take again the remains of those lime-secreting organisms that habitually live at the bottom of the sea, such as Foraminifera, Polyzoa, Ostracodes, Molluscs, Corals, Annelids, and Algæ. The greater or less abundance of these in a deposit give most useful indications as to the depth and the distance from land at which the specimen was collected. These organisms are as a whole more abundant and better developed in shallow water, and in both these respects a change is observed in their fragmentary remains in greater depths and at a greater distance from land. Some species, however, denote, when present in abundance, ranges of depth. The greater or less abundance of some of the remains of the pelagic species give indications as to longitude; for instance, some pelagic species of Foraminifera are much more indicative of an Atlantic deposit than of a deposit from a similar latitude and depth in the Pacific.

In the same way the remains of siliceous organisms may furnish information as to depth and locality. The frustules of the large Diatom *Ethmodiscus*, Castracane, is quite characteristic of some of the deepest tropical Red Clays and Radiolarian Oozes far from land; it is quite absent in temperate and polar regions. A typical Diatom Ooze is only found in the neighbourhood of the great Southern Ocean surrounding the Antarctic continent, although some deposits that might be called Diatom Oozes are found in the most northern parts of the Pacific. A typical Radiolarian Ooze is limited to certain of the deeper tropical and subtropical portions of the Indian and Pacific Oceans.

When we consider the mineral particles, they too testify as to the conditions under which the deposit was formed. Typical glauconite and glauconitic casts appear to be limited to deposits now forming in relatively shallow depths in more or less close proximity to continental land, and especially along those high and bold coasts that are removed to some distance from the embouchures of rivers bearing abundance of fine silt into the ocean. Phosphatic and glauconitic nodules appear also to be indicative of deep water off continental shores.

In typical oceanic deposits, should there be any casts of the calcareous organisms, these are with few exceptions imperfect or mere skeletons, and are always of a reddish colour from the presence of ferric oxide. Quartz particles are relatively rare, or absent, in deposits far removed from the continents, with the exception of those regions affected by floating ice. They are, however, abundant along many continental shores for many miles seawards. Small round wind-borne fragments of quartz and other minerals are, however, found in the deposits many hundreds of miles to the west of the northern shores of Africa and off the shores of Australia. The size and nature of the mineral particles in an organic ooze, as well as the colour and amount of the amorphous clayey matter, or *fine washings* of our descriptions, very frequently enable us to tell the position from which the specimen was collected. Volcanic fragments, and especially glassy fragments and pieces of pumice stone, are in many cases markedly indicative of a deep-sea deposit; for instance, when these have undergone decomposition and are associated with nodules of manganese peroxide, sharks' teeth, bones of whales and cosmic spherules, we are sure that the specimen must have come from the greatest depths of the ocean, far removed from large masses of continental land.

Such are some of the main points on which we would rely for determining the position and depth from which a specimen of any deposit might have been procured were these unknown, but there are many others which have not been touched upon. Enough has been said, however, to show that at the present time a careful study of a deposit enables us to state with much precision the conditions under which it must have been laid down.

The application of the same reasoning to those geological strata which resemble modern marine formations is at once apparent.

CHAPTER II.

ON THE NATURE AND COMPOSITION OF THE SPECIMENS OF DEEP-SEA DEPOSITS COLLECTED DURING THE CHALLENGER EXPEDITION, AND THEIR VARIATIONS WITH CHANGE OF CONDITIONS.

IN this chapter each specimen of marine deposit collected during the Challenger Expedition is described with considerable detail in a series of Synoptical Tables, and these Tables are followed by observations indicating the more striking variations which these deposits undergo with a change in the depth, in latitude, in the temperature of the surface waters, and in the distance from continental and other lands.

a. SYNOPTICAL TABLES.

In Chapter I. the methods followed in the macroscopic and microscopic examination, as well as in the chemical analyses of the deposits, have been pointed out. The results obtained by the application of these methods to the study of the Challenger collections are set forth in the following Synoptical Tables, which form a methodical repertory of the facts observed at each of the Challenger's sounding and dredging stations in so far as these refer to the deposits now in process of formation. The descriptions follow the order in which the specimens were collected during the voyage. The specimens have all been treated in a uniform manner, and it is believed that these Tables contain all essential details regarding the characteristic properties of each specimen of the deposits. The numbers of the stations correspond to those on the charts and diagrams at the end of the volume, in which the temperature conditions and the geographical and bathymetrical distribution of the deposits are represented. The reader is referred to the previous chapter for a definition of all the terms and headings made use of in the tables.[1]

The facts summarised in these Tables serve as a foundation for the descriptions in Chapter III., where each type of Deep-Sea Deposit is considered in its ensemble, and for the conclusions in subsequent chapters where the origin of the materials which make up these deposits is discussed. In addition, however, to the Challenger collections, a very large number of samples from other expeditions and from many other regions of the ocean, have been examined in a similar manner, and have likewise served as a foundation for all general conclusions.

[1] See page 26.

See Charts 2 and 3.

England to Gibraltar.

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
		° ′ ″		°	°				
I	1872 Dec. 30	41 58 0 N. 9 42 0 W.	1125	...	...	Blue Mud, ...	...	*Globigerina, Pulvinulina.*	Coccoliths, Coccospheres.
IA	1873 Jan. 1	40 25 0 N. 9 38 30 W.	325	52·0	57·0	}			
IB	,, 1	40 24 0 N. 9 45 0 W.	730	49·0	57·0	} Hard Ground, ...	...	...	...
IC	,, 1	40 23 0 N. 9 43 0 W.	950	...	57·0	}			
ID	,, 2	39 55 0 N. 10 5 0 W.	1975	...	57·0	...	...	...	...
II	,, 13	38 10 0 N. 9 14 0 W.	470	...	57·0	Green Mud, green-grey when dry, granular.	[40·00]	(10·00 %), Globigerinidæ, *Pulvinulina.* (15·00 %), Miliolidæ, *Textularia*, Lagenidæ.	(15·00 %), Otoliths and teeth of fish, Gasteropods, Cirripedia plates, Ostracodes, fragments of Echinoderms, Coccoliths.
IIA	,, 13	38 5 0 N. 9 39 0 W.	1270	...	57·0	Green Mud, ...	...	...	...
IIB	,, 14	38 31 0 N. 9 31 0 W.	84	...	57·0	} Green Muds, ...	...	A few Globigerinidæ and other Foraminifera.	Fragments of Gasteropoda.
IIC	,, 14	38 28 0 N. 9 35 0 W.	280	...	57·0	}			
IID	,, 14	38 26 0 N. 9 38 0 W.	560	52·0	57·5	Green Sand, greenish grey when dry, finely granular, earthy. **Residue** dark yellow-green.	31·81	(12·00 %), Globigerinidæ, *Pulvinulina.* (15·00 %), Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(4·81 %), Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
IIE	,, 14	38 22 30 N. 9 44 0 W.	1290	...	57·0	Blue Mud, greyish when dry, plastic, coherent, lustrous streak. **Residue** red-brown.	19·00	(10·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), *Textularia, Uvigerina, Nonionina.*	(4·00 %), Echinoderm fragments, Polyzoa, Coccoliths.
IIF	,, 14	38 14 25 N. 9 49 42 W.	1475	37·5	57·5	Blue Mud, light grey when dry, very coherent, plastic, lustrous streak. **Residue** red-brown.	26·50	(20·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Uvigerina, Discorbina.*	(5·50 %), Echinoderm fragments, Coccoliths, a few Rhabdoliths.
IIG	,, 14	38 9 43 N. 9 48 0 W.	1380	38·0	57·5	Blue Mud, light grey when dry, very coherent, plastic, earthy. **Residue** red-brown, flocculent.	28·86	(20·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Uvigerina, Truncatulina.*	(7·86 %), Echini spines, Coccoliths, Rhabdoliths.
IIH	,, 14	37 56 0 N. 10 8 0 W.	1800	37·0	57·0	Blue Mud, grey when dry, plastic, coherent, earthy, very fine grained, breaking up in water. **Residue** red-brown.	19·88	(16·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Rotalidæ.	(2·88 %), Ostracodes, Echinoderm fragments, Coccoliths, a few Rhabdoliths.
IIJ	,, 15	37 1 45 N. 9 23 45 W.	1000	39·5	59·5	Green Mud, grey when dry, plastic, coherent, earthy, breaking up in water. **Residue** yellow-brown, flocculent.	18·88	(6·00 %), Globigerinidæ, *Pulvinulina.* (8·00 %), *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ, *Nonionina.*	(4·88 %), Gastropods, *Serpula*, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
...	...	Small mineral particles.	Much amorphous clayey matter.	On this occasion the first sounding and dredging were taken by the Challenger; they were quite successful, the dredge bringing up several Echinoderms and Crustaceans, but this and several of the subsequent soundings were trials of the apparatus, and frequently none of the deposit was obtained or preserved.
...	..	...	...	In each of these soundings the tube brought up no indication of the nature of the bottom. The dredge, which was put over in 1000 fathoms, came up empty.
...	...	...	...	Both the sounding line and dredging line broke in heaving in.
[60·00]	(40·00%), Sponge spicules, Astrorhizidæ, *Haplophragmium*, glauconitic casts, a few Diatoms.	(10·00%), Quartz, mica, felspar, glauconite.	(10·00%), Amorphous matter, mineral and siliceous remains.	Over one hundredweight (50 kilogrammes) of this deposit was obtained by the dredge. The percentages have been approximated, there being too little preserved for analysis. Light green glauconitic casts of the Foraminifera remained after treatment with acid.
...	...	...	...	The dredge brought up mud much the same as at 470 fathoms, which was twenty-five miles further east.
...	...	Many mineral particles with glauconite.	Amorphous matter.	These deposits contained a good deal of glauconite, but none was preserved for subsequent examination.
68·19	(10·00 %), Sponge spicules, glauconitic casts, Diatoms.	(40·00 %), m. di. 0·20 mm., angular; quartz, felspar, glauconite, mica, magnetite.	(18·19 %), many minute mineral particles, clayey and organic matter.	The shells of the larger organisms in this deposit are fragmentary. Many beautiful glauconitic casts of Foraminifera and other organisms remained after treatment with dilute hydrochloric acid.
81·00	(5·00 %), glauconitic casts and a few siliceous spicules of Sponges.	(10·00 %), m. di. 0·10 mm., angular; quartz, dark and pale glauconite, felspar, mica, magnetite.	(66·00 %), amorphous matter, fine mineral particles and minute fragments of siliceous spicules.	This deposit contains much amorphous clayey matter. All the Foraminifera are very small and much broken. Glauconitic matter is less abundant than at previous stations.
73·50	(3·00 %), a few glauconitic casts, arenaceous Foraminifera, and siliceous Sponge spicules.	(5·00 %), m. di. 0·07 mm., angular; quartz grains, mica, felspar, a few glauconitic particles, tourmaline, a few glassy volcanic fragments.	(65·50 %), amorphous matter and numerous fine mineral particles.	Some two or three bright green imperfect casts of Foraminifera remained after treatment with dilute acid. Coccoliths are abundant and large.
71·14	(1·00 %), siliceous Sponge spicules, arenaceous Foraminifera, a few glauconitic casts.	(5·00 %), m. di. 0·06 mm., angular; felspar, mica, some glassy volcanic particles, one or two quartz and glauconitic grains.	(65·14 %), amorphous matter, many minute mineral particles.	One or two dark green glauconitic casts of Foraminifera remained after treatment with dilute acid. Coccoliths are abundant and large.
80·12	(1·00 %), a few siliceous Sponge spicules, *Rhabdammina*.	(10·00 %), m. di. 0·06 mm., angular; felspar, augite, hornblende, mica, magnetite, quartz, tourmaline, a few glassy volcanic fragments.	(69·12 %), amorphous matter, many fine mineral particles, a few minute fragments of siliceous organisms.	No glauconitic matter observed in this deposit, although in shallower water nearer shore it is relatively abundant.
81·12	(2·00 %), glauconitic casts, Sponge spicules, *Haplophragmium*.	(25·00 %), m. di. 0·08 mm., angular and rounded; quartz, felspar, mica, magnetite, augite, glauconite, glassy volcanic fragments.	(54·12 %), amorphous matter, many fine mineral particles and minute fragments of siliceous organisms.	The mineral particles of this deposit are angular, except the glauconite and some of the large quartz grains, which are more or less rounded. Many glauconitic grains and casts of Foraminifera and other organisms remained after treatment with dilute acid, chiefly of a dark green colour.

England to Gibraltar.

See Charts 2, 3, and 4.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
England to Gibraltar—*continued.*	IIE	1873 Jan. 15	° ′ ″ 36 58 50 N. 9 14 20 W.	525	° 54·0	° 60·0				
	III	„ 15	37 2 0 N. 9 14 0 W.	900	...	60·0	Green Sands, ...	...	Globigerinidæ and other Foraminifera.	Fragments of Echinoderms, Molluscs, &c.
	IV	„ 16	36 25 0 N. 8 12 0 W.	600	...	60·0				
Gibraltar to Madeira.	V	„ 28	35 47 0 N. 8 23 0 W.	1090	38·5	61·0	Globigerina Ooze, pale yellow with rose tinge, slightly coherent when dry. **Residue** red.	66·84	(60·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Biloculina*, Textularidæ, *Truncatulina*.	(5·84 %), Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	VA	„ 29	36 13 0 N. 10 7 0 W.	2500	...	59·0	...	...	...	...
	VI	„ 30	36 23 0 N. 11 18 0 W.	1525	36·0	58·0	Globigerina Ooze, red-grey when wet, white with pink tinge when dry, finely granular, slightly coherent, breaking up readily in water. **Residue** red.	67·54	(60·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Biloculina*, Textularidæ, *Lagena*.	(6·54 %), Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
	VII	„ 31	35 20 0 N. 13 4 0 W.	2125	37·0	60·0	Globigerina Ooze, . . .	...	...	...
	VIIA	Feb. 1	34 4 0 N. 14 18 0 W.	2250	37·0	61·0	Globigerina Ooze, yellow when wet, white when dry, finely granular, pulverulent. **Residue** red.	74·77	(65·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Biloculina*, Textularidæ, Lagenidæ, Rotalidæ.	(8·77 %), Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
	VIIB	„ 2	32 43 0 N. 15 52 0 W.	2225	37·0	63·0	Globigerina Ooze, yellowish, granular, slightly coherent, breaking up readily in water. **Residue** red-brown.	53·13	(45·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, *Truncatulina*, *Nonionina*.	(7·13 %), Lamellibranchs, Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
Off Madeira.	VIIC	„ 2	32 21 0 N. 16 24 0 W.	670	46·8	63·0	Calcareous Sand, brown, coarse. **Residue** red-brown.	96·27	(5·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, *Polystomella*.	(88·27 %), Otoliths and teeth of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Cirripeds, Echinoderm fragments, Corals, Polyzoa.
	VIID	„ 2	32 16 0 N. 16 28 0 W.	1150	...	64·0	Volcanic Mud, pale grey when dry, granular, pulverulent. **Residue** brown-grey.	38·40	(25·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Textularidæ, *Uvigerina*, *Truncatulina*.	(10·40 %), Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths.
	VIIE	„ 2	32 20 15 N. 16 32 0 W.	930	43·5	63·5	Volcanic Mud, grey-brown, granular, slightly coherent, earthy. **Residue** red.	29·20	(22·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, *Bolivina*, *Truncatulina*.	(6·20 %), Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
...	Sponge spicules and Diatoms.	Quartz, felspar, glauconite, mica, magnetite.	Amorphous clayey and organic matter.	The deposits in these soundings were nearly the same as at 560 fathoms on January 14 (Station IID), but none was preserved for subsequent examination. From 900 fathoms the dredge came up full of mud.	England to Gibraltar—*continued.*
33·16	(2·00 %), a few Radiolaria and Sponge spicules, one or two arenaceous Foraminifera, a few imperfect casts.	(2·00 %), m. di. 0·06 mm., angular; felspar, augite, hornblende, tourmaline, glassy volcanic particles, quartz sometimes rounded.	(29·16 %), amorphous matter, many minute fragments of minerals and siliceous organisms.	A few imperfect casts of pelagic Foraminifera remained after treatment with dilute acid. Only one or two of the organisms are macroscopic.	Gibraltar to Madeira.
...	...	...	...	No deposit obtained; line carried away.	
32·46	(1·00 %), a few Radiolaria, Sponge spicules, Lituolidæ.	(5·00 %), m. di. 0·07 mm., angular; lapilli, felspar, augite, magnetite, glassy volcanic fragments, pumice.	(26·46 %), ferruginous amorphous matter, fragments of minerals and fine portions of siliceous organisms.	A few particles of volcanic rocks measured 0·15 mm. in diameter or larger. Much magnetite and many brown altered glassy particles were observed.	
...	...	...	...	Deposit quite similar to the next. Trawl brought up several specimens.	
25·28	(1·00 %), Radiolaria, a few Sponge spicules, *Haplophragmium.*	(3·00 %), m. di. 0·06 mm., angular; quartz, felspar, lapilli, augite, glassy volcanic fragments.	(21·28 %), amorphous matter, many minute mineral particles and fragments of siliceous organisms.	Among the minerals were a few rounded quartz grains, some of which were covered with limonite.	
46·87	(1·00 %), Radiolaria, Sponge spicules, *Hyperammina, Haplophragmium,* a few imperfect casts.	(5·00 %), m. di. 0·13 mm., rounded and angular; fragments of volcanic rocks, plagioclase, magnetite, orthoclase, manganese grains, augite, olivine, glassy volcanic particles, quartz, hornblende.	(40·87 %), amorphous matter, minute fragments of minerals and siliceous organisms.	A few brown casts of the Foraminifera remained after treatment with dilute acid. The Coccoliths are notably large.	
3·73	Sponge spicules.	(1·00 %), m. di. 0·25 mm., angular and rounded; basaltic rock fragments, glassy volcanic particles, olivine, augite, magnetite, felspar.	(2·73 %), fine mineral fragments and some amorphous matter.	The organisms and minerals had mostly a slight coating of manganese. Some fragments of rocks measured nearly 1 cm. in diameter.	Off Madeira.
61·60	(1·00 %), a few Sponge spicules.	(40·00 %), m. di. 0·07 mm., angular; lapilli of vesicular basalt, felspar, augite, magnetite, olivine, glassy volcanic particles.	(20·60 %), fine fragments of minerals, amorphous matter, and a few minute fragments of Sponge spicules.	Some of the Gasteropods, Lamellibranchs, Pteropods, and Heteropods in this deposit are macroscopic; much olivine and magnetite present.	
70·80	(1·00 %), Sponge spicules, Astrorhizidæ.	(15·00 %), m. di. 0·06 mm., angular; numerous lapilli of vesicular basalt, augite, magnetite, felspar, glassy volcanic particles.	(54·80 %), amorphous matter, many small fragments of minerals, a few fragments of siliceous organisms.		

See Charts 2, 4, and 5.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Off Maderia—*continued.*	VIIF	1873 Feb. 2	° ′ ″ 32 27 0 N. 16 40 30 W.	1500	° ...	° 63·0	VOLCANIC MUD, brown, slightly coherent, gritty. Residue brown.	36·93	(17·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(17·93 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.
	VIIG	,, 3	32 32 45 N. 16 48 0 W.	1150	39·0	63·0	VOLCANIC MUDS, . . .	...	Globigerinidæ and other Foraminifera.	Fragments of many calcareous organisms.
	VIIH	,, 3	32 35 0 N. 16 51 0 W.	790	45·0	62·8				
	VIIJ	,, 3	32 36 15 N. 16 53 15 W.	490	...	63·0				
Maderia to Tenerife.	VIIK	,, 6	29 19 0 N. 16 38 0 W.	1975	36·2	62·5	GLOBIGERINA OOZE, . . .	...	...	...
Between the Canary Islands.	VIIL	,, 10	28 28 0 N. 16 12 30 W.	278	...	64·0	VOLCANIC MUDS, brown, earthy, slightly coherent, gritty. Residue red-brown.	10·36	(About 5·00%), Globigerinidæ, *Pulvinulina.* (About 1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(About 5·00 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
	VIIM	,, 10	28 28 0 N. 16 10 0 W.	630	45·0	64·0		11·84		
	VIIN	,, 10	28 30 30 N. 16 3 30 W.	975	41·0	64·0	VOLCANIC MUD . . .	...	...	...
	VIIO	,, 10	28 33 0 N. 16 4 0 W.	560	45·5	64·0	VOLCANIC MUD, brown, earthy, slightly coherent, gritty. Residue red-brown.	25·93	(5·00 %), Globigerinidæ, *Pulvinulina.* (4·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(16·93 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
	VIIP	,, 10	28 35 0 N. 16 5 0 W.	78	...	64·0	VOLCANIC SAND, mottled, black, white, and red. Residue black, sandy.	45·09	(15·00 %), *Miliolina*, *Polytrema*, Nummulinidæ.	(30·09 %), fragments of Crustaceans, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Echini spines, Polyzoa, calcareous Algæ.
	VIIQ	,, 10	28 38 0 N. 16 5 0 W.	179	...	64·0	HARD GROUND, . . .	...	...	...
	*VIIR	,, 10	28 41 0 N. 16 6 0 W.	640	45·8	64·0	VOLCANIC MUD, brown, earthy, slightly coherent, gritty. Residue red-brown.	31·70	(22·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·70 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
	VIIS	,, 10	28 45 0 N. 16 7 0 W.	1390	38·5	63·0	VOLCANIC MUD, . . .	...	...	...

* See anal. 68.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
63·07	(1·00 %), a few Radiolaria and Sponge spicules.	(40·00 %), m. di. 0·10 mm., angular; lapilli and scoriæ, magnetite, olivine, sanidine, plagioclase, augite, hornblende, glassy volcanic particles.	(22·07 %), amorphous matter, many minute mineral fragments, a few remains of siliceous organisms.	Some of the organisms are macroscopic. The mineral particles form a red-brown volcanic sand. Trawl line broke in heaving in.	Off Madeira—*continued.*
...	...	Many volcanic mineral particles.	...	The deposits were in all these soundings similar to the above, the mineral particles being larger nearer shore.	
...	...	...	...	No deposit preserved; the small quantity on the tube indicated a Globigerina Ooze.	Madeira to Teneriffe.
89·64 88·16	(About 1·00 %), a few Sponge spicules, *Haplophragmium.*	(About 40·00 %), m. di. 0·08 mm., angular; lapilli of vesicular basalt, augite, sanidine, plagioclase, magnetite, olivine, glassy volcanic fragments, glauconite.	(About 48·00 %), amorphous matter, numerous minute fragments of minerals, and a few remains of siliceous organisms.	These two soundings are practically the same. The size of the mineral particles is a little less in the deeper sounding, viz., 630 fathoms, and here the pelagic Foraminifera make up the greater part of the carbonate of calcium. The same remark holds good for all these soundings off the Canary Islands; the deeper ones might be called Globigerina Oozes.	Between the Canary Islands.
...	...	...	...	No deposit preserved.	
74·07	(1·00 %), a few Sponge spicules, *Haplophragmium.*	(40·00 %), m. di. 0·10 mm., angular; lapilli of vesicular basalt, augite, sanidine, plagioclase, magnetite, olivine, glassy volcanic fragments.	(33·07 %), amorphous matter, many minute mineral particles, and a few remains of siliceous organisms.	This deposit resembles those of Stations VIIL. and VIIM.	
54·91	...	(53·91 %), m. di. 1·00 mm., rounded; fragments of basaltic rocks, augite, black glassy particles, magnetite.	(1·00 %), amorphous matter.	The carbonate of calcium is made up for the most part of rounded fragments of Molluscs, *Serpula*, Echinoderms, Polyzoa, and Foraminifera.	
...	...	...	...	No trace of any deposit obtained.	
68·30	(1·00 %), a few Sponge spicules, *Haplophragmium.*	(30·00 %), m. di. 0·06 mm., angular; lapilli of vesicular basalt, augite, sanidine, plagioclase, magnetite, olivine, glassy volcanic particles.	(37·30 %), many minute fragments of minerals, amorphous matter, a few remains of siliceous organisms.	This deposit is similar to those at Stations VIIL. and VIIM., so far as the inorganic constituents are concerned.	
...	...	...	...	No deposit preserved.	

See Charts 5 and 6, and Diagram 1.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Between the Canary Islands—*continued.*	*VIIT	1873 Feb. 11	° ′ ″ 28 42 0 N. 17 8 0 W.	1750	° 37·5	° 63·0	Volcanic Mud, grey when dry, slightly coherent, earthy, gritty. **Residue** dark red-brown.	36·50	(32·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Bolivina*, *Lagena*, *Truncatulina*, *Nonionina.*	(3·50 %), Ostracodes, Echini spines.
	VIIU	,, 11	28 20 0 N. 17 34 0 W.	1340	38·5	65·0	Volcanic Muds, ...	...	...	...
	VIIV	,, 11	27 58 0 N. 17 39 0 W.	1620	37·5	65·0				
	†VIII	,, 12	28 3 15 N. 17 27 0 W.	620	...	64·5	Volcanic Mud, grey-brown when dry, slightly coherent, gritty, earthy. **Residue** brown.	29·02	(17·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, *Chilostomella*, Lagenidæ, Rotalidæ, *Polystomella.*	(9·02 %), Otoliths of fish, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa.
Tenerife to Sombrero Island.	‡1	,, 15	27 24 0 N. 16 55 0 W.	1890	36·8	64·5	Globigerina Ooze, grey when dry, slightly coherent, earthy. **Residue** brown.	50·00	(45·00 %), Globigerinidæ, *Pulvinulina.*	(5·00 %), Pteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	§2	,, 17	25 52 0 N. 19 22 0 W.	1945	36·8	67·0	Globigerina Ooze, white with a yellow tinge, slightly coherent, finely granular. **Residue** red-brown.	64·55	(55·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(7·55 %), Otoliths of fish, Gasteropods, fragments of Pteropods Echinoderms and Corals, Coccoliths, Rhabdoliths.
	‖3	,, 18	25 45 0 N. 20 14 0 W.	1525	37·0	65·0	Pteropod Ooze, light brown with pink tinge, very slightly coherent, granular. **Residue** red.	[70·00]	(50·00 %), Globigerinidæ, *Pulvinulina.* A few specimens of *Bolivina.*	(20·00 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Cirripedia, Echinoderm fragments, Coral fragments, Coccoliths, Rhabdoliths.
	4	,, 19	25 28 0 N. 20 22 0 W.	2220	...	66·0	...	...	...	...
	¶5	,, 21	24 20 0 N. 24 28 0 W.	2740	37·0	68·0	Red Clay, plastic, light red-brown when dry, sublustrous streak, coherent. **Residue** brick-red.	12·00	(9·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, *Gaudryina*, *Lagena*, *Truncatulina.*	(2·00 %), Gasteropod and Lamellibranch shells, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	6	,, 23	23 14 0 N. 28 22 0 W.	2950	37·0	69·2	Red Clay, ...	...	A few Globigerinidæ.	...
	**7	,, 24	23 23 0 N. 31 31 0 W.	2750	36·9	68·0	Red Clay, plastic, homogeneous, unctuous, drying into coherent red coloured lumps which break up readily in water, lustrous streak. **Residue** brick-red.	4·11	(3·00 %), broken shells of *Globigerina.*	(1·11 %), small teeth of fish.

* See anal. 69. † See anal. 70. ‡ See anal. 33. § See anal. 34. ‖ See anal. 96, 97; Pl. III. figs. 1, 2, 3. ¶ See anal. 1, 2. ** See anal. 3.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
63·50	(1·00 %), a few Sponge spicules, *Haplophragmium*.	(25·00 %), m. di. 0·06 mm., angular; lapilli of basaltic rocks, plagioclase, sanidine, augite, olivine, magnetite.	(37·50 %), many fine mineral particles, amorphous matter, a few remains of siliceous spicules.	Except for the large number of mineral particles of volcanic origin, these deposits might equally well be called Globigerina Oozes.	Between the Canary Islands—*continued*.
...	...	...	...		
70·98	(2·00 %), Sponge spicules, fragments of Radiolaria, Astrorhizidæ, *Cyclammina*, Textularidæ.	(40·00 %), m. di. 0·08 mm., angular; lapilli of basaltic rocks, scoriaceous fragments, felspar, augite, olivine, hornblende, magnetite, glassy volcanic particles.	(28·98 %), minute fragments of minerals, amorphous matter, many minute fragments of siliceous organisms.	This deposit contains very many particles of volcanic sand and a considerable quantity of amorphous matter. There are also many coloured particles, some altered to palagonite. Some of the Foraminifera are macroscopic. Dredge brought up a large quantity of the mud.	
50·00	(2·00 %), Radiolaria, Sponge spicules, Diatoms.	(15·00 %), m. di. 0·07 mm., angular; quartz, sanidine, olivine, augite, lapilli, magnetite, fragments of pumice.	(33·00 %), amorphous matter, many minute fragments of minerals, remains of siliceous organisms.	The carbonate of calcium is made up almost entirely of pelagic Foraminifera. Among the minerals are some rounded grains of quartz covered with limonite. Dredge came up empty.	Teneriffe to Sombrero Island.
35·45	(1·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, *Trochammina*, a few imperfect casts.	(2·00 %), m. di. 0·07 mm., angular; quartz, monoclinic and triclinic felspars, magnetite, olivine, augite, glassy volcanic particles.	(32·45 %), amorphous matter, many fine mineral particles, a few fragments of siliceous organisms.	Some of the quartz grains are covered with limonite, and measure about 1 mm. in diameter. Some of the organisms are macroscopic. Dredge half full of mud; nothing found on sifting except otoliths of fish and Pteropod shells.	
30·00	(20·00 %), Sponge spicules, Radiolaria, thin imperfect casts of Foraminifera and other organisms, *Hyperammina*.	(10·00 %), m. di. 0·10 mm., angular; felspar, black mica, augite, manganese grains, glassy volcanic particles, red-coloured altered fragments.	Amorphous matter.	Two soundings were taken, and on each occasion no deposit came up in the tube. The dredge brought up a large Sponge, *Poliopogon amadou*, and a small quantity of the ooze was obtained attached to the basal portion. In the dredge there were manganese nodules and many fragments of a dead Coral covered with a thin coating of black shining manganese. Many of the organisms are macroscopic.	
...	...	...	...	No deposit obtained; sounding line broke in hauling in.	
88·00	(1·00 %), Radiolaria, Sponge spicules, *Aschemonella*, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular and rounded; quartz covered with limonite, magnetite, felspar, augite, pumice, black mica.	(86·00 %), a great many fine mineral particles, amorphous matter, fragments of siliceous organisms.	Dredge full of clay, on sifting which a few shells of Molluscs were found in addition to the Foraminifera.	
	...	A few mineral particles.	Much amorphous matter.	A small quantity of the deposit came up in the tube.	
95·89	(1·00 %), Siliceous spicules, *Haplophragmium*.	(1·00 %), m. di. 0·06 mm., angular; felspar, black mica, fragments of pumice, a few small rounded grains of quartz covered with limonite, zircon, manganese grains.	(93·89 %), amorphous matter, many minute fragments of minerals, and a few remains of siliceous organisms.	This deposit was of a brown-yellow colour when taken from the tube, smooth and homogeneous.	

See Chart 6 and Diagram 1.

Tenerife to Sombrero Island—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1873	° ′ ″		°	°				
*8	Feb. 25	23 12 0 N. 32 56 0 W.	2700	37·0	67·0	Red Clay, plastic, unctuous, homogeneous, drying into coherent red coloured lumps which break up readily in water, lustrous streak. **Residue** brick-red.	16·42	(15·00%), Globigerinidæ, *Pulvinulina*, and their broken parts. A few *Truncatulina pygmæa*.	(1·42 %), small teeth of fish.
†9	„ 26	23 23 0 N. 35 11 0 W.	3150	36·8	69·0	Red Clay, plastic, unctuous, homogeneous, drying into light red coloured coherent masses which break up in water, lustrous streak. **Residue** dark red-brown.	3·11	(2·11 %), *Globigerina*, *Pulvinulina*.	(1·00 %), small teeth of fish.
‡10	„ 28	23 10 0 N. 38 42 0 W.	2720	36·5	71·0	Red Clay, light red, plastic, unctuous, homogeneous, lustrous streak. **Residue** brick-red.	13·30	(12·00 %), Globigerinidæ, *Pulvinulina*.	(1·30 %), small teeth of fish, Echini spines.
§11	Mar. 1	22 45 0 N. 40 37 0 W.	2575	36·5	72·2	Globigerina Ooze, light yellow-red when dry, slightly coherent, earthy. **Residue** red.	51·16	(50·00 %), Globigerinidæ, *Pulvinulina*.	(1·16 %), Echini spines, Coccoliths, Rhabdoliths.
‖12	„ 3	21 57 0 N. 43 29 0 W.	2025	36·9	73·0	Globigerina Ooze, granular, many black particles. **Residue** red.	44·88	(40·00 %), Globigerinidæ, *Pulvinulina*.	(4·88 %), Fragments of Pteropods, Echini spines, Coccoliths, Rhabdoliths.
¶13	„ 4	21 38 0 N. 44 39 0 W.	1900	36·8	72·0	Globigerina Ooze, light reddish yellow, slightly coherent, gritty, drying into friable lumps. **Residue** red.	74·50	(66·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ,	(6·50 %), Otoliths of fish, *Serpula*, Gasteropod and Lamellibranch shells, Pteropod fragments, Coccoliths, Rhabdoliths.
**14	„ 5	21 1 0 N. 46 29 0 W.	1950	36·8	74·0	Globigerina Ooze, light reddish yellow, slightly coherent, granular. **Residue** red.	70·43	(67·00 %), Globigerinidæ, *Pulvinulina*.	(3·43 %), Echinoderm fragments, Coccoliths, Rhabdoliths.
††15	„ 6	20 49 0 N. 48 45 0 W.	2325	36·2	72·5	Globigerina Ooze, pale yellow-brown, granular, slightly coherent. **Residue** red.	67·60	(60·00 %), Globigerinidæ, *Pulvinulina*.	(7·60 %), Otoliths of fish, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
‡‡16	„ 7	20 39 0 N. 50 33 0 W.	2435	36·2	74·0	Globigerina Ooze, light yellow-brown, granular, slightly coherent. **Residue** brown.	52·22	(46·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ.	(5·22 %), Echinoderm fragments, Coccoliths, Rhabdoliths.
§§17	„ 8	20 7 0 N. 52 32 0 W.	2385	36·5	74·0	Globigerina Ooze, light red-brown, granular, slightly coherent, breaking up readily in water. **Residue** brown.	58·40	(51·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ.	(6·40 %), Echinoderm fragments, Coccoliths, Rhabdoliths.

* See anal. 4. † See anal. 5, 24. ‡ See anal. 6. § See anal. 35. ‖ See anal. 36.
¶ See anal. 37; Pl. XI. fig. 5. ** See anal. 38. †† See anal. 39. ‡‡ See anal. 40, 98. §§ See anal. 41.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
83·58	(1·00 %), Sponge spicules, *Haplophragmium.*	(1·00 %), m. di. 0·06 mm., angular; fragments of monoclinic and triclinic felspars, augite, hornblende, magnetite, black mica, rounded grains of quartz covered with limonite, manganese grains.	(81·58 %), amorphous matter, minute mineral particles, and a few fragments of siliceous organisms.	The Globigerinidæ are very much broken, and have a corroded appearance. The rounded quartz grains are almost certainly wind-borne. Dredge was empty, probably never reached the bottom.
96·89	(1·00 %), Sponge spicules, *Sorosphæra, Reophax.*	(1·00 %), m. di. 0·06 mm., angular and rounded; felspar, magnetite, black mica, augite, pumice, rounded grains of quartz covered with limonite, manganese grains.	(94·89 %), amorphous matter, minute fragments of minerals and siliceous organisms.	Only a few points of effervescence were noticed on treating a portion of the deposit with dilute acid. The deposits have been gradually altering in character, becoming less rich in Foraminiferá. This deposit consists almost entirely of Red Clay in a state of fine division. Dredge one-fourth full of the clay; sounding tube penetrated over a foot (30·48 cm.) into the deposit.
86·70	(1·00 %), Sponge spicules, Radiolaria, *Haplophragmium.*	(1·00 %), m. di. 0·06 mm., angular; felspar, hornblende, magnetite, black mica, glassy volcanic particles.	(84·70 %), amorphous matter, minute mineral particles, and remains of siliceous organisms.	Note the increasing percentage of carbonate of lime with the lesser depth.
48·84	(1·00 %), Sponge spicules.	(2·00 %), m. di. 0·06 mm., angular; sanidine, augite, magnetite, glassy volcanic particles.	(45·84 %), amorphous matter, fine mineral particles.	Dredge came up empty.
55·12	(1·00 %), Radiolaria.	(30·00 %), m. di. 0·80 mm., rounded and angular; grains of manganese, red and yellow fragments of palagonite, sanidine, augite, pumice.	(24·12 %), amorphous matter, minute mineral fragments, a few siliceous remains.	The finer portions of the deposit seem to have been washed away in pulling up the tube. The large quantity of manganese and palagonite is remarkable, and accounts for the large percentage and size of the minerals. Some of the organisms are macroscopic. Dredge empty.
25·50	(1·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·08 mm., angular; lapilli, sanidine, augite, magnetite, palagonite, glassy volcanic particles, a few manganese grains.	(23·50 %), amorphous matter, many fine mineral particles, a few fragments of siliceous organisms.	The deposit is remarkably pure as regards the carbonate of calcium being chiefly made up of the remains of pelagic Foraminifera. Some of the organisms are macroscopic. Dredge contained a small quantity of the ooze.
29·57	(1·00 %), Radiolaria, a few imperfect red casts of the Foraminifera.	(1·00 %), m. di. 0·07 mm., angular; monoclinic and triclinic felspars, augite, hornblende, magnetite, glassy volcanic particles.	(27·57 %), amorphous matter, minute mineral and siliceous remains.	Although the primordial chambers of the Foraminifera are abundant, no Coccospheres were observed; Coccoliths are abundant and large. Water-bottle contained some ooze, but there was none in the trawl.
32·40	(1·00 %), Radiolaria, imperfect red casts of pelagic Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; sanidine, augite, magnetite, pumice, manganese grains.	(30·40 %), amorphous matter, fine mineral and siliceous remains.	Note the decrease of carbonate of lime with increasing depth, and consequent increase of amorphous matter in this and the next sounding.
47·78	(1·00 %), Radiolaria, red imperfect casts of Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; sanidine, magnetite, augite, pumice, manganese grains.	(45·78 %), amorphous matter, many fine mineral particles, and remains of Radiolaria.	The dredge brought up some concretions covered with manganese, two or three sharks' teeth and valves of *Scalpellum* also covered with a thin coating of manganese. The manganese grains found among the residue left on treating the deposit with acid were round, and had a diameter of about 0·1 mm.
41·60	(1·00 %), Radiolaria, Sponge spicules, a few imperfect casts of Foraminifera.	(1·00 %), m. di. 0·08 mm., angular; monoclinic and triclinic felspars, lapilli of basaltic rocks, magnetite, augite, pumice, brown glassy volcanic particles.	(39·60 %), amorphous matter, fine mineral particles, and siliceous remains.	The deposits are becoming more clayey with increase of depth (see next station).

Teneriffe to Sombrero Island—*continued.*

See Charts 6 and 7, and Diagrams 1 and 2.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Tenerife to Sombrero Island—*continued.*	*18	1873 Mar. 10	° ′ ″ 19 41 0 N. 55 13 0 W.	2650	° 36·0	74·0	Red Clay, light red-brown, plastic, coherent when dry, breaking up readily in water, lustrous streak. **Residue** dark brown.	15·78	(12·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Miliolina, Truncatulina.*	(2·78 %) Coccoliths and Rhabdoliths.
	†19	" 11	19 15 0 N. 57 47 0 W.	3000	35·5	75·0	Red Clay, light red-brown, coherent, breaking up in water, lustrous streak, plastic and unctuous when wet. **Residue** red-brown.	1·49	*Globigerina* (fragments).	...
	‡20	" 12	18 56 0 N. 59 35 0 W.	2975	36·0	75·0	Red Clay, light red-brown, coherent, lustrous streak, breaking up in water, plastic and unctuous when wet. **Residue** red-brown.	3·50	(2·50 %), Globigerinidæ, *Pulvinulina.*	(1·00 %), small teeth of fish.
	§21	" 13	18 54 0 N. 61 28 0 W.	3025	35·5	76·0	Red Clay, light red-brown, coherent, breaking up readily in water, lustrous streak, plastic and unctuous when wet. **Residue** dark brown.	2·44	(1·44 %), *Globigerina.*	(1·00 %), fragments of Echini spines.
	‖22	" 14	18 40 0 N. 62 56 0 W.	1420	38·4	76·0	Pteropod Ooze, white, very slightly coherent, granular. **Residue** brown.	80·69	(47·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), *Miliolina, Cassidulina, Truncatulina.*	(30·69 %), Gasteropods, Lamellibranchs, Pteropods, Heteropods, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
Off Sombrero Island.	¶23	" 15	18 24 0 N. 63 28 0 W.	450	...	76·0	Pteropod Oozes, light brown, granular, slightly coherent, chalky. **Residue** brown.	84·27	(44·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(35·27 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Corals and their fragments, Polyzoa, Alcyonarian spicules, Coccoliths, Rhabdoliths.
	23A	" 15	18 26 0 N. 63 31 15 W.	460	...	76·0				
	23B	" 15	18 28 0 N. 63 35 0 W.	590	...	76·0				
St. Thomas to Bermuda.	**24	" 25	18 38 30 N. 65 5 30 W.	390	...	76·0	Pteropod Ooze, light brown when dry, slightly coherent, earthy. **Residue** red.	73·88	(30·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(40·88 %), Otoliths of fish, Cephalopod beaks, *Serpula, Dentalium,* Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Corals and their fragments, Polyzoa, Coccoliths, Rhabdoliths.
	24A	" 25	18 43 30 N. 65 5 0 W.	625	...	76·0	Pteropod Ooze, light yellow when dry, slightly coherent. **Residue** light yellow.	68·88	(30·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(35·88 %), Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.

* See anal. 7. † See anal. 8. ‡ See anal. 9. § See anal. 10.
‖ See anal. 60. ¶ See anal. 61; Pl. XI. fig. 6. ** See anal. 62.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
84·22	(1·00 %), a few spicules of Radiolaria.	(1·00 %), m. di. 0·07 mm., angular; sanidine, magnetite, augite, pumice, a few grains of manganese.	(82·22 %), amorphous matter, minute fragments of minerals and Radiolaria.	The small fragments of quartz covered with limonite, believed to be wind-borne, which are very common in the soundings on, and to the east side of, the Dolphin Ridge, are, apparently, quite absent in this and the following soundings on the western side.	Tenerife to Sombrero Island—*continued.*
98·51	(1·00 %), Radiolaria.	(1·00 %), m. di. 0·07 mm., angular; fragments of sanidine, augite, magnetite, glassy volcanic particles, a few manganese grains.	(96·51 %), amorphous matter, fine mineral particles, and broken pieces of Radiolaria.	No effervescence was observed on treating a portion with dilute acid, and only one or two fragments of pelagic Foraminifera were observed on microscopic examination.	
96·50	(1·00 %), Sponge spicules, Radiolaria, *Haplophragmium.*	(1·00 %), m. di. 0·10 mm., angular; felspar, magnetite, augite, lapilli, fragments of pumice.	(94·50 %), amorphous matter, many minute mineral particles, and fragments of siliceous organisms.	The dredge brought up a large quantity of the Red Clay. On passing this through fine sieves many small worm tubes (*Myriochele*) were found. These were composed of the minute mineral particles mentioned and Sponge and Radiolarian spicules; many of the tubes contained living worms. Some of the volcanic particles are partially transformed into zeolitic matter.	
97·56	(1·00 %), Radiolaria, Sponge spicules, *Haplophragmium.*	(3·00 %), m. di. 0·10 mm., angular; felspar, augite, hornblende, magnetite, lapilli, glassy volcanic particles.	(93·56 %), amorphous matter, minute mineral particles, fragments of siliceous organisms.	The calcareous organisms are much decomposed and broken up.	
19·31	(2·00 %), Sponge spicules, Radiolaria, imperfect red and brown casts of Foraminifera, *Haplophragmium.*	(2·00 %), m. di. 0·07 mm., angular; monoclinic and triclinic felspars, magnetite, augite, hornblende, black mica, lapilli.	(15·31 %), amorphous matter, minute fragments of minerals and siliceous organisms.	Most of the finer particles in the deposit appear to be fragments of Pteropods and other pelagic Molluscan shells. In this respect it differs very considerably from a true Globigerina Ooze where the finer particles can be observed to be formed chiefly of Coccoliths, Rhabdoliths, and the smaller fragments of Globigerinidæ. Very few of the Pteropods are perfect. Many of the organisms are macroscopic.	
15·73	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ.	(2·00 %), m. di. 0·07 mm., angular; sanidine, augite, plagioclase, magnetite, lapilli, hornblende, a few glassy volcanic fragments.	(11·73 %), amorphous matter, minute mineral and siliceous remains.	The finer portions of the calcareous material appear to be composed chiefly of fragments of Pteropods and other pelagic Molluscs. Coccoliths and Rhabdoliths are present but rare. A large number of the organisms are macroscopic. A large quantity of the deposit and a large number of animals belonging to all the invertebrate groups were obtained in the dredgings at these depths.	Off Sombrero Island.
26·12	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, imperfect brown casts.	(1·00 %), m. di. 0·08 mm., angular; quartz, felspar, augite, magnetite, mica, hornblende.	(23·12 %), red amorphous matter, fine mineral particles, fragments of siliceous organisms.	The washings procured by passing the ooze through fine sieves are composed almost entirely of Pteropod and Heteropod shells, and a large part of the finer portions of the ooze seems to be made up of the comminuted fragments of the shells of these pelagic Molluscs. The Coccoliths and Rhabdoliths are small and rare. Many of the organisms are macroscopic. Three hauls were taken with the dredge on this date, and yielded a large quantity of the deposit and many animals.	St. Thomas to Bermuda.
31·12	(1·00 %), Sponge spicules, and imperfect brown casts.	(1·00 %), m. di. 0·10 mm., angular; sanidine, plagioclase, hornblende, augite, magnetite, mica.	(29·12 %), amorphous matter, minute mineral particles, a few fragments of Sponge spicules.		

See Chart 8 and Diagram 2.

St. Thomas to Bermuda—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1878	° ′ ″		°	°				
25	Mar. 26	19 41 0 N. 65 7 0 W.	3875	...	76·0	RED CLAY, grey when dry, coherent, breaking up in water, lustrous streak. **Residue** brown.	7·15	(4·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Lagenidæ, *Truncatulina, Amphistegina.*	(2·15 %), Gasteropods, Lamellibranchs, Echini spines, Polyzoa, Coccoliths.
26	„ 27	21 26 0 N. 65 16 0 W.	2800	...	76·0	RED CLAY, red-brown when dry, very coherent, dried portions breaking up quickly in water, lustrous streak, plastic and unctuous when wet. **Residue** dark brown.	6·00	(4·00 %), *Globigerina, Pulvinulina.* (1·00 %), *Miliolina, Textularia,* Rotalidæ.	(1·00 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
*27	„ 28	22 49 0 N. 65 19 0 W.	2960	36·2	75·5	RED CLAY, grey when dry, very coherent, plastic, unctuous, homogeneous, breaking up in water, lustrous streak. **Residue** dark red.	3·25	(1·25 %), *Globigerina.* (2·00 %), *Truncatulina.*	Two or three Coccoliths only observed.
28	„ 29	24 39 0 N. 65 25 0 W.	2850	36·3	75·0	RED CLAY, red-grey when dry, unctuous, homogeneous, plastic, lustrous streak. **Residue** dark red.	18·79	(15·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Truncatulina.*	(1·79 %), small teeth of fish.
†29	„ 31	27 49 0 N. 64 59 0 W.	2700	36·4	72·0	RED CLAY, red-grey when dry, unctuous, plastic, homogeneous, lustrous streak. **Residue** dark red.	21·84	(15·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina, Textularia, Lagena,* Rotalidæ.	(4·84%), Otoliths and teeth of fish, Gasteropods, Lamellibranchs, Ostracodes, Echini spines, a few Coccoliths.
30	April 1	29 5 0 N. 65 1 0 W.	2600	36·5	72·0	RED CLAY, red-grey, plastic, unctuous, homogeneous, sub-lustrous streak. **Residue** red.	28·88	(20·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), *Miliolina, Textularia, Lagena, Truncatulina.*	(5·88 %), fragments of Lamellibranch shells, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
31	„ 3	31 24 0 N. 65 0 0 W.	2475	36·5	69·5	GLOBIGERINA OOZE, dirty white or grey, pulverulent, slightly plastic. **Residue** red brown.	54·70	(43·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ.	(10·70 %), teeth of fish, Ostracodes, a few minute fragments of calcareous Algæ, Coccoliths, Rhabdoliths.
32	„ 3	31 49 0 N. 64 55 0 W.	2250	36·7	68·0	GLOBIGERINA OOZE, dirty white, pulverulent, homogeneous. **Residue** red-brown.	69·61	(45·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, *Marginulina,* Rotalidæ, *Nummulina.*	(21·61 %), Otoliths of fish, Gasteropods, Ostracodes, Echini spines, Polyzoa, many fragments of calcareous Algæ, Coccoliths, Rhabdoliths.
32A	„ 3	32 1 0 N. 64 51 0 W.	1820	...	68·0	CORAL MUD, white, chalky, pulverulent, granular. **Residue** dark brown.	81·86	(30·00 %), Globigerinidæ, *Pulvinulina.* (10·00 %), Miliolidæ, Textularidæ, *Nodosaria,* Rotalidæ, *Nummulina.*	(41·86 %), Otoliths of fish, *Serpula,* Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.

* See anal. 11.

† See anal. 25.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
92·85	(1·00 %), Radiolaria, Sponge spicules, *Rhabdammina.*	(20·00%), m. di. 0·10 mm., angular; felspar, augite, magnetite, glauconite, a few glassy volcanic particles.	(71·85 %), amorphous matter, minute mineral particles, a few remains of siliceous organisms.	In this sounding—which is the deepest taken by the Challenger in the Atlantic—the deposit was red on the surface, while the deeper layers were greyish, and appeared to contain more carbonate of lime than the upper. The dredge contained a red coloured mud, but no organisms, other than a few dead shells of Foraminifera. A sounding tube which was sent down attached to the dredge gave on the outside some traces of a blue mud. The deposit brought home contains some Pteropods and other Molluscan shells and Foraminifera, which appear to have come from a previous dredging, possibly from the same dredge having been used. During the early part of the cruise there was not so much care taken as later. There are, however, some things which indicate two distinct layers in this deposit.
94·00	(1·00 %), Radiolaria and Sponge spicules.	(1·00 %), m. di. 0·07 mm., angular; sanidine, augite, magnetite, tourmaline, epidote, zircon, glassy volcanic fragments (some altered to palagonite), manganese grains.	(92·00 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	Note the increase of amorphous matter with decrease of carbonate of lime in these soundings. The organisms are few in number, and are in a more or less fragmentary condition. The manganese grains are relatively rare.
96·75	(1·00 %), one or two siliceous spicules, and fragments of Radiolaria.	(1·00 %), m. di. 0·06 mm., angular; felspar, magnetite, glassy volcanic fragments.	(94·75 %), amorphous matter, with many minute fragments of minerals, and a very few fragments of siliceous organisms.	Only slight effervescence was observed when the deposit was treated with dilute acid. Even in the washings of a large quantity of the deposit there were few calcareous organisms.
81·21	(1·00 %), a few Sponge spicules and one or two arenaceous Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; felspar, magnetite, minute pieces of pumice, one or two manganese grains.	(79·21 %), amorphous matter, many minute mineral particles, and a few fragments of siliceous organisms.	The organisms observed in this deposit are very minute, and in a more or less fragmentary condition. Dredge empty.
78·16	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, *Haplophragmium.*	(1·00 %), m. di. 0·06 mm., angular; a few fragments of felspar, augite, palagonite, volcanic glass, manganese grains.	(76·16 %), amorphous matter, fine mineral particles, and fragments of siliceous organisms.	A large quantity of the deposit came up in the dredge. When this was passed through fine sieves a few pellets of manganese, about one millimetre in diameter, were obtained, also some pieces of palagonite, and one piece of pumice.
71·12	(1·00 %), a few Sponge spicules, one or two Radiolaria, *Haplophragmium.*	(1·00 %), m. di. 0·06 mm., angular; a few fragments of sanidine, magnetite, and volcanic glass.	(69·12 %), amorphous matter, minute mineral particles, and a few fragments of siliceous organisms.	The deposit in the sounding tube indicated the same kind of clay as in preceding station.
45·30	(1·00 %), Sponge spicules, *Haplophragmium.*	(1·00 %), m. di. 0·06 mm., angular; felspar, volcanic glass, magnetite.	(43·30 %), amorphous matter, minute mineral particles, and small fragments of siliceous organisms.	This deposit contained much amorphous matter. Note the increase of carbonate of lime with decreasing depth in the last few soundings.
30·39	(1·00 %), Radiolaria and Sponge spicules, *Trochammina.*	(1·00 %), m. di. 0·06 mm., angular; fragments of felspar and volcanic glass, magnetite, augite.	(28·39 %), amorphous matter, minute mineral particles, and fragments of siliceous organisms.	Some of the organisms are macroscopic. The presence of fragments of calcareous Algæ shows the approach to shallower water.
18·14	(2·00 %), Radiolaria, Sponge spicules, *Rhabdammina, Haplophragmium*, a few Diatoms.	(1·00 %), m. di. 0·06 mm., angular; a few fragments of felspar.	(15·14 %), amorphous matter, small fragments of siliceous organisms and minerals.	Many of the organisms are macroscopic. Between 10 and 20 per cent. of the carbonate of calcium contained in this deposit is made up of numerous fragments of calcareous Algæ, a true indication of sudden shallowing of water, which the following soundings show.

St. Thomas to Bermuda—*continued.*

See Chart 8 and Diagram 2.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
St. Thomas to Bermuda—*continued.*	*32B	1873 April 8	° ′ ″ 32 10 0 N. 64 52 0 W.	950	° ...	° 68·0	Coral Mud, white, chalky, granular. **Residue** brown-black.	89·36	(35·00 %), Globigerinidæ, *Pulvinulina.* (6·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(48·36 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
Off Bermuda.	†32D	,, 4	32 19 0 N. 64 40 0 W.	380	...	67·0	Coral Mud, white, chalky, pulverulent, granular. **Residue** brown-black.	89·68	(15·00 %), Globigerinidæ, *Pulvinulina*, *Cymbalopora.* (15·00 %), Miliolidæ, Textularidæ, Chilostomellidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(59·68 %), Otoliths of fish, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, fragments of Echinoderms, Polyzoa, *Bathyactis* and other Madreporaria, Alcyonarian spicules, calcareous Algæ, Coccoliths, a few Rhabdoliths.
	33	,, 4	32 21 30 N. 64 35 55 W.	435	...	68·0	Coral Mud, white, chalky, pulverulent, granular. **Residue** brown-black.	...	...	...
	‡...	,, 17	1 mile from reef.	200	...	...	Coral Sand, white, with red fragments. **Residue** green coloured, with organic matter.	93·34	(5·00 %), Globigerinidæ, *Pulvinulina.* (35·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(53·34 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Corals, Alcyonarian spicules, calcareous Algæ.
At Bermuda, inside the reef.	...	,,	32 24 0 N. 64 44 0 W.	9½	...	...	Coral Mud, white or grey, very slightly coherent. **Residue** brown.	95·48	(40·00 %), Miliolidæ.	(55·48 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, calcareous Algæ.
	...	,,	32 21 10 N. 64 32 30 W.	5	...	...	Coral Mud, white, with green tinge, somewhat coherent, plastic, chalky, granular. **Residue** brown.	91·09	(40·00 %), Miliolidæ, *Polystomella.*	(51·09 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, Corals, calcareous Algæ.
	...	,,	32 18 31 N. 64 51 45 W.	4½	...	...	Coral Sand, mottled grey and white, granular. **Residue** brown.	90·18	(10·00 %), Miliolidæ, Rotalidæ, *Polystomella.*	(80·18 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Polyzoa, Corals, Alcyonarian spicules, calcareous Algæ.
	...	,,	32 22 30 N. 64 42 10 W.	6	...	...	Coral Mud, white, with yellow tinge, coherent, chalky, gritty, plastic when wet. **Residue** dark green-brown.	86·77	(30·00 %), Miliolidæ, *Rotalia*, *Polystomella.*	(56·77 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, calcareous Algæ.
Off Bermuda—*continued.*	35A	,, 22	32 39 0 N. 65 6 0 W.	2450	36·5	67·8	Globigerina Ooze, dirty white, granular, slightly coherent, chalky. **Residue** red-brown.	66·00	(48·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, *Truncatulina.*	(15·00 %), Gasteropods, Pteropods, Polyzoa, calcareous Algæ, Coccoliths, Rhabdoliths.

* See Pl. XIII. figs. 2*a*, 2*b*. † See Pl. XIII. fig. 4. ‡ See Pl. XIII. fig. 1.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		Locality
10·64	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ, a few Diatoms.	(1·00 %), m. di. 0·06 mm., angular; a few fragments of felspar and volcanic glass.	(8·64 %), amorphous matter, fragments of siliceous organisms, and a few fragments of minerals.	Some of the organisms are macroscopic. There is a great deal of amorphous calcareous matter in the deposit.	St. Thomas to Bermuda—*continued.*
10·32	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ, arenaceous Textularidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar and volcanic glass.	(8·32 %), amorphous matter, with fragments of siliceous organisms and minerals.	Many of the shells and fragments of other organisms are macroscopic, the latter varying in size from 1 to 20 mm., the majority being from 4 to 6 mm. in length. The washings which remain after passing these deposits through the sieves consist chiefly of the shells of pelagic Molluscs and Foraminifera, with broken pieces of large calcareous Foraminifera, *Serpula* tubes, Polyzoa, Corals, calcareous Algæ, &c. The percentage of carbonate of lime is the mean of the analyses of the two samples.	Off Bermuda.
...	...	...	...	Dredge half full of chalky Coral Mud.	Off Bermuda.
6·66	(1·00 %), Radiolaria, Sponge spicules, Lituolidæ, one or two Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar and volcanic glass.	(4·66 %), some amorphous matter, minute fragments of minerals, siliceous spicules, and organic matter.	The majority of the particles making up the sand are about 1 or 2 mm. in diameter, but some are much larger. Although pelagic Molluscs and Foraminifera are present the carbonate of calcium is mostly made up of the shells of bottom-living organisms.	Off Bermuda.
4·57	(1·00 %), Sponge spicules, imperfect casts of Foraminifera, Diatoms.	(1·00 %), m. di. 0·15 mm., angular and rounded; quartz, felspar, a few glassy volcanic fragments, black mica.	(2·57 %), a small quantity of amorphous matter, fragments of siliceous spicules and Diatoms, a few fine glassy particles.	This deposit is chiefly made up of calcareous Algæ and fragments of Gasteropod and Lamellibranch shells. The finer parts appear to be chiefly derived from the decomposition of calcareous Algæ.	At Bermuda, inside the reef.
8·91	(1·00 %), Sponge spicules, a few imperfect casts of Foraminifera, Diatoms.	(1·00 %), m. di. 0·40 mm., angular; a few particles of quartz and glassy volcanic fragments.	(6·91 %), fine flocculent amorphous matter, siliceous and mineral remains.	The deposit is made up chiefly of calcareous Algæ and their broken down parts, with a few of the other organisms mentioned; these latter are fragmentary. The whole forms a coarse cement-like mass with a greenish tinge. Many of the organisms are macroscopic.	At Bermuda, inside the reef.
9·82	(1·00 %), Sponge spicules, one or two imperfect casts of Foraminifera, Diatoms.	(1·00 %), m. di. 0·50 mm., angular and rounded; particles of quartz, glassy volcanic fragments.	(7·82 %), a small quantity of amorphous matter, siliceous and mineral remains.	About 50 per cent. of the carbonate of lime in the sand is made up of calcareous Algæ, the particles measuring from 1 to 10 mm. in diameter. Many of the organisms are macroscopic.	At Bermuda, inside the reef.
13·23	(1·00 %), Sponge spicules, Diatoms.	(2·00 %), m. di. 0·80 mm., rounded; quartz, hornblende, glassy volcanic particles.	(10·23 %), amorphous matter, fragments of Sponge spicules and Diatoms, small mineral particles.	The residue contained many fragments of coal. It is possible that at least some of the minerals found here have been discharged from passing ships.	At Bermuda, inside the reef.
34·00	(1·00 %), Radiolaria, Sponge spicules, *Haplophragmium*, one or two Diatoms.	(1·00 %), m. di. 0·07 mm., angular; sanidine, plagioclase, volcanic glass, augite, hornblende, magnetite.	(32·00 %), amorphous matter, minute fragments of minerals and siliceous organisms.	The Foraminifera obtained in this deposit are mostly of pelagic origin. Note the decrease in the quantity of carbonate of lime with increase of depth and distance from the reefs.	Off Bermuda.

See Charts 8 and 9, and Diagram 2.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
		1873	° ′ ″		°	°				
Off Bermuda—*continued*.	35B	April 22	32 26 0 N. 65 9 0 W.	2100	36·5	68·0	Globigerina Ooze, dirty white, granular, chalky. **Residue** red-brown.	77·13	(45·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(27·13 %), Otoliths of fish, *Serpula*, Gasteropods, Pteropods, Echinoderm fragments, Polyzoa, calcareous Algæ, Coccoliths, Rhabdoliths.
	*35C	,, 22	32 15 0 N. 65 8 0 W.	1950	...	68·0	Globigerina Ooze, white, chalky, granular, slightly coherent. **Residue** brown.	81·31	(53·00 %), Globigerinidæ, *Cymbalopora*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(25·31 %), Otoliths of fish, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Ostracode valves, fragments of Echinoderms, Polyzoa, calcareous Algæ, Coccoliths, Rhabdoliths.
	...	,, 23	Challenger Bank.	32	...	...	...	...	Large specimens of *Cristellaria* and other Foraminifera.	Fragments of Echinoderms, Molluscs, &c.
Bermuda to Halifax.	37	,, 24	32 18 0 N. 65 38 8 W.	2650	36·5	68·0	Globigerina Ooze, brownish when wet, dirty white when dry, slightly coherent, granular. **Residue** red.	62·47	(50·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Verneuilina*, Lagenidæ, *Truncatulina*.	(10·47 %), Otoliths of fish, Lamellibranchs, Pteropods, Ostracodes, Echini spines, Polyzoa, calcareous Algæ, Coccoliths, Rhabdoliths.
	38	,, 25	33 3 0 N. 66 32 0 W.	2600	36·5	70·0	Globigerina Ooze, brown when wet, dirty white when dry, granular, slightly coherent. **Residue** red.	50·84	(45·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Cassidulina*, *Truncatulina*, *Nonionina*.	(4·84 %), small teeth of fish, Coccoliths, Rhabdoliths.
	39	,, 27	34 3 0 N. 67 32 0 W.	2850	36·5	65·0	Red Clay, grey when dry, coherent, earthy, sublustrous streak. **Residue** red.	28·31	(20·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Verneuilina*, *Pullenia*, Rotalidæ.	(6·31 %), small teeth of fish, Ostracodes, Coccoliths, a few Rhabdoliths.
	40	,, 28	34 51 0 N. 68 30 0 W.	2675	...	69·5	Globigerina Ooze, grey when dry, with a pink tinge, slightly coherent, gritty. **Residue** dark brown.	45·83	(40·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, *Pullenia*, *Truncatulina*.	(4·83 %), small teeth of fish, Cephalopod beaks, Pteropod fragments, Echini spines, Coccoliths, a few Rhabdoliths.
	42	,, 30	35 58 0 N. 70 35 0 W.	2425	36·8	65·0	Blue Mud, dirty grey when dry, plastic, coherent, homogeneous, earthy. **Residue** brown.	24·34	(20·00 %) Globigerinidæ, *Pulvinulina*. (1·00 %), *Gaudryina*, *Truncatulina*.	(3·34 %), Cephalopod beaks, fragments of Echinoderms, Coccoliths, one or two Rhabdoliths.
	43	May 1	36 23 0 N. 71 46 0 W.	2600	36·2	56·5	...	...	...	...
	44	,, 2	37 25 0 N. 71 40 0 W.	1700	...	...	Blue Mud, with reddish upper layer, blue-grey when dry, plastic, containing gritty particles, earthy. **Residue** dark brown.	24·61	(18·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(4·61 %), Otoliths of fish, Lamellibranch shells, Echinoderm fragments, Coccoliths, Coccospheres, a few Rhabdoliths.

* See Pl. XII. fig. 3.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
22·87	(1·00 %), Radiolaria, Sponge spicules, Lituolidæ, one or two Diatoms.	(1·00 %), m. di. 0·07 mm., angular; felspar, volcanic glass, augite, magnetite.	(20·87 %), amorphous matter, small fragments of minerals and siliceous organisms.	With the exception of the Foraminifera the organisms are mostly fragmentary; some of the fragments are macroscopic.	Off Bermuda—*continued.*
18·69	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, one or two Diatoms.	(1·00 %), m. di. 0·07 mm., angular; felspar, volcanic glass, augite, magnetite.	(16·69 %), amorphous matter, many minute fragments of siliceous organisms, and small mineral particles.	Some of the shells are macroscopic. The pelagic organisms here predominate over the fragments of calcareous Algæ, Polyzoa, &c., washed from the reefs. The finer portions contain many more Coccoliths and Rhabdoliths than the deposits nearer the reefs.	
...	...	...	...	This bank is covered with Corals, *Serpula*, and calcareous pebbles.	
37·53	(1·00 %), Sponge spicules, one or two Radiolaria, *Aschemonella*, Lituolidæ.	(1·00 %), m. di. 0·07 mm., angular; felspar, augite, volcanic glass, magnetite.	(35·53 %), amorphous matter, minute fragments of minerals and siliceous organisms.	With the exception of the Foraminifera all the other organisms are represented by minute fragments; some of these are much corroded as if being slowly dissolved. Dredge contained a quart bottle (over a litre) of deposit.	Bermuda to Halifax.
49·16	(1·00 %), a few Sponge spicules and Radiolaria, one or two specimens of *Haplophragmium* and *Gaudryina*.	(2·00 %), m. di. 0·08 mm., angular, a few rounded; sanidine, plagioclase, augite, hornblende, magnetite, volcanic glass, black mica, quartz, manganese grains.	(46·16 %), amorphous matter, with minute fragments of minerals and siliceous spicules.	The organisms in this deposit are very much broken up and decomposed. One or two grains of manganese, 1 to 3 mm. in diameter, were observed.	
71·69	(1·00 %), one or two fragments of siliceous spicules, Lituolidæ, Diatoms.	(5·00 %), m. di. 0·10 mm., angular; quartz, monoclinic and triclinic felspars, tourmaline, augite, hornblende, mica, manganese grains, glauconite.	(65·69 %), amorphous matter, with a great many minute fragments of minerals and a few fragments of siliceous organisms.	The minerals are mostly angular; a few of them approach 0·4 mm. in diameter. Note decrease of carbonate of lime with increasing depth. This deposit is intermediate in character between a Red Clay and Blue Mud; the mineral particles are ice-borne.	
54·17	(1·00 %), Sponge spicules, two or three Radiolaria, a few imperfect casts, Lituolidæ.	(3·00 %), m. di. 0·06 mm., angular; felspar, hornblende, augite, magnetite, mica, quartz, glauconite, glassy volcanic particles, coloured altered particles, a few manganese grains.	(50·17 %), amorphous matter, many fine mineral particles, and a few fragments of siliceous organisms.	No deposit was obtained in the sounding tube, but a small quantity of the ooze came up in the dredge. The mineral particles are chiefly angular, but among them are many rounded quartz grains.	
75·66	(1·00 %), Sponge spicules, Radiolaria, *Rhabdammina*, Lituolidæ, Diatoms.	(40·00 %), m. di. 0·20 mm., angular; monoclinic and triclinic felspars, augite, hornblende, quartz, tourmaline, lapilli, mica, glauconite, a few manganese grains, pyrites, magnetite.	(34·66 %), amorphous matter, with minute fragments of minerals, a few fragments of Radiolaria and Diatoms.	This deposit had a reddish surface layer. Rhabdoliths have almost entirely disappeared, only a few being recognised on the examination of a large quantity of the deposit. The minerals are mostly angular; a few are rounded.	
...	...	...	...	In first sounding line parted; in second no bottom at a depth exceeding 2600 fathoms.	
75·39	(1·00 %), a few Sponge spicules, Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(40·00 %), m. di. 0·20 mm., angular; felspar, augite, hornblende, quartz, mica-schist and other rocks, some of them chloritic, magnetite, glauconite.	(34·39 %), amorphous matter, many fine mineral particles, fragments of Sponge spicules and Diatoms.	The minerals are mostly angular; some fragments of quartz and gneissic rocks are about 1 mm. in diameter. Several rounded pebbles were obtained in the washings from the dredge, measuring from 2 to 6 cm. in diameter, also a few irregular fragments of hardened deposit, forming a conglomerate of a yellow-green colour; amongst these were several rounded compact chalky nodules, apparently formed of the deposit, measuring from 1 to 3 cm. in diameter.	

See Chart 9 and Diagram 2.

Route	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Temperature of the Sea-water (Fahr.). Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Carbonate of Calcium. Foraminifera.	Carbonate of Calcium. Other Organisms.
		1873	° ′ ″		°	°				
Bermuda to Halifax—*continued.*	45	May 3	38 34 0 N. 72 10 0 W.	1240	37·2	49·5	Blue Mud, blue-grey when dry, coherent, earthy, containing gritty particles. **Residue** dark grey.	14·59	(10·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(3·59 %), Otoliths of fish, Lamellibranch shells, Ostracode valves, Echinoderm fragments, Coccoliths, Coccospheres, one or two Rhabdoliths.
Bermuda to Halifax—*continued.*	46	,, 6	40 17 0 N. 66 48 0 W.	1350	37·2	40·0	Blue Mud, blue-grey when dry, coherent, earthy, with gritty particles. **Residue** dark grey.	15·40	(8·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Rotalidæ.	(5·40 %), Otoliths of fish, Lamellibranchs, Pteropods, Echinoderm fragments, Coccoliths, Coccospheres.
Bermuda to Halifax—*continued.*	47	,, 7	41 14 0 N. 65 45 0 W.	1340	...	42·0	Blue Mud, blue-grey when dry, coherent, earthy, containing many gritty particles. **Residue** dark brown.	6·68	(3·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(2·68 %), Cephalopod beaks, Echinoderm fragments, Coccoliths, Coccospheres.
Bermuda to Halifax—*continued.*	48	,, 8	43 4 0 N. 64 5 0 W.	51	...	38·0	Rock, gravel, stones, &c.	...	...	...
Halifax to Bermuda.	49	,, 20	43 3 0 N. 63 39 0 W.	85	35·0	40·5	Gravel, stones, &c.	...	...	...
Halifax to Bermuda.	50	,, 21	42 8 0 N. 63 39 0 W.	1250	38·0	45·0	Blue Mud, blue-grey when dry, coherent, earthy, containing gritty particles. **Residue** dark blue-brown.	16·25	(10·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), *Miliolina, Textularia,* Lagenidæ, *Truncatulina.*	(3·25 %), Echinoderm fragments, Coccoliths, Coccospheres.
Halifax to Bermuda.	51	,, 22	41 19 0 N. 63 12 0 W.	2020	36·0	59·0	Blue Mud, dirty grey when dry, containing sandy particles, earthy. **Residue** brown.	27·75	(20·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, *Nonionina.*	(5·75 %), Echinoderm fragments, Coccoliths, Coccospheres.
Halifax to Bermuda.	52	,, 23	39 44 0 N. 63 22 0 W.	2800	36·2	67·2	Blue Mud, brown-grey when dry, coherent, containing gritty particles, earthy. **Residue** brown.	25·02	(20·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina,* Lagenidæ, *Truncatulina.*	(3·02 %), fragments of Echinoderms, Coccoliths, a few Coccospheres.
Halifax to Bermuda.	53	,, 26	36 30 0 N. 63 40 0 W.	2650	36·3	73·0	Blue Mud, brown-grey when dry, coherent, earthy, containing gritty particles. **Residue** red-brown.	31·88	(25·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina, Textularia,* Rotalidæ.	(4·88 %), fragments of Echinoderms, Coccoliths, Coccospheres, a few Rhabdoliths.
Halifax to Bermuda.	54	,, 27	34 51 0 N. 63 59 0 W.	2650	...	70·5	Blue Mud, grey when dry, coherent, homogeneous, earthy. **Residue** red-brown.	24·56	(18·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina, Lagena, Truncatulina.*	(4·56 %), Echinoderm fragments, Coccoliths, one or two Rhabdoliths.
Halifax to Bermuda.	55	,, 28	33 20 0 N. 64 37 0 W.	2500	...	70·5	Globigerina Ooze, grey, pulverulent, homogeneous. **Residue** brown-red.	54·81	(45·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, *Bulimina, Truncatulina.*	(6·81 %), fragments of Echinoderms, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
85·41	(2·00 %), a few Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(40·00 %), m. di. 0·10 mm., angular and rounded; quartz, monoclinic and triclinic felspars, fragments of mica-schist, diabase, &c., magnetite, glauconite, mica.	(43·41 %), amorphous matter, minute fragments of Diatoms and minerals.	The coarser siftings of this mud, of which a large quantity came up in the dredge, consist of a grey gravel, some of the pebbles or large grains measuring from 1 to 5 cm. in diameter. One of these pebbles is a quartzite containing zircon, tourmaline, rutile, kaolinised felspar, and chloritic matter; others are diabases, basalts, and dolomites.	Bermuda to Halifax—*continued.*
84·60	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(45·00 %), m. di. 0·12 mm., angular and rounded; mica, quartz, felspar, magnetite, tourmaline, garnet.	(37·60 %), amorphous matter, many minute fragments of minerals and siliceous spicules and Diatoms.	The mud from the dredge contained a good many rounded and angular pebbles from a millimetre to a centimetre in diameter, composed of quartziferous diabase, mica-schist, &c., the same as at the last station. Traces of manganese are found on some of the pebbles. Rhabdoliths have quite disappeared; on the other hand, there are a good many Coccospheres.	
93·32	(6·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, a few glauconitic casts, Diatoms.	(70·00 %), m. di. 0·15 mm., rounded and angular; quartz, fragments of older volcanic and other rocks, felspar, pumice, glauconite, magnetite, &c.	(17·32 %), amorphous matter, with fragments of minerals, Sponge spicules, and Diatoms.	No deposit was obtained in the sounding tube; description taken from mud obtained in dredge. A large block of syenite came up with the dredge. It weighed about 5 cwts. (253·7 kilogrammes), and was jammed between the mouth and arms of the dredge. Some of the mnieral fragments measure over 1 mm. in diameter. Many of the quartz grains are covered with limonite.	
...	...	...	..	...	
...	...	...	...	...	
83·75	(3·00 %), Radiolaria, Sponge spicules, *Haplophragmium*, Diatoms.	(20·00 %), m. di. 0·10 mm., angular and rounded; felspar, pumice, quartz, glauconite, augite, hornblende, magnetite.	(60·75 %), amorphous matter, many fine mineral particles, and fragments of Radiolaria, Sponge spicules, and Diatoms.	Some of the minerals measure over 1 mm. in diameter. Fragments of older crystalline rocks are also found, many covered with chlorite.	Halifax to Bermuda.
72·25	(3·00 %), Radiolaria, *Rhabdammina*, *Haplophragmium*, brown imperfect casts, Diatoms.	(20·00 %), m. di. 0·08 mm., angular; quartz, monoclinic and triclinic felspars, fragments of older crystalline and other rocks, glauconite, augite, hornblende.	(49·25 %), amorphous matter, many fine mineral particles, and fragments of Diatoms.	The minerals are mostly angular, but a few are rounded and measure about 1 mm. in diameter. Dredge line broke.	
74·98	(3·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, *Trochammina*, glauconitic casts, Diatoms.	(25·00 %), m. di. 0·15 mm., rounded and angular; monoclinic and triclinic felspars, quartz, fragments of rocks, augite, mica, hornblende, magnetite, glauconite.	(46·98 %), amorphous matter, with fragments of minerals and Diatoms.	*Uvigerina*, which has been very common or abundant in all the soundings lately, is here very sparingly represented; the pelagic Foraminifera are, on the other hand, larger and more numerous.	
68·12	(3·00 %), Radiolaria, Sponge spicules, *Rhabdammina*, brown imperfect casts, Diatoms.	(10·00 %), m. di. 0·08 mm., angular; monoclinic and triclinic felspars, quartz, rock fragments, augite, hornblende, volcanic glass, magnetite, glauconite.	(55·12 %), amorphous matter, fragments of minerals and siliceous organisms.	Many of the larger Foraminifera, as *Pulvinulina menardii*, &c., are much perforated and corroded, showing well the solvent action of sea-water. This, together with the preceding and following deposits, are in some respects Red Clays or Globigerina Oozes; the presence of ancient rocks places them among the Blue Muds.	
75·44	(2·00 %), fragments of Radiolaria and Sponge spicules, *Haplophragmium*, a few Diatoms.	(2·00 %), m. di. 0·07 mm., angular; monoclinic and triclinic felspars, quartz, volcanic glass, glauconite, magnetite, mica.	(71·44 %), amorphous matter, fragments of minerals, Radiolaria, and Diatoms.	This deposit contains much amorphous clayey matter, and was formerly classed with the Red Clays.	
45·19	(1·00 %), a few Radiolaria and Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·07 mm., angular; felspar, augite, hornblende, magnetite, glassy volcanic fragments, mica.	(43·19 %), amorphous matter, with fragments of minerals and siliceous organisms.	A few of the mineral particles are about 3 mm. in diameter, and are probably ice-borne.	

See Charts 6 and 8, and Diagram 3.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
		1873	° ′ ″		°	°				
Off Bermuda.	55B	May 29	32 7 35 N. 64 53 45 W.	1325	...	72·0	Coral Mud, white, pulverulent, chalky. Residue brown.	86·00	(56·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina*, *Textularia*, Lagenidæ, Rotalidæ.	(28·00 %), *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
	56	,, 29	32 8 45 N. 64 59 35 W.	1075	38·2	72·5	Coral Mud, white, chalky, pulverulent. Residue brown.	83·02	(40·00 %), Globigerinidæ, *Pulvinulina.* (4·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(39·02 %), Otoliths of fish, *Serpula*, Gasteropod and Lamellibranch shells (larval), Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
	57A	,, 30	32 9 30 N. 65 7 35 W.	1250	...	73·0	Coral Mud, white, chalky, pulverulent. Residue black.	84·75	(40·00 %), Globigerinidæ, *Pulvinulina.* (4·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(40·75 %), Otoliths of fish, *Serpula*, Gasteropod and Lamellibranch shells (larval), Pteropods, Heteropods, Ostracodes, fragments of Echinoderms, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
	57B	,, 30	32 9 45 N. 65 10 50 W.	1575	...	73·0	Coral Mud, dirty white, pulverulent, granular, chalky. Residue red.	89·11	(35·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(49·11 %), Otoliths of fish, *Serpula*, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
	58	June 13	32 37 0 N. 64 21 0 W.	1500	37·2	73·5	Coral Mud, dirty white, chalky, pulverulent. Residue dark brown.	77·38	(33·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(39·38 %), Otoliths of fish, Gasteropods, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
Bermuda to Azores.	59	,, 14	32 54 0 N. 63 22 0 W.	2360	36·3	74·0	Globigerina Ooze, with a rose tint, light brown when dry, slightly coherent, earthy. Residue red-brown.	54·59	(45·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina*, Textularidæ, Rotalidæ.	(7·59 %), Echini spines, Coccoliths, Rhabdoliths.
	60	,, 16	34 28 0 N. 58 56 0 W.	2575	36·2	71·5	Globigerina Ooze, light brown, slightly coherent, earthy, presenting small white spots to the naked eye. Residue red.	31·38	(25·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina*, *Truncatulina.*	(4·38 %), Echini spines, Coccoliths, Rhabdoliths.
	61	,, 17	34 54 0 N. 56 38 0 W.	2850	36·2	71·0	Red Clay, coherent, earthy, containing gritty particles. Residue red.	8·02	(5·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Lagenidæ, Rotalidæ.	(2·02 %), Echini spines, Coccoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
14·00	(1·00 %), Sponge spicules, Radiolaria, *Rhabdammina*, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; one or two fragments of felspar and volcanic glass.	(12·00 %), amorphous matter, with small fragments of siliceous organisms and minerals.	These deposits off Bermuda, together with those taken in March and April, as well as many others not described but which are marked on the accompanying chart, show that the quantity of carbonate of lime increases as the reefs are approached, and the water shallows. The carbonate of lime is, near the reef, almost wholly derived from the reef organisms; as the distance from the reef increases the remains of pelagic animals become more and more abundant, the remains of the reef organisms, on the other hand, diminishing. The Coral Sand passes into a Coral Mud, this into a Globigerina Ooze, and in very deep water far from the reefs the Globigerina Ooze is replaced by a Red Clay; some of the deeper deposits in this series might be called Globigerina Oozes. See Plate XIII., which shows the variation of the deposit with depth and distance from the reef.	Off Bermuda.
16·98	(1·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; a few fragments of felspar and volcanic glass.	(14·98 %), amorphous matter, with fragments of Radiolaria, Sponge spicules, minerals, and Diatoms.		
15·25	(1·00 %) Sponge spicules, one or two Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; felspar, augite, pumice.	(13·25 %), amorphous matter, with fragments of siliceous organisms and minerals.		
10·89	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; felspar, quartz, pumice.	(8·89 %), amorphous matter, fragments of siliceous organisms, one or two fragments of minerals.		
22·62	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ.	(1·00 %), m. di. 0·07 mm., angular; felspar, augite, magnetite, volcanic glass.	(20·62 %), amorphous matter, with fragments of siliceous organisms and minerals.		
45·41	(1·00 %), Sponge spicules, one or two fragments of Radiolaria, Lituolidæ.	(1·00 %), m. di. 0·07 mm., angular; fragments of sanidine, augite, hornblende, magnetite, glassy volcanic particles.	(43·41 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	This deposit, which is about 60 miles from the reefs, does not appear to contain any fragments of reef organisms.	Bermuda to Azores.
68·62	(1·00 %), Radiolaria, Sponge spicules, *Haplophragmium*.	(3·00 %), m. di. 0·08 mm., angular and rounded; monoclinic and triclinic felspars, quartz, magnetite, hornblende, glassy particles, glauconite.	(64·62 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	The quartz grains are covered with limonite, while there are also, among the minerals, fragments with chloritic coatings. Trawl had not reached the bottom.	
91·98	(1·00 %), Sponge spicules, a few Radiolaria, glauconitic casts, Diatoms.	(60·00 %), m. di. 0·15 mm., angular and rounded; monoclinic and triclinic felspars, quartz, glauconite, fragments of mica-schist and older volcanic rocks, garnet epidote, magnetite, augite, actinolite, volcanic glass.	(30·98 %), amorphous matter, with fragments of minerals, Radiolaria, and Diatoms.	From the large percentage of minerals this deposit might equally well be called a Blue Mud; the minerals are evidently all ice-borne. Glauconitic casts of some of the organisms remained after treatment with acid. Note the decrease of carbonate of lime with increase of depth. Trawl brought up no deposit, but some concretions covered with manganese.	

See Chart 6, and Diagram 3.

Bermuda to Azores—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1873	° ′ ″		°	°				
62	June 18	35 7 0 N. 52 32 0 W.	2875	36·4	70·0	Red Clay, plastic, homogeneous, coherent, sublustrous streak. **Residue** red.	10·72	(7·00 %), *Globigerina*, *Pulvinulina*. (1·00 %) Rotalidæ.	(2·72 %), Echini spines, Coccoliths, a few Coccospheres.
63	,, 19	35 29 0 N. 50 53 0 W.	2750	...	71·0	Globigerina Ooze, light brown, slightly coherent, plastic. **Residue** brown.	33·93	(25·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Textularidæ, *Lagena*, Rotalidæ.	(6·93 %), Echini spines, Coccoliths, Rhabdoliths.
*64	,, 20	35 35 0 N. 50 27 0 W.	(2700)	...	75·0	Globigerina Ooze, light brown, slightly coherent, homogeneous. **Residue** brown.	35·00	(25·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(5·00 %), Otoliths and teeth of fish, *Serpula*, one or two fragments of *Cleodora pyramidata*, Ostracodes, fragments of Echinoderms, Polyzoa, Coccoliths, Rhabdoliths.
65	,, 21	36 33 0 N. 47 58 0 W.	2700	36·2	72·5	Red Clay, light brown, slightly coherent, homogeneous, sublustrous streak. **Residue** brown.	27·59	(20·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), *Textularia*, Lagenidæ, Rotalidæ.	(4·59 %), Echini spines, Coccoliths.
66	,, 22	37 24 0 N. 44 14 0 W.	2750	36·5	70·0	Globigerina Ooze, light brown, homogeneous, slightly coherent. **Residue** brown.	35·31	(25·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), *Miliolina*, Lagenidæ, Rotalidæ.	(7·31 %), a few fragments of Echini spines, Coccoliths.
67	,, 23	37 54 0 N. 41 44 0 W.	2700	36·3	70·0	Globigerina Ooze, with red tinge, slightly coherent. **Residue** brown.	54·30	(46·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Miliolina*, Lagenidæ, Rotalidæ.	(6·30 %), Ostracode valves, Echini spines, Coccoliths.
68	,, 24	38 3 0 N. 39 19 0 W.	2175	36·2	70·0	Globigerina Ooze, with rose tint, chalky, slightly coherent. **Residue** brown.	71·76	(60·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, *Lagena*, Rotalidæ, *Nonionina*.	(8·76 %), Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
69	,, 25	38 23 0 N. 37 21 0 W.	2200	36·2	71·0	Globigerina Ooze, white with rose tint.	...	...	..
70	,, 26	38 25 0 N. 35 50 0 W.	1675	...	70·0	Globigerina Ooze, dirty white, pulverulent, granular, chalky. **Residue** brown.	83·31	(70·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(10·31 %), Otoliths and teeth of fish, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
71	,, 27	38 18 0 N. 34 48 0 W.	1675	36·8	71·0	Globigerina Ooze, dirty white, pulverulent, granular, chalky. **Residue** brown.	88·31	(70·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(13·31 %), Otoliths of fish, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.

* See anal. 42.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
89·28	(1·00 %), a few Sponge spicules and Diatoms.	(2·00 %), m. di. 0·10 mm., angular; monoclinic and triclinic felspars, quartz, mica, hornblende, glassy fragments, glauconite.	(86·28 %), amorphous matter, with fragments of minerals, Radiolaria, and Diatoms.	Most of the organisms are fragmentary. Many of the mineral particles are evidently ice-borne.
66·07	(1·00 %), a few Sponge spicules, Radiolaria, Lituolidæ.	(1·00 %), m. di. 0·10 mm., angular; felspar, volcanic glass, augite, mica, magnetite, manganese, pumice, glauconite.	(64·07 %), amorphous matter, with fragments of minerals and siliceous organisms.	Some of the Globigerinidæ have grains of manganese scattered over and adhering to their surfaces. Amorphous clayey matter partially fills some of the Foraminifera. In the washings from the trawl one small piece of pumice, containing a large crystal of sanidine, was obtained.
65·00	(1·00 %), a few Sponge spicules, Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; sanidine, augite, magnetite, fragments of pumice, glauconite, quartz.	(63·00 %), amorphous matter, many fine mineral particles, fragments of Radiolaria and Diatoms.	Glauconite in these depths is unusual and is only represented by a few grains. Dredge contained one hundredweight (50 kilogrammes) of deposit, in which were some pellets of manganese.
72·41	(1·00 %), Sponge spicules, Radiolaria, *Haplophragmium*.	(1·00 %), m. di. 0·07 mm., angular; felspar, augite, magnetite, volcanic glass, one or two small particles of quartz covered with limonite, manganese grains.	(70·41 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	The organisms are, for the most part, fragmentary. There is little difference between this and the previous and succeeding deposits, though this is classed as a Red Clay.
64·69	(1·00 %) Radiolaria, a few Sponge spicules, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·10 mm., angular; monoclinic felspar, augite, pumice, lapilli, magnetite.	(62·69 %), amorphous matter, fragments of Radiolaria and minerals.	This deposit is similar to that obtained at Station 65, except in having a higher percentage of carbonate of lime.
45·70	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·07 mm., angular; monoclinic and triclinic felspars, augite, magnetite, volcanic glass.	(43·70 %), amorphous matter, fragments of minerals and siliceous organisms.	The rise in the percentage of carbonate of lime with decrease of depth is here again illustrated. The appearance of the pelagic Foraminifera is different from that in tropical deposits.
28·24	(1·00 %), Radiolaria, Sponge spicules, one or two arenaceous Foraminifera.	(1·00 %), m. di. 0·07 mm., angular; a few fragments of felspar, magnetite, volcanic glass.	(26·24 %), amorphous matter, fragments of minerals and siliceous organisms.	
...	...	...	...	Only a small quantity of the deposit came up in the tube; the examination of this quantity, however, indicated a deposit, in some respects, similar to that at Station 68.
16·69	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, a few Diatoms.	(1·00 %), m. di. 0·10 mm., angular; a few fragments of sanidine, volcanic glass, magnetite, manganese grains.	(14·69 %), amorphous matter, fragments of minerals, Radiolaria, and Diatoms.	In the washings of a large quantity of the deposit from the trawl there were a great many Pteropod shells and fragments, also concretions of the ooze with black spots.
11·69	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, imperfect brown casts, a few Diatoms.	(1·00 %), m. di. 0·10 mm., angular; fragments of pumice, felspar, lapilli, magnetite, augite, manganese.	(8·69 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	In the trawl there were several aggregations of the ooze from 3 to 4 cm. in diameter, perforated by worms and coated with a deposit of manganese; also a fragment of compact volcanic rock more or less rounded and about 7 cm. in longest diameter; this fragment has a slight deposit of manganese over the whole surface, with a *Serpula*-tube attached. There was also a fragment of sandstone, containing mica and stained with limonite, and a large cinder, evidently from some ocean steamer.

Bermuda to Azores—*continued*.

See Charts 6 and 10, and Diagram 3.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Bermuda to Azores—*continued*.	72	1873 June 28	° ′ ″ 38 34 0 N. 32 47 0 W.	1240	° 37·8	° 71·0	PTEROPOD OOZE, white with yellow tint, slightly coherent, finely granular, chalky. Residue brown.	81·59	(60·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(16·59 %), Otoliths of fish, fragments of Pteropods and Heteropods, a few Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
	73	,, 30	38 30 0 N. 31 14 0 W.	1000	39·4	69·0	PTEROPOD OOZE, white with pink tint, chalky, slightly coherent. Residue brown.	73·20	(35·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(33·20 %), Otoliths of fish, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Polyzoa, Coccoliths, Rhabdoliths.
	74	July 1	38 22 0 N. 29 37 0 W.	1350	...	69·8	PTEROPOD OOZE, yellow, white when dry, chalky, slightly coherent. Residue brown.	73·50	(50·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(20·50 %), Otoliths of fish, Lamellibranchs, fragments of Pteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
Off the Azores.		,, 2	Between Fayal and Pico.	50–90	..	...	VOLCANIC SAND, mottled black brown and white, very coarse. Residue brown.	68·73	(10·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(53·73 %), *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, calcareous Algæ.
	75	,, 2	38 38 0 N. 28 28 30 W.	450	...	70·0	VOLCANIC MUD, dark grey when dry, slightly coherent, gritty, earthy. Residue dark brown.	20·59	(6·00 %), Globigerinidæ, *Pulvinulina*. (4·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(10·59 %), Otoliths of fish, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, calcareous Algæ, Coccoliths, Rhabdoliths.
	76	,, 3	38 11 0 N. 27 9 0 W.	900	40·0	70·0	PTEROPOD OOZE, light grey when dry, slightly coherent, chalky. Residue brown.	52·22	(28·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(22·22 %), Otoliths of fish, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths, Coccospheres, Rhabdoliths.
	78	,, 10	37 26 0 N. 25 13 0 W.	1000	...	71·0	VOLCANIC MUD, grey, very fine grained, very slightly coherent. Residue brown.	7·68	(3·00 %) Globigerinidæ. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(2·68 %), Otoliths of fish, fragments of *Pagurus* and other Crustaceans, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Corals.
Azores to Madeira.	79	,, 11	36 21 0 N. 23 31 0 W.	2025	35·9	71·5	GLOBIGERINA OOZE, dirty white, slightly coherent, chalky. Residue red-brown.	55·65	(45·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Miliolina*, *Lagena*, *Truncatulina*.	(8·65 %), fragments of Echinoderms, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
18·41	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, imperfect brown casts, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; augite, magnetite, felspar, sanidine, lapilli, pumice.	(15·41 %), amorphous matter, minute fragments of minerals, Radiolaria, and Diatoms.	A few rounded fragments of pumice, from 1 to 6 mm. in diameter, were obtained in this deposit; some of these are much altered and decomposed. Much of the amorphous calcareous matter is apparently derived from Pteropods and Heteropods.	Bermuda to Azores—*continued.*
26·80	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, a few Diatoms.	(10·00 %), m. di. 0·10 mm., angular; monoclinic and triclinic felspars, lapilli, magnetite, augite, quartz, pumice.	(15·80 %), amorphous matter, many fine mineral particles, fragments of Radiolaria and Diatoms.	In the washings of a large quantity of the deposit from the dredge there were many shells of pelagic and other Mollusca, and a great quantity of pumice, the pieces varying from 1 mm. to 6 cm. in diameter. They are all of the light-coloured felspathic variety and much altered; some of the fragments are overgrown by *Serpula* and other organisms.	
26·50	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, a few Diatoms.	(1·00 %), m. di. 0·10 mm., angular; minute fragments of volcanic rocks, plagioclase, sanidine, magnetite, augite, hornblende, volcanic glass.	(24·50 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	*Pulvinulina menardii* appears to be almost, if not quite, absent from this deposit, as well as from most of the deposits in this region.	
31·27	(4·00 %), Sponge spicules, arenaceous Foraminifera.	(20·00 %), m. di. 1·00 mm., angular; pumice, magnetite, felspar, augite, hornblende, sanidine, and many fragments of volcanic rocks.	(7·27 %), a small quantity of amorphous matter, fine mineral particles, and fragments of siliceous spicules.	About a bushel of this calcareous sand came up in the dredge, mixed with many rounded fragments of pumice and volcanic rock, measuring from 1 to 6 cm. in diameter. Many of these are completely covered with *Serpulæ*, calcareous Algæ, or Polyzoa. Fully 80 per cent. of the carbonate of calcium is made up by the fragments of Polyzoa alone, while *Polytrema miniaceum* is very abundant.	Off the Azores.
79·41	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(60·00 %), m. di. 0·15 mm., angular; fragments of volcanic rocks, pumice, plagioclase, sanidine, black mica, augite, magnetite, hornblende.	(17·41 %), amorphous matter, with many minute fragments of minerals, Radiolaria, and Diatoms.	In the washings from the dredge many Pteropods, Gasteropods, Lamellibranchs, *Serpulæ*, and large quantities of broken fragments of Polyzoa were obtained, also numerous round and angular fragments of pumice and volcanic rocks, from 4 to 6 cm. in diameter. In many instances the pumice fragments were completely covered with *Serpula*-tubes, Algæ, and *Polytrema.*	
47·78	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, a few Diatoms.	(5·00 %), m. di. 0·10 mm., angular; fragments of volcanic rocks, pumice, monoclinic and triclinic felspars, augite, hornblende, black mica, olivine.	(41·78 %), amorphous matter, with many minute fragments of minerals, and siliceous organisms.	The washings of the mud from the dredge consisted chiefly of large *Cavolinia trispinosa* and other Pteropod shells, with many fragments of pumice varying from 1 mm. to 1 cm. in diameter.	
92·32	(1·00 %), Sponge spicules, fragments of Radiolaria, Astrorhizidæ, Lituolidæ.	(75·00 %), m. di. 0·20 mm., angular; pumice, plagioclase, sanidine, augite, magnetite.	(16·32 %), amorphous matter, with minute fragments of pumice and other minerals and siliceous organisms.	The washings, on passing the deposit through sieves, consisted of fragments of pumice (usually about 3 cm. in diameter and smaller) and Pteropod shells. Many of the pumice nodules have *Serpulæ* and Foraminifera attached to them.	
44·35	(1·00 %), Radiolaria, Sponge spicules, Diatoms.	(20·00 %), m. di. 0·15 mm., angular; pumice, fragments of volcanic rocks, felspar, magnetite, augite, olivine.	(23·35 %), amorphous matter, with minute fragments of pumice, siliceous spicules, and Diatoms.	The dredge brought up a small quantity of the ooze the same as indicated by that in the sounding tube.	Azores to Madeira

See Charts 5 and 6, and Diagrams 3 and 7.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Azores to Madeira—*continued.*	80	1873 July 12	35° 3′ 0″ N. 21 25 0 W.	2660	36°·6	71°·0	Globigerina Ooze, white with rose tinge, slightly coherent, chalky. Residue red-brown.	66·43	(55·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina, Lagena,* Rotalidæ.	(9·43 %), Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	81	„ 13	34 11 0 N. 19 52 0 W.	2675	37·0	71·0	Globigerina Ooze, white with rose tinge, slightly coherent, chalky. Residue red-brown.	62·38	(50·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, *Lagena,* Rotalidæ.	(10·38 %), Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	82	„ 14	33 46 0 N. 19 17 0 W.	2400	36·6	70·7	Globigerina Ooze, white with rose tinge, slightly coherent, chalky. Residue brown.	79·79	(69·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(7·79 %), Echinoderm fragments, Coccoliths, Rhabdoliths.
	83	„ 15	33 13 0 N. 18 13 0 W.	1650	37·0	71·0	Globigerina Ooze, white when dry, slightly coherent, chalky. Residue red-brown.	71·09	(60·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(9·09 %), Otoliths of fish, *Serpula, Dentalium,* Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.
Madeira to Cape Verde Islands.	85	„ 19	28 42 0 N. 18 6 0 W.	1125	...	69·2	Volcanic Mud, brown with white spots, slightly coherent, earthy. Residue brown-black.	6·54	(2·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(3·54 %), Otoliths of fish, Pteropods, Heteropods, Echinoderm fragments, Coccoliths, Rhabdoliths.
	86	„ 21	25 46 0 N. 20 34 0 W.	2300	36·6	71·0	Globigerina Ooze, with yellow tinge, slightly coherent, chalky. Residue red.	57·77	(50·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, *Textularia, Truncatulina.*	(6·77 %), Ostracode valves, Echini spines, Coccoliths, Rhabdoliths.
	87	„ 21	25 49 0 N. 20 12 0 W.	1675	...	72·0	Nearly the same spot as Station 3, February 18, 1873, where indications were found of a Pteropod Ooze.	...	...	...
	88	„ 22	23 58 0 N. 21 16 0 W.	2300	36·4	72·0	Globigerina Ooze, white with a rose or yellow tinge, slightly coherent, chalky. Residue red.	64·38	(57·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Rotalidæ.	(6·38 %), fragments of Echinoderms, Coccoliths, Rhabdoliths.
	89	„ 23	22 18 0 N. 22 2 0 W.	2400	36·6	73·5	Globigerina Ooze, yellowish red tinge, slightly coherent, chalky. Residue red.	58·50	(50·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Rotalidæ.	(7·50 %), fragments of Echinoderms, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
33·57	(1·00 %), fragments of Radiolaria and Sponge spicules, Lituolidæ.	(2·00 %), m. di. 0·10 mm., angular; pumice, felspar, magnetite, augite.	(30·57 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	The majority of the organisms in this deposit are in a fragmentary condition.	Azores to Madeira—*continued.*
37·62	(1·00 %), one or two Radiolaria, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; pumice, augite, felspar, magnetite, some small rounded grains of quartz covered with limonite, mica.	(35·62%), amorphous matter, with minute fragments of minerals, Radiolaria, and Diatoms.	The deposits at this and the preceding stations are remarkable for the relatively small number of perfect shells of pelagic Foraminifera; those present are fragmentary. *Pulvinulina menardii* appears to be nearly, if not quite, absent in this part of the Atlantic. A quantity of ooze came up in the water-bottle.	
20·21	(1·00 %), Radiolaria and Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; pumice, lapilli, felspar, magnetite, augite, olivine.	(18·21 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	Note in these deposits the complete, or nearly complete, absence of the shells of Pteropods and Heteropods in the deeper soundings.	
28·91	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, a few Diatoms.	(2·00 %), m. di. 0·08 mm., angular; pumice, lapilli, monoclinic and triclinic felspars, magnetite, black mica, augite, olivine.	(25·91 %), amorphous matter, with fragments of minerals and siliceous organisms.	The washings of the deposit, on being passed through sieves, contained many small round fragments of pumice, about 1 cm. in diameter, also a good many otoliths of fish and fragments of Pteropods and other Molluscan shells. Some of the pumice nodules are overgrown by *Serpulæ*.	
93·46	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, a few Diatoms.	(75·00 %), m. di. 0·10 mm., angular; pumice, fragments of volcanic rocks, scoriaceous lapilli, monoclinic and triclinic felspars, magnetite, augite, olivine, palagonite, manganese grains.	(17·46 %), amorphous matter, with fragments of minerals and siliceous organisms.	The washings obtained by passing a large quantity of the mud through sieves were almost wholly made up of the dead shells of Pteropods and Heteropods, with those of a few bottom-living Molluscs. There were several large fragments of a Gorgonoid Coral coated with manganese. All the coral was dead and in the same condition as at Station 3. There were in addition some fragments of volcanic rocks, about 1 cm. in diameter, also coated with manganese.	Madeira to Cape Verde Islands.
42·23	(1·00 %), a few Radiolaria, *Haplophragmium*, imperfect brown casts.	(2·00 %), m. di. 0·08 mm., angular and rounded; small rounded grains of quartz, felspar, hornblende, magnetite, mica, volcanic glass, manganese grains.	(39·23 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	*Pulvinulina menardii* appears in this deposit; it is absent in the soundings to the north of this station.	
...	...	...	...	A piece of a Gorgonoid Coral covered with manganese came up in the sounding tube; there were also some pieces taken in the dredge. There was nothing further to indicate the nature of the deposit (see Station 3).	
35·62	(1·00 %), one or two Radiolaria, Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·07 mm., angular and rounded; small quartz grains covered with limonite, felspar, augite, hornblende, pumice, magnetite, mica, a few grains of manganese.	(33·62 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	The manganese in the last three soundings shows that it must be abundant over a large area.	
41·50	(1·00 %), Sponge spicules, Radiolaria, a few arenaceous Foraminifera.	(1·00 %), m. di. 0·07 mm., angular and rounded; quartz grains covered with limonite, monoclinic and triclinic felspars, magnetite, augite, hornblende, volcanic glass.	(39·50 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	This deposit contains a considerable quantity of amorphous clayey matter. The specimens of *Pulvinulina menardii* obtained here are very large, some macroscopic.	

See Charts 6 and 11, and Diagram 7.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Madeira to Cape Verde Islands—*continued.*	90	1873 July 24	° ′ ″ 20 58 0 N. 22 57 0 W.	2400	° 36·5	° 74·0	GLOBIGERINA OOZE.	...	...	...
	91	„ 25	19 4 0 N. 24 6 0 W.	2075	36·5	74·0	GLOBIGERINA OOZE, with red tinge, slightly coherent, chalky. Residue red.	60·95	(52·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Miliolina*, Rotalidæ.	(7·95 %), Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	92	„ 26	17 54 0 N. 24 41 0 W.	1975	...	74·7	GLOBIGERINA OOZE, red tinge, slightly coherent, chalky. Residue red-brown.	57·15	(50·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(6·15 %), Otoliths of fish, Ostracodes, fragments of Echinoderms, Coccoliths, Rhabdoliths.
Off Cape Verde Islands.	93	„ 27	17 12 45 N. 24 55 45 W.	1070	...	75·0	VOLCANIC MUD, brown, slightly coherent, earthy. Residue brown-black.	8·29	(4·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(2·29 %), Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	93A	„ 27	17 3 30 N. 24 53 0 W.	1000	...	75·0	VOLCANIC MUD, brown, coherent, earthy. Residue brown-black.	13·65	(5·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(5·65 %), Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.
	93B	„ 27	16 59 15 N. 24 57 45 W.	465	43·4	75·0	VOLCANIC MUD, brown with white spots, coherent, earthy. Residue brown-black.	13·63	(5·00 %), *Globigerina*, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(5·63 %), *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.
	93C	„ 27	16 57 15 N. 25 1 0 W.	52	...	76·0	CORALLINE SAND, mottled white and rose. Residue brown.	94·20	(4·00 %), Globigerinidæ, *Pulvinulina.* (20·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(70·20 %), *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, calcareous Algæ.
	...	„ 30	Harbour, St. Vincent.	7–25	...	...	CALCAREOUS SAND, white. Residue brown.	89·47	(2·00 %), Globigerinidæ. (55·00 %), Miliolidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(32·47 %), Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, calcareous Algæ.
	93F	Aug. 5	16 50 0 N. 25 8 0 W.	260	...	78·0	VOLCANIC MUD, grey-green with many white fragments, slightly coherent. Residue greenish black.	56·59	(30·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(21·59 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
...	...	...	...	Only a small quantity of ooze came up in the sounding tube and proved to be in all respects the same as that at Station 89.	Madeira to Cape Verde Islands—*continued.*
39·05	(1·00 %), a few Radiolaria and Sponge spicules, *Haplophragmium.*	(1·00 %), m. di. 0·08 mm., rounded and angular; quartz grains covered with limonite, monoclinic and triclinic felspars, augite, hornblende, mica, magnetite, pumice, volcanic glass.	(37·05 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	All the pelagic Foraminifera found in this deposit are large and well developed, especially *Pulvinulina menardii.*	
42·85	(1·00 %), a few Radiolaria and Sponge spicules, Astrorhizidæ, Lituolidæ.	(5·00 %), m. di. 0·10 mm., angular; fragments of volcanic rocks, monoclinic and triclinic felspars, volcanic glass altered to palagonite, magnetite, augite, hornblende, olivine.	(36·85 %), amorphous matter, with fragments of minerals and siliceous organisms.	Some of the shells are macroscopic. The dredge did not bring up any of the deposit. The increase in the minerals point to the approach to the island of St. Vincent.	
91·71	(1·00 %), a few Radiolaria and Sponge spicules.	(70·00 %), m. di. 0·10 mm., angular; fragments of volcanic rocks and volcanic glass, olivine, augite, hornblende, magnetite, felspar, black mica, quartz.	(20·71 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	A very great many particles of volcanic sand of a red, black, and yellow colour are present, derived from the disintegration of the rocks of the islands.	Off Cape Verde Islands.
86·35	(1·00 %), a few Sponge spicules, Diatoms.	(65·00 %), m. di. 0·10 mm., angular; fragments of volcanic rocks, some of them glassy, augite, magnetite, small crystals of olivine, hornblende, black mica, palagonite.	(20·35 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	A few of the organisms are macroscopic. With the exception of the Foraminifera all the organisms are, more or less, in a fragmentary condition.	
86·37	(1·00 %), a few Sponge spicules.	(70·00 %), m. di. 0·15 mm., angular; fragments of volcanic rocks, volcanic glass, lapilli, felspar, augite, magnetite, olivine, black mica.	(15·37 %), amorphous matter, with many minute fragments of minerals.	Some of the organisms are macroscopic, though chiefly fragmentary. Many of the lapilli are highly altered.	
5·80	...	(3·00 %), m. di. 0·20 mm., angular; fragments of volcanic rocks, glassy particles, felspar, augite.	(2·80 %), flocculent organic matter, with amorphous matter.	This deposit is chiefly composed of calcareous Algæ of a white and pink colour, which make up fully 40 per cent. of the carbonate of calcium. These white and pink particles measure from 1 to 7 mm. in diameter.	
10·53	...	(1·00 %), m. di. 0·10 mm., angular; fragments of volcanic rocks, felspar, augite, volcanic glass, magnetite.	(9·53 %), organic matter, amorphous matter, and minute fragments of minerals.	The mean diameter of the particles making up this sand is 2 mm. Nearly two-thirds of these particles are made up solely of *Amphistegina lessonii*, the remainder of a few *Orbitolites* and other Foraminifera, fragments of Polyzoa, Echinoderms, and calcareous Algæ.	
43·41	(3·00 %), Sponge spicules, Radiolaria, Lituolidæ.	(25·00 %), m. di. 0·15 mm., angular and rounded; fragments of volcanic rocks and volcanic glass, felspar, olivine, magnetite, augite.	(15·41 %), amorphous matter, green flocculent organic matter, minute fragments of minerals and siliceous organisms.	With the exception of the Foraminifera, the majority of the organisms are in a fragmentary condition; some are macroscopic. The Gasteropods and Lamellibranchs appear to be chiefly larval forms.	

See Charts 11 and 12, and Diagrams 4 and 7.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.) Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Off Cape Verde Islands—*continued.*	93c	1873 Aug. 5	16° 46′ 0″ N. 25 10 0 W.	675	...	78·0	Volcanic Mud, grey, coherent, earthy. Residue red-brown.	39·25	(20·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(14·25 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.
	94	„ 5	16 42 0 N. 25 12 0 W.	1150	...	78·0	Volcanic Mud, light brown, coherent, earthy. Residue red-brown.	47·52	(35·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), *Miliolina,* Textularidæ, Lagenidæ, Rotalidæ.	(9·52 %), Otoliths of fish, Lamellibranchs (larval), Pteropods, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
St. Vincent to St. Paul's Rocks.	95	„ 10	13 36 0 N. 22 49 0 W.	2300	36·5	79·0	Globigerina Ooze, with rose tint, slightly coherent, chalky. Residue brown.	54·29	(48·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Miliolina,* Rotalidæ.	(5·29 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
	97	„ 13	10 25 0 N. 20 30 0 W.	2575	36·6	78·0	Globigerina Ooze, yellow tinge when dry, granular, pulverulent, earthy. Residue red-brown.	30·15	(25·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Rotalidæ.	(4·15 %), Ostracodes, fragments of Echini spines, Coccoliths, Rhabdoliths.
	98	„ 14	9 21 0 N. 18 28 0 W.	1750	36·7	78·2	Globigerina Ooze, grey with blue tinge, finely granular, slightly coherent. Residue brown-black.	62·22	(55·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ.	(5·22 %), Otoliths of fish, Pteropods, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	101	„ 19	5 48 0 N. 14 20 0 W.	2500	36·4	79·2	Blue Mud, blue-grey, coherent, unctuous, lustrous streak. Residue blue-black.	6·22	(4·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Rotalidæ.	(1·22 %), a few Coccoliths.
	102	„ 21	3 8 0 N. 14 49 0 W.	2450	36·4	78·0	Globigerina Ooze, light grey, granular, slightly coherent. Residue grey-black.	66·27	(60·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(4·27 %), Lamellibranchs, Ostracodes, Echinoderm fragments, Coccoliths.
	103	„ 22	2 52 0 N. 17 0 0 W.	2475	36·0	77·0	Globigerina Ooze.	...	...	...
	104	„ 23	2 25 0 N. 20 1 0 W.	2500	36·6	78·0	Globigerina Ooze, grey, finely granular, slightly coherent. Residue brown-black.	71·70	(65·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Miliolina,* Rotalidæ.	(5·70 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
	105	„ 24	2 6 0 N. 22 53 0 W.	2275	36·0	78·0	Globigerina Ooze.	...	...	...
	106	„ 25	1 47 0 N 24 26 0 W.	1850	36·6	78·0	Globigerina Ooze, grey, finely granular, pulverulent. Residue brown-black.	89·47	(80·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina,* Rotalidæ.	(7·47 %), Pteropods, Echinoderm fragments, Coccoliths, Rhabdoliths.
	107	„ 26	1 22 0 N. 26 36 0 W.	1500	37·9	78·8	Globigerina Ooze, grey, pulverulent. Residue brown.	80·47	(70·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Rotalidæ.	(8·47 %), Pteropods, Ostracodes, fragments of Echini spines, Coccoliths, Rhabdoliths.
Off St. Paul's Rocks.	108	„ 27	1 10 0 N. 28 23 0 W.	1900	36·8	78·0	Globigerina Ooze, grey-white, granular. Residue brown.	84·90	(77·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Biloculina,* Rotalidæ.	(6·90 %), fragments of Echini spines, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
60·75	(3·00 %), Radiolaria, Sponge spicules, Diatoms.	(10·00 %), m. di. 0·15 mm., angular; felspar, augite, magnetite, volcanic glass, fragments of volcanic rocks, olivine.	(47·75 %), amorphous matter, with fragments of minerals, Radiolaria, Sponge spicules, and Diatoms.	Some of the shells of Foraminifera and fragments of other organisms are macroscopic. The fine washings are chiefly made up in these deposits, as well as in many others similarly situated, of minute mineral particles less than 0·02 mm. in diameter.	Off Cape Verde Islands—*continued.*
52·48	(2·00 %), Radiolaria, Sponge spicules, arenaceous Foraminifera, Diatoms.	(5·00 %), m. di. 0·10 mm., angular; fragments of volcanic rocks and volcanic glass, olivine, felspar, magnetite, augite, black mica.	(45·48 %), amorphous matter, with minute fragments of minerals and siliceous organisms.		
45·71	(1·00 %), a few Radiolaria and Diatoms.	(1·00 %), m. di. 0·08 mm., angular, except a few rounded fragments of quartz; fragments of volcanic rocks some of them vitreous, augite, hornblende, magnetite, olivine, palagonite, manganese grains.	(43·71 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	All the pelagic Foraminifera, of which this deposit is chiefly composed, are very large and well developed forms, especially *Pulvinulina menardii.* Many of these Foraminifera appear to show striking indication of having been acted upon by some solvent.	
69·85	(1·00 %), a few Radiolaria, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, augite, hornblende, magnetite.	(67·85 %), much flocculent amorphous matter, with minute particles of minerals, Radiolaria, and Diatoms.	Fine washings more than half made up of mineral fragments less than 0·02 mm. in diameter. This deposit might be called a Red Clay.	St. Vincent to St. Paul's Rocks.
37·78	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, imperfect brown casts, Diatoms.	(1·00 %), m. di. 0·07 mm., generally angular; felspar, hornblende, round green fragments resembling glauconite.	(35·78 %), amorphous matter, with minute mineral particles and fragments of siliceous organisms.	The dredge brought up some dark coloured ooze, the colour being due to land detritus. There were small yellow grains in the deposit, which on micro-analysis were found to be phosphate of lime.	
93·78	(1·00 %), Radiolaria and Diatoms.	(35·00 %), m. di. 0·10 mm., angular; felspar, plagioclase, quartz, mica, hornblende, zircon, glauconite, a good many small manganese grains.	(57·78 %), flocculent amorphous matter, many minute mineral particles, fragments of siliceous organisms.	This deposit contains much amorphous clayey matter and many fine mineral particles. The glauconite in the deposit at this and the last station is represented by one or two grains.	
33·73	(1·00 %), a few Radiolaria, Astrorhizidæ, Lituolidæ.	(2·00 %), m. di. 0·06 mm., angular; sanidine, hornblende, magnetite.	(30·73 %), flocculent amorphous matter, with many small mineral particles.	Only a small quantity of this deposit came up. The subjoined analysis was made with less than half a gramme. The specimen does not appear to be quite so dark coloured as that obtained in 1876 at nearly the same place. As at Station 98 the specimens of *Pulvinulina menardii* predominate.	
...	...	...	...	Some traces of deposit on outside of the tube.	
28·30	(2·00 %), Radiolaria, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·13 mm., angular; felspar, augite, magnetite, a few manganese grains.	(25·30 %), amorphous matter, with minute mineral particles.	This deposit still shows traces of land detritus.	
...	...	...	...	Some traces of deposit on outside of tube.	
10·53	(1·00 %), Radiolaria, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; fragments of sanidine and pumice, manganese grains.	(8·53 %), amorphous matter and minute mineral particles.	Note the increase of carbonate of lime in the lesser depths. Some ooze in the trawl.	
19·53	(1·00 %), a few Radiolaria.	(1·00 %), m. di. 0·15 mm., angular; sanidine, augite, glassy volcanic particles, magnetite, one small piece of pumice observed.	(17·53 %), clayey matter and fine mineral particles.	Owing to some rusty particles from the sounding tube becoming mixed with the deposit, the percentage of carbonate of calcium in the accompanying analysis is probably less than it ought to be.	
15·10	(1·00 %), Radiolaria, a few arenaceous Foraminifera, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; olivine, magnetite, enstatite, actinolite, chromite, serpentine.	(13·10 %), amorphous matter, with many minute mineral particles.	Mineral particles evidently from St. Paul's Rocks.	Off St Paul's Rocks.

See Charts 12, 13, 14, and 15, and Diagram 4.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Temperature of the Sea-water (Fahr.). Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Carbonate of Calcium. Foraminifera.	Carbonate of Calcium. Other Organisms.
Off St. Paul's Rocks.	109C	1873 Aug. 29	° ′ ″ 0 56 23 N. 29 22 15 W.	780	° ...	° 76·5	GLOBIGERINA OOZE, grey, finely granular, pulverulent. **Residue** grey with green tinge.	57·34	(50·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ.	(5·34 %), Pteropods, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	109D	„ 29	0 56 4 N. 29 25 2 W.	1425	...	77·0	GLOBIGERINA OOZE, grey, finely granular, pulverulent, chalky. **Residue** grey with green tinge.	72·77	(60·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ.	(9·77 %), Pteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	110	„ 30	0 9 0 N. 30 18 0 W.	2275	34·8	77·5	GLOBIGERINA OOZE, white or light grey, finely granular, pulverulent. **Residue** brown.	72·93	(65·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Lagenidæ, Rotalidæ.	(6·93 %), Ostracodes, fragments of Echini spines, Coccoliths, Rhabdoliths.
St. Paul's Rocks to Fernando Noronha.	111	„ 31	1 45 0 S. 30 58 0 W.	2475	33·7	78·0	GLOBIGERINA OOZE, with red tinge, slightly coherent. **Residue** yellow-brown.	36·06	(32·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Rotalidæ.	(3·06 %), Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	112	Sept. 1	3 33 0 S. 32 16 0 W.	2200	34·0	78·0	GLOBIGERINA OOZE, of a dirty white colour, granular, pulverulent. **Residue** brown.	81·27	(75·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(5·27 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
	113A	„ 2	3 47 0 S. 32 24 30 W.	25	...	78·0	CALCAREOUS SAND, mottled red and white. **Residue** greenish brown.	92·28	(5·00 %), Globigerinidæ, *Pulvinulina*. (20·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(67·28 %), Gasteropods, Lamellibranchs, Echinoderm fragments, Polyzoa, calcareous Algæ.
Fernando Noronha to Pernambuco.	115	„ 3	4 2 0 S. 32 47 0 W.	2150	...	78·0	GLOBIGERINA OOZE, with a very slight rose tinge, granular, pulverulent. **Residue** brown.	79·30	(70·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Lagenidæ, Rotalidæ.	(8·30 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
	116	„ 4	5 1 0 S. 33 50 0 W.	2275	34·3	78·0	GLOBIGERINA OOZE, red tinge, granular, pulverulent, earthy. **Residue** red-brown.	65·04	(57·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(7·04 %), Otoliths and small teeth of fish, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	117	„ 6	5 56 0 S. 34 45 0 W.	1375	...	78·0	GLOBIGERINA OOZE, yellow-brown when dry, slightly coherent, earthy, gritty. **Residue** red-brown.	56·59	(40·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, *Textularia*, Lagenidæ, Rotalidæ.	(11·59 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, fragments of Echini spines, Rhabdoliths.
	117A	„ 6	6 4 0 S. 34 51 0 W.	500	...	78·0	RED MUD, grey-brown, slightly coherent, finely granular, earthy. **Residue** yellow-brown fine clayey sand.	60·79	(15·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(40·79 %), fragments of Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
42·66	(1·00 %), a few Radiolaria and Diatoms.	(30·00 %), m. di. 0·17 mm., rounded; olivine, enstatite, serpentine, magnetite, actinolite.	(11·66 %), amorphous matter, with minute mineral particles.	The mineral particles are chiefly from St. Paul's Rocks and consist of grains of olivine, numerous fragments of micaceous scales, finely lamellar, yellowish with bronze or silver lustre,—of which the microscopic characters are those of enstatite or bronzite,—sometimes having brown linear inclusions following the prismatic cleavage. There are also present fragments of serpentine almost colourless or slightly green. A few of the organisms are macroscopic. Might be called Pteropod Oozes.	Off St. Paul's Rocks.
27·23	(1·00 %), one or two Radiolaria, Sponge spicules, Lituolidæ.	(15·00 %) m. di. 0·18 mm., rounded; olivine, enstatite, serpentine, actinolite, felspar, augite.	(11·23 %), amorphous matter and minute mineral particles.		
27·07	(2·00 %), Radiolaria, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, hornblende, augite, magnetite, pumice, glassy volcanic particles, grains of manganese.	(24·07 %), amorphous matter, with minute mineral particles.	Note the absence of shells of Pteropods at this depth, and the less amount of carbonate of lime in the next with reference to the depth.	St. Paul's Rocks to Fernando Noronha.
63·94	(1·00 %), Radiolaria and Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, magnetite, hornblende, augite, glassy volcanic particles.	(61·94 %), amorphous matter, minute mineral particles, fragments of siliceous organisms.	This deposit contains much amorphous clayey matter compared with those at Stations 110 and 112 in lesser depths. The majority of the organisms which make up the carbonate of calcium are in a fragmentary condition. Might be called a Red Clay.	
18·73	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·10 mm., angular; plagioclase, felspar, pyroxene, black mica, zircon, magnetite, glassy volcanic particles.	(16·73 %), amorphous matter, with minute mineral particles.	Many of the Foraminifera, especially *Pulvinulina menardii*, are macroscopic.	
7·72	A few Sponge spicules.	(1·00 %), m. di. 0·60 mm., rounded; fragments of volcanic rocks, quartz, felspar, glauconite, magnetite, augite, hornblende, glassy volcanic fragments.	(6·72 %), a small quantity of flocculent organic matter and fine mineral particles.	The individual particles which make up this deposit vary from 2 to 3 cm. in diameter, and are chiefly composed of calcareous Algæ of various species, some of these being bright red in colour. Volcanic pebbles were numerous in the dredgings.	
20·70	(1·00 %), Radiolaria, Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·10 mm., rounded and angular; quartz, felspar, augite, hornblende, black mica, magnetite, glassy volcanic fragments.	(18·70 %), amorphous matter and small mineral particles.	Some of the Foraminifera are macroscopic. Black mica is rare, but magnetite in isolated crystals and as inclusions in other minerals is abundant; some of the glassy fragments are reddish, and transformed into palagonite.	Fernando Noronha to Pernambuco.
34·96	(1·00 %), a few Radiolaria and Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; quartz, felspar, augite, hornblende, mica, magnetite, glassy volcanic particles.	(32·96 %), amorphous matter and fine mineral particles.	Many of the shells of Foraminifera—*Pulvinulina menardii*, &c.,—are macroscopic; some of the quartz particles are rounded.	
43·41	(1·00 %), one or two fragments of Radiolaria, Sponge spicules, Lituolidæ, imperfect brown casts.	(5·00 %), m. di. 0·10 mm., angular and rounded; quartz, felspar, augite, magnetite, mica.	(37·41 %), amorphous and flocculent matter, many fine mineral particles, and minute fragments of siliceous spicules.	The pelagic Molluscs do not seem to be so abundant as in the sounding at 500 fathoms, nor are the mineral particles so large. Some of the shells are macroscopic.	
39·21	(1·00 %), one or two Sponge spicules, Astrorhizidæ, Lituolidæ.	(10·00 %), m. di. 0·15 mm., rounded and angular; quartz, mica, felspar, hornblende, olivine, epidote.	(28·21 %), amorphous matter, with many small mineral particles.	The majority of the organisms found in this deposit are in a fragmentary condition; some of them are macroscopic. The felspar is kaolinised.	

See Charts 12 and 15, and Diagram 4.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea water. (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
			° ′ ″		°	°				
Fernando Noronha to Pernambuco—*continued.*	118	1873 Sept. 8	7 28 0 S. 34 2 0 W.	2050	35·2	77·5	Globigerina Ooze, with yellow tinge, finely granular, slightly coherent, earthy. **Residue** yellow-red.	37·18	(25·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(9·18 %), Otoliths of fish, fragments of Pteropods and Heteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	119	,, 8	7 39 0 S. 34 12 0 W.	1650	37·2	77·5	Globigerina Ooze, yellowish, finely granular, slightly coherent. **Residue** red.	48·61	(30·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Rotalidæ.	(15·61 %), Otoliths of fish, Pteropods, Heteropods, Echini spines, Coccoliths, Rhabdoliths.
Off the Coast of South America between Pernambuco and Bahia.	*120	,, 9	8 37 0 S. 34 28 0 W.	675	...	78·0	Red Mud, red-brown, granular, pulverulent, earthy, with white calcareous spots. **Residue** yellow.	38·93	(25·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(11·93 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, fragments of *Isis*, *Ianthina*, fragments of *Lepas*, Brachiopods, Pteropods, Heteropods, Ostracode valves, Echinoderm fragments, Coccoliths, Rhabdoliths.
	121	,, 9	8 28 0 S. 34 31 0 W.	500	...	78·0	Red Mud, red-brown, arenaceous, presenting white calcareous spots, pulverulent, earthy, sublustrous streak. **Residue** yellow and sandy.	38·56	(30·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(5·56 %), Otoliths of fish, Gasteropods, Lamellibranchs (larval), Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	122	,, 10	9 5 0 S. 34 50 0 W.	350	...	77·5	Red Mud, yellow-brown, arenaceous, pulverulent, dotted with white calcareous spots. **Residue** light brown, sandy.	42·15	(10·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(27·15 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, calcareous Algæ, Rhabdoliths.
	122A	,, 10	9 10 0 S. 34 52 0 W.	120	...	77·5	Red Mud, red-brown, arenaceous, with white calcareous spots, slightly coherent, earthy, gritty, sublustrous streak. **Residue** red-brown.	49·10	(15·00 %), Globigerinidæ, *Pulvinulina.* (8·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(26·10 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, a few Coccoliths and Rhabdoliths.
	122B	,, 10	9 9 0 S. 34 53 0 W.	32	...	77·5	Red Sandy Mud, with shells.	...	...	...
	122C	,, 10	9 10 0 S. 34 49 0 W.	400	...	77·5	Red Mud, similar to that of Station 122A.	..	...	..
	123	,, 11	10 9 0 S. 35 11 0 W.	1715	37·0	77·5	Globigerina Ooze, yellowish, slightly coherent, earthy, gritty. **Residue** red-brown.	54·52	(35·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(16·52 %), Otoliths of fish, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.

* See anal. 54, 55.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
62·82	(1·00 %), Sponge spicules, Lituolidæ.	(15·00 %), m. di. 0·15 mm., angular and rounded; quartz, mica, hornblende, augite, felspar, zircon.	(46·82 %), amorphous matter, with many minute mineral particles.	The mineral particles are angular and rounded and very abundant. With the exception of the Foraminifera the organisms are all fragmentary.	Fernando Noronha to Pernambuco—*continued.*
51·39	(1·00 %), a few Radiolaria, Sponge spicules, one or two imperfect casts of Foraminifera, Lituolidæ.	(10·00 %), m. di. 0·10 mm., angular; quartz, mica, hornblende, felspar, zircon.	(40·39 %), amorphous matter, with many minute mineral particles.	The Foraminifera in some instances give internal casts, which are hollow and imperfect, black or red, the colour being due to iron or carbonaceous matter. Most of the organisms are fragmentary; some are macroscopic.	
61·07	(1·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ.	(25·00 %), m. di. 0·10 mm., rounded and angular; quartz, felspar, mica, hornblende, zircon.	(35·07 %), amorphous matter, with many minute mineral particles.	Many of the shells are macroscopic. The particles of quartz are mostly angular, but sometimes rounded and covered with limonite; felspars are kaolinised; zircon is rare.	Off the Coast of South America between Pernambuco and Bahia.
61·44	(1·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ.	(15·00 %), m. di. 0·12 mm., rounded and angular; quartz, plagioclase, zircon.	(45·44 %), amorphous matter, with many minute mineral particles.	The percentage of "other carbonate of lime organisms" appears low when compared with preceding and following stations, but the specimen examined did not seem to justify a higher estimate.	
57·85	(1·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ.	(15·00 %), m. di. 0·30 mm., rounded and angular; quartz, mica, felspar, hornblende, tourmaline, glassy volcanic particles.	(41·85 %), amorphous matter, with a great number of minute mineral particles.	The washings of the mud from the trawl and dredge gave a great many small Gasteropod and Lamellibranch shells, fragments of Echinoderms, Sponges, Polyzoa, &c. The minerals are generally angular, but in the washings from the trawl there were large rounded grains of milky quartz. The felspar is sometimes kaolinised.	
50·90	(1·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ.	(25·00 %), m. di. 0·30 mm., rounded and angular; quartz, mica, augite, tourmaline, a few glassy volcanic particles.	(24·90 %), amorphous matter, many fine mineral particles, and a few minute fragments of siliceous spicules.	Both the trawl and dredge were worked in depths which probably varied between the 350 fathoms of Station 122, and 120 fathoms of this station. Some large rounded grains of milky quartz approaching 4 mm. in diameter were obtained in the washings of the trawl. Many of the pelagic and bottom-living organisms are macroscopic; the larger of these are chiefly fragmentary. Among the minerals the quartz is very abundant.	
...	...	...	...	All the deposits along this Brazilian coast have a red colour; some of the Globigerina Oozes might, from the nature and abundance of minute mineral particles, be called Red Muds.	
...	..	...	...		
45·48	(1·00 %), Sponge spicules, one or two Radiolaria, Astrorhizidæ, Lituolidæ, imperfect casts.	(1·00 %), m. di. 0·10 mm., angular; quartz, mica, felspar, hornblende, augite, a few volcanic particles some of them glassy.	(43·48 %), amorphous matter, flocculent matter, many fine mineral particles, and minute fragments of siliceous spicules.	Some of the shells are macroscopic. A few red coloured casts of the pelagic Foraminifera were obtained in the residue after treatment with acid.	

See Charts 12, 15, and 16, and Diagram 5.

Off the Coast of South America between Pernambuco and Bahia—continued.

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water. (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1873	° ′ ″		°	°				
124	Sept. 11	10 11 0 S. 35 22 0 W.	1600	...	77·5	Globigerina Ooze, yellowish, slightly coherent, earthy. **Residue** red-brown.	40·63	(25·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Rotalidæ.	(12·63 %), Gasteropods (larval), Pteropods, Heteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
125	,, 12	10 46 0 S. 36 2 0 W.	1200	...	77·0	Red Mud, red-brown, slightly coherent, finely granular, with white calcareous spots, sublustrous streak. **Residue** reddish yellow.	20·79	(10·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Miliolina*, Rotalidæ.	(8·79 %), fragments of Pteropods, larval Gasteropods, Echini spines, Coccoliths, Rhabdoliths.
126	,, 12	10 46 0 S. 36 8 0 W.	770	...	77·0	Red Muds, red-brown, earthy, granular, slightly coherent, sublustrous streak. **Residue** red-brown.	5·75	(3·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ.	(1·75 %), fragments of Pteropods, Echini spines, Coccoliths, Rhabdoliths.
126A	,, 12	10 45 0 S. 36 9 0 W.	700	...	77·0				
127	,, 13	11 42 0 S. 37 3 0 W.	1015	38·5	77·0	Red Mud, red-brown, slightly coherent, earthy, finely granular. **Residue** red-brown, with many glistening scales of mica.	28·72	(10·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(15·72 %), Pteropods, Heteropods, Ostracodes, fragments of Echini spines, Coccoliths, Rhabdoliths.
128	,, 14	13 6 0 S. 38 7 0 W.	1275	...	76·5	Globigerina Ooze, with a yellowish tinge, slightly coherent, earthy. **Residue** yellow-red.	50·65	(30·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(17·65 %), Gasteropods (larval), Pteropods, Heteropods, Echini spines, Coccoliths, Rhabdoliths.
...	,, 16	Off Bahia.	10–17	...	...	Quartziferous Mud, of a light greenish grey colour, slightly coherent, granular, presenting white calcareous spots. **Residue** brown, sandy, with black specks.	30·90	(15·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(15·90 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, Alcyonarian spicules.

Bahia to Tristan da Cunha.

Number of Station.	Date.	Position.	Depth in Fathoms.	Bottom	Surface	Designation and Physical Characters.	Per cent.	Foraminifera.	Other Organisms.
129	,, 30	20 13 0 S. 35 19 0 W.	2150	34·2	74·0	Globigerina Ooze, drying into clayey masses of a dirty red colour, fine grained. **Residue** red-brown.	46·43	(40·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Lagenidæ, Rotalidæ.	(5·43 %), small teeth of fish, Echini spines, Coccoliths, Rhabdoliths.
130	Oct. 3	26 15 0 S. 32 56 0 W.	2350	34·7	69·0	Globigerina Ooze, greyish red when dry, finely granular, coherent. **Residue** reddish.	35·93	(27·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, *Lagena*, Rotalidæ.	(7·93 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
131	,, 6	29 35 0 S. 28 9 0 W.	2275	34·6	65·0	Globigerina Ooze, yellow-brown, drying into coherent masses. **Residue** red.	55·63	(45·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, *Lagena*, Rotalidæ.	(8·63 %), fragments of Echini spines, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
59·37	(1·00 %), a few Sponge spicules, one or two Radiolaria, Lituolidæ, imperfect brown casts.	(1·00 %), m. di. 0·12 mm., angular and rounded; quartz, hornblende, felspar, mica, augite, magnetite, a few glassy volcanic particles.	(57·37 %), many very fine mineral particles mixed with amorphous matter, and a few minute fragments of siliceous spicules.	Many of the shells are macroscopic, but are much broken up. Some of the mineral particles attain a diameter of 2 mm.	Off the Coast of South America between Pernambuco and Bahia—*continued*.
79·21	(1·00 %), Sponge spicules, Lituolidæ.	(25·00 %), m. di. 0·08 mm., angular and rounded; quartz, mica, felspar, hornblende, pumice, glassy volcanic particles.	(53·21 %), amorphous matter mixed with many fine mineral particles.	Quartz is the principal mineral in this deposit; the smaller particles are angular, but when the grains are large they are rounded. Mica is abundant, and plagioclase is present in some quantity; pumice rarely occurs. Some of the grains attain a size of 1 mm.	
94·25	(1·00 %), a few fragments of Sponge spicules, Lituolidæ.	(25·00 %), m. di. 0·13 mm., angular; quartz, mica, felspar, hornblende.	(68·25 %), amorphous matter, many fine mineral particles, a few minute fragments of siliceous spicules.	The felspar is generally kaolinised.	
71·28	(1·00 %), a few Sponge spicules, Astrorhizidæ, Lituolidæ.	(25·00 %), m. di. 0·07 mm., angular and rounded; quartz, mica, felspar.	(45·28 %), amorphous matter, very many minute mineral particles, a few fragments of siliceous spicules.	The amorphous matter in this deposit is small in quantity compared with the mineral particles; these latter form the essential part of the residue, and their dimensions vary from 1 to 0·02 mm. The quartz particles are generally angular, rarely rounded, and are the most abundant of the minerals in this deposit. Mica is also abundant; felspar is frequent and sometimes kaolinised. Many of the shells are macroscopic although much broken up.	
49·35	(1·00 %), a few Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·15 mm., rounded and angular; quartz, mica, felspar, hornblende.	(47·35 %), amorphous matter, many minute mineral particles, and a few fragments of siliceous spicules.	A few of the pelagic shells are macroscopic. The felspar in some cases is kaolinised. Note that in all the deposits along this coast Radiolaria are exceedingly rare, and glauconite nearly, if not quite, absent.	
69·10	(1·00 %), Sponge spicules, and a few Diatoms.	(45·00 %), m. di. 0·40 mm., rounded and angular; quartz, felspar, magnetite, hornblende; mica, minute rock fragments, grains of glauconite.	(23·10 %), amorphous flocculent matter, many minute mineral particles, and fragments of siliceous organisms.	In some places the deposit is a quartz sand; in others a mud containing all the above-mentioned material, along with fine amorphous matter. Many of the organisms are macroscopic.	
53·57	(1·00 %), a few siliceous spicules, red casts of pelagic Foraminifera, *Astrorhiza*.	(1·00 %), m. di. 0·06 mm., angular; quartz, mica, monoclinic and triclinic felspars, hornblende, glassy volcanic fragments, augite.	(51·57 %), amorphous matter and very many fine mineral particles.	Some of the quartz grains are rounded and covered with limonite. The particles of felspar are in some cases kaolinised. Scales of mica are abundant, having sometimes a diameter of 0·2 mm.; some silver-white scales are probably muscovite. Dredge-rope carried away.	Bahia to Tristan da Cunha.
64·07	(1·00 %), a few fragments of Sponge spicules.	(1·00 %), m. di. 0·06 mm., angular and rounded; quartz, felspar, augite, hornblende, pumice, a few grains of manganese.	(62·07 %), amorphous matter, with a great many fine mineral particles.	Many of the quartz grains are rounded and have a diameter of 0·2 mm. The trawl was hauled up just to the ship's side when the line parted; judging from the extension of the accumulators, it was apparently heavily laden.	
44·37	(1·00 %), Radiolaria, Lituolidæ.	(1·00 %), m. di. 0·06 mm., a few particles have a diameter of 0·20 mm., angular; brown and red glassy volcanic particles, felspar, augite, hornblende, mica, a few grains of quartz and pumice.	(42·37 %), amorphous matter, with many very minute mineral particles and a few fragments of siliceous organisms.	This deposit contains much amorphous clayey matter. The trawl brought up the earbone of a *Ziphius*,* having a very slight coating of manganese; growing on it was a polyp, to which an egg capsule was attached. There was also a rounded piece of pumice, 3 to 4 cm. in diameter, white coloured and very fibrous, and containing small crystals of magnetite and hornblende.	

* See Zool. Chall. Exp., pt. iv. p. 39., pl. ii. fig. 10.

See Charts 16 and 17, and Diagrams 5 and 6.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water. (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Bahia to Tristan da Cunha—*continued.*	132	1873 Oct. 10	° ′ ″ 35 25 0 S. 23 40 0 W.	2050	° 35·0	° 58·0	Globigerina Ooze, white with a rose tint, drying into white chalky masses, slightly coherent, finely granular, homogeneous. **Residue** red.	85·04	(75·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Biloculina*, Rotalidæ.	(9·04 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
Bahia to Tristan da Cunha—*continued.*	133	,, 11	35 41 0 S. 20 55 0 W.	1900	35·4	58·0	Globigerina Ooze, white with a slight rose tint, when dry forming white chalky masses, friable, pulverulent, homogeneous, granular. **Residue** red.	86·04	(75·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(9·04 %), Otoliths of fish, one or two fragments of larval Gasteropods and of Pteropods, Echinoderm fragments, Coccoliths, Rhabdoliths.
Bahia to Tristan da Cunha—*continued.*	134	,, 14	36 12 0 S. 12 16 0 W.	2025	36·0	53·5	Globigerina Ooze, grey-white, when dry forming grey chalky masses, homogeneous, very slightly coherent. **Residue** dark brown.	59·18	(50·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Miliolina*, Textularidæ, Rotalidæ.	(8·18 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
Off Tristan da Cunha.	135	,, 15	37 1 50 S. 12 19 10 W.	360	...	53·5	Volcanic Sand, when dry forming a red-brown dust or ash, very slightly coherent. **Residue** grey-brown.	6·93	(3·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(2·93 %), *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echini spines.
Off Tristan da Cunha.	135A	,, 16	37 16 50 S. 12 45 15 W.	75	...	54·0	Hard Ground, shells and gravel.	..	...	..
Off Tristan da Cunha.	135B	,, 17	37 22 30 S. 12 33 0 W.	465	...	53·5	Hard Ground, shells and gravel.	...	...	..
Off Tristan da Cunha.	135C	,, 17	37 25 30 S. 12 28 30 W.	110–150	...	54·0	Coarse Shelly Bottom.	96·00	(5·00 %), Globigerinidæ, *Pulvinulina.* (15·00 %), Miliolidæ, Textularidæ, Lagenidæ.	(76·00 %), *Serpula*, Gasteropods, Lamellibranchs, Brachiopods, Pteropods, Echinoderm fragments, Polyzoa.
Off Tristan da Cunha.	135D	,, 17	37 25 0 S. 12 30 30 W.	72	...	54·0	Coarse Shelly Bottom.	...	...	...
Off Tristan da Cunha.	135E	,, 18	37 21 0 S. 12 22 30 W.	1000	...	53·5	Hard Ground, shells and gravel.	..	...	...
Off Tristan da Cunha.	135F	,, 18	37 14 45 S. 12 20 15 W.	1100	...	53·5	Hard Ground.	...	...	...
Off Tristan da Cunha.	135G	,, 18	37 10 50 S. 12 18 30 W.	550	...	54·0	Hard Ground.	...	...	...

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
14·96	(1·00 %), Radiolaria, Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; fragments of felspar, glassy volcanic particles, augite, hornblende.	(12·96 %), amorphous matter, fine mineral particles, and minute fragments of siliceous organisms.	Glassy volcanic particles are abundant in this deposit, many of them pale green or red owing to decomposition. Plagioclase, hornblende, and augite fragments are rare. The Foraminifera are exceptionally small, and *Pulvinulina menardii* was not observed.	Bahia to Tristan da Cunha—*continued*.
13·96	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; quartz, felspar, hornblende, mica, volcanic glass.	(11·96 %), amorphous matter, many fine mineral particles, fragments of siliceous spicules.	The trawl brought up *Ianthina* shells occupied by *Pagurus*. The Foraminifera are very minute and all the typical tropical forms have disappeared. Rounded grains of quartz are very rare.	
40·82	(1·00 %), a few Radiolaria and Sponge spicules, Lituolidæ.	(5·00 %), m. di. 0·06 mm., chiefly angular, a few rounded; quartz, felspar, hornblende, magnetite, black mica, pumice, red and brown rounded glassy particles.	(34·82 %), amorphous matter, many fine black and other mineral particles, and a few fragments of siliceous organisms.	...	
93·07	(1·00 %), a few Radiolaria, Lituolidæ, Diatoms.	(80·00 %), m. di. 0·50 mm., angular; magnetite, augite, hornblende, pumice, volcanic glass sometimes altered to palagonite.	(12·07 %), many fine mineral particles, amorphous matter, a few fragments of Radiolaria and Diatoms.	Some of the fragments of volcanic rocks found in this deposit have a diameter of from 1 to 3 mm.; fragments of felspathic rocks are numerous. Some of the shells are macroscopic.	Off Tristan da Cunha.
...	...	...	...	The dredge brought up a few volcanic rock fragments.	
...	...	...	...	The material brought up by the sounding tube indicated a hard shelly bottom.	
4·00	(1·00 %), Sponge spicules, Lituolidæ.	(2·00 %), m. di. 0·30 mm., angular and rounded; sanidine, plagioclase, augite, hornblende, black mica, olivine, glassy volcanic particles, magnetite, lapilli.	(1·00 %), a small quantity of flocculent organic matter, minute mineral particles, a few fragments of siliceous spicules.	There are one or two fragments of basaltic lava from 3 to 4 cm. in diameter, in which can be distinguished crystals of augite and magnetite; these are surrounded by a red zone of decomposition. It may be safely said that the bulk of this deposit is made up of Polyzoa.	
...	...	...	...	Similar in every respect to the above.	
...	...	...	...	...	
...	...	...	...	The dredge brought up several large pumice stones.	
...	...	...	...	...	

See Charts 16 and 18, and Diagrams 6 and 8.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water. (Fahr.).		Designation and Physical Characters.	CARBONATE OF CALCIUM.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Tristan da Cunha to Cape of Good Hope.	136	1873 Oct. 20	° ′ ″ 36 48 0 S. 7 13 0 W.	2100	° 35·2	° 54·0	...	...	...	...
	137	,, 23	35 59 0 S. 1 34 0 E.	2550	34·5	56·1	GLOBIGERINA OOZE, when dry forming yellow-grey clayey masses, homogeneous, pulverulent. **Residue** red.	35·22	(25·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Rotalidæ.	(9·22 %), Ostracodes, Echini spines, Polyzoa, Coccoliths, a very few Rhabdoliths.
	138	,, 25	36 22 0 S. 8 12 0 E.	2650	35·1	56·2	RED CLAY, red-grey, drying into marly masses, finely granular, slightly coherent, earthy, sublustrous streak. **Residue** red-brown.	26·22	(20·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Rotalidæ.	(5·22 %), small teeth of fish, fragments of Echini spines, Coccoliths.
	139	,, 27	35 35 0 S. 16 9 0 E.	2325	34·1	56·2	GLOBIGERINA OOZE, grey, drying into chalky masses, with a fine grain, pulverulent. **Residue** dark grey, sandy.	47·15	(35·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Miliolina*, Lagenidæ, Rotalidæ, Nummulinidæ.	(10·15 %), small teeth of fish, Echini spines, Coccoliths, Rhabdoliths.
	140	,, 28	35 0 0 S. 17 57 0 E.	1250	...	59·0	GLOBIGERINA OOZE, greenish-grey, drying into slightly coherent grey coloured masses. **Residue** greenish brown.	50·26	(40·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(9·26 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
	...	Dec.	Simon's Bay, Cape of Good Hope.	20	...	...	SHELLY QUARTZ SAND, yellow-green when wet, greenish coloured when dry. **Residue** green.	22·17	(10·00 %), Miliolidæ, Textularidæ, Lagenidæ, *Globigerina*, Rotalidæ, Nummulinidæ.	(12·17 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
Cape of Good Hope to Marion Island.	*141	,, 17	34 41 0 S. 18 36 0 E.	98	49·5	66·5	GREEN SAND, with white spots, grey-green and slightly coherent when dry, granular. **Residue** green.	49·46	(15·00 %), Globigerinidæ. (25·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(9·46 %), Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths.
	†142	,, 18	35 4 0 S. 18 37 0 E.	150	47·0	65·5	GREEN SAND, green, presenting white spots, calcareous, fine grained, slightly coherent when dry. **Residue** green.	67·75	(30·00 %), Globigerinidæ. (15·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(22·75 %), Otoliths, teeth, and fragments of bones of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths.

* See anal. 66. † See anal. 72; Pl. XX. fig. 1; Pl. XXIV. fig. 1.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
...	...	..	...	There was nothing in the sounding tube to indicate the nature of the bottom. The dredge came up empty and without any marks or material to indicate the nature of the deposit.	Tristan da Cunha to Cape of Good Hope.
64·78	(1·00 %), Radiolaria, Sponge spicules, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; quartz, felspar, magnetite.	(62·78 %), amorphous matter, many very minute mineral particles, fragments of Diatoms.	The quartz grains in some cases are rounded, and about 1 mm. in diameter. The pelagic Foraminifera are much broken, and composed entirely of the dwarfed, heavy, and thick-shelled forms; there is no great variety. The bottom-living forms are very rare; there are a few macroscopic fragments of Polyzoa.	
73·78	(1·00 %), Radiolaria, Sponge spicules, Diatoms.	(2·00 %), m. di. 0·07 mm., rounded and angular; quartz, orthoclase, hornblende, augite, tourmaline, magnetite, grains of manganese.	(70·78 %), amorphous matter, with many minute mineral particles and fragments of siliceous spicules.	The pelagic Foraminifera are fragmentary; the bottom-living forms are very rare. Several of the quartz grains are rounded and have a diameter of 1 mm.	
52·85	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(8·00 %), m. di. 0·07 mm., angular; quartz, glauconite, plagioclase, augite, hornblende, magnetite.	(43·85 %), amorphous matter and very fine mineral particles.	Some of the bottom-living Foraminifera are macroscopic. The felspar is kaolinised.	
49·74	(1·00 %), a few Radiolaria, Sponge spicules, Lituolidæ, glauconitic casts, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; quartz, glauconite, felspar, augite, magnetite.	(47·74 %), amorphous matter and fine mineral particles.	The pelagic Foraminifera are dwarfed in character. Glauconite is abundant; glauconitic casts of the Foraminifera were observed. Note the appearance of glauconite on approaching a continental shore.	
77·83	(1·00 %), Sponge spicules.	(70·00 %), m. di. 2·00 mm., rounded; quartz, felspar, augite, glauconite, mica, magnetite, hornblende.	(6·83 %), amorphous matter, flocculent organic matter, and minute fragments of minerals.	Many of the organisms are macroscopic. Quartz is the principal mineral, many of the grains of which are milky and rounded, some of the largest having a diameter of 1 cm. There is also present a quantity of amorphous flocculent clayey and organic matter, which gives a light green tinge to the deposit.	
50·54	(6·00 %), Sponge spicules, white and pale green casts of Foraminifera and other organisms, Lituolidæ, Diatoms.	(40·00 %), m. di. 0·35 mm., rounded and angular; quartz, glauconite, felspar, garnet, black mica, hornblende.	(4·54 %), greenish coloured matter (possibly organic), fragments of minerals and Diatoms.	The quartz grains in many cases are rounded and the felspar kaolinised; all the minerals are more or less covered with a greenish substance. Small glauconitic concretions contained phosphate of lime.	Cape of Good Hope to Marion Island.
32·25	(6·00 %), Sponge spicules, grey and green casts of Foraminifera, Astrorhizidæ, Lituolidæ, Diatoms.	(20·00 %), m. di. 0·20 mm., rounded; quartz, glauconite, felspar, hornblende.	(6·25 %), amorphous matter, fragments of minerals and siliceous organisms, with some green particles.	In the dredge there were a few glauconitic concretions measuring from 2 to 6 mm. in diameter. There was here, as at the last station, much green coloured amorphous matter in the mud. Some portions seemed like vegetable tissue; when heated on platinum it gave off an organic smell. This green substance and the glauconite give the green colour to the residue. There were a good many phosphatic concretions, some of them over a centimetre in diameter.	

See Charts 18 and 19, and Diagram 8.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water. (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Cape of Good Hope to Marion Island.—*continued.*	*143	1873 Dec. 19	° ′ ″ 36 48 0 S. 19 24 0 E.	1900	° 35·6	° 78·0	Globigerina Ooze, dirty-white, slightly coherent, granular. **Residue** yellow-green, with black grains.	90·34	(70·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(15·34%), Otoliths of fish, larval Gasteropods, larval Lamellibranchs, *Terebratula*, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths.
	144	,, 24	45 57 0 S. 34 39 0 E.	1570	35·8	43·0	Globigerina Ooze, white, granular, slightly coherent when dry. **Residue** yellow-grey.	92·34	(80·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(10·34 %), Ostracode valves, Echini spines, Coccoliths.
Off Marion Island.	144A	,, 26	46 48 0 S. 37 49 30 E.	50–100	...	41·0	Volcanic Sand, black, fine grained, but mixed with large fragments of shells, *Serpula*, and Polyzoa. **Residue** black.	26·13	(5·00 %), Globigerinidæ. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(16·13 %), *Serpula*, *Dentalium*, Brachiopods, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
	145	,, 27	46 43 0 S. 38 4 30 E.	85–140	...	41·0	Volcanic Sand.	...	...	..
	145A	,, 27	46 41 0 S. 38 10 0 E.	310	...	41·5	Volcanic Sand.	...	...	...
Marion Island to Crozet Islands.	†146	,, 29	46 46 0 S. 45 31 0 E.	1375	35·6	43·0	Globigerina Ooze, white, fine grained, slightly coherent. **Residue** yellow-grey.	86·36	(75·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(9·36 %), tubes of *Serpula* and other Annelids, Gasteropods, Lamellibranchs, Cirripedia, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths.

* See anal. 73, 74; Pl. XX. figs. 2, 3, 4. † See anal. 43.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
9·66	(1·00 %), a few Radiolaria, Sponge spicules, white and green imperfect casts of Foraminifera, Astrorhizidæ, Lituolidæ, Diatoms.	(3·00 %), m. di. 0·12 mm., rounded and angular; quartz, felspar, plagioclase, glauconite, grains of manganese.	(5·66 %), amorphous matter, fine mineral particles, flocculent matter, and fragments of siliceous organisms.	This deposit contains but little fine calcareous or clayey matter and is almost entirely composed of isolated white Foraminifera shells. There were in the dredge many small, irregular, phosphatic concretions, 1 to 4 centimetres in diameter, coated with manganese, and containing glauconite and Foraminifera.	Cape of Good Hope to Marion Island.—*continued.*
7·66	(1·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, imperfect casts, Diatoms.	(1·00 %), m. di. 0·12 mm., angular and rounded; monoclinic and triclinic felspars, augite, hornblende, magnetite, olivine transformed into serpentine, bronzite, fragments of volcanic glass and allied rocks, manganese grains, quartz.	(5·66 %), amorphous matter, with minute mineral particles and fragments of Diatoms.	This deposit, like that obtained at Station 143, is remarkable for the small quantity of minute and amorphous particles. Some rolled fragments of quartz attain a diameter of about 1 mm. The pelagic Foraminifera are of the small and thick-shelled varieties peculiar to the colder waters of the ocean, although they are not of the typical Arctic and Antarctic varieties, *Globigerina bulloides* predominating.	
73·87	(1·00 %), a few Radiolaria, Sponge spicules, Lituolidæ, Diatoms.	(65·00 %), m. di. 0·15 mm., angular and rounded; plagioclase, felspar, augite, olivine, magnetite, small lapilli of vitreous basaltic rocks.	(7·87 %), minute fragments of minerals and Diatoms, amorphous matter, vegetable matter.	Four hauls were taken with the dredge, two at 50, one at 75, and one at 100 fathoms. The bottom was covered with Polyzoa of several species, the swabs and dredge being filled with them, together with the remains of a great many other animals.	Off Marion Island.
...	...	...	...	Two hauls of the dredge were taken, one in 85 and the other in 140 fathoms when a small quantity of deposit, similar to that described at Station 144A, came up. The animals were similar to those obtained on the previous day when dredging nearer to Marion Island.	
...	...	...	...	A little mud in the dredge indicated the same kind of deposit as in the shallower depths on the same day. One of the most successful hauls of the cruise was made with the dredge, it being filled with animals.	
13·64	(3·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, many Diatoms.	(1·00 %), m. di. 0·10 mm., angular; felspar, plagioclase, microcline, hornblende, magnetite, garnet, tourmaline, pumice.	(9·64 %), fragments of Diatoms, a little amorphous matter and a few mineral particles.	No Rhabdoliths or Orbulinas were observed in this deposit; their southern limit seems to have been passed at this point. There was a fragment about 1 cm. in diameter chiefly formed of a lamellar mineral, probably bronzite, with metalloid lustre, extinction parallel to the direction of the cleavage, hardly fusible. It was attached to some pale green serpentinous matter. The trawl was used and one of the best hauls during the cruise was obtained, the bag being filled with animals. In the trawl were five irregular scoriaceous lapilli, from 1 to 5 centimetres in diameter; they are more or less porous, like pumice, but the vitreous substance is deep brown.	Marion Island to Crozet Islands.

See Charts 18, 20, 21, and 22.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water. (Fahr.) Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Marion Island to Crozet Islands—*continued.*	147	1873 Dec. 30	° ′ ″ 46 16 0 S. 48 27 0 E.	1600	° 34·2	° 41·0	DIATOM OOZE, grey, very fine grained, very slightly coherent, small grains recognisable to the touch. **Residue** brown-black, lighter portions white.	34·63	(30·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Rotalidæ.	(3·63 %), Echinoderm fragments, Coccoliths.
Off Crozet Islands.	147A	1874 Jan. 1	46 45 0 S. 50 42 0 E.	600	...	42·0	DIATOM OOZE, grey, pulverulent, mineral particles perceptible to the touch. **Residue**, heavier portions black, lighter portions white.	36·34	(30·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Rotalidæ.	(5·34 %), Ostracodes, Echini spines, a few Coccoliths.
	148	,, 3	46 47 0 S. 51 37 0 E.	210	...	41·0	HARD GROUND, gravel, shells.	...	...	...
	148A	,, 3	46 53 0 S. 51 52 0 E.	550	...	41·0	HARD GROUND, gravel, shells.	...	...	...
Off Kerguelen Island.	149, 149A, 149B, 149C, 149D, 149E, 149F, 149G, 149H, 149J, 149K	Jan. 9.—Jan. 29.	Off Kerguelen.	20–150	...	...	GREEN MUDS, when dry grey-green, slightly coherent, earthy. **Residue** dark green.	1·00	Miliolidæ, Textularidæ, Lagenidæ, Globigerinidæ, Rotalidæ, Nummulinidæ.	*Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
Off Heard Island.	150	Feb. 2	52 4 0 S. 71 22 0 E.	150	35·2	37·5	COARSE GRAVEL. (The description is made from material obtained in the dredge. The percentages are approximated.)	[20·00]	(3·00 %), Globigerinidæ. (1·00 %), Miliolidæ, Lituolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(16·00 %), *Terebratula*, Ostracodes, Echinoderms, *Millepora*, Polyzoa.
	151	,, 7	52 59 30 S. 73 33 30 E.	75	...	36·2	VOLCANIC SAND, black, fine grained. **Residue** black.	2·58	(1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Globigerinidæ, Rotalidæ.	(1·58 %), tubes of *Serpula* and other Annelids, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
65·37	(25·00 %), Radiolaria, Sponge spicules, numerous Diatoms.	(25·00 %), m. di 0·12 mm., angular and rounded; felspar, plagioclase, augite, hornblende, olivine, magnetite, brown and red decomposed glassy volcanic fragments, one or two rounded quartz grains, brown and red mammillated fragments.	(15·37 %), fragments of Diatoms and minute mineral particles.	Very little of the deposit was obtained. There were several pebbles in the trawl; one fragment, about 3 cm. in diameter, is angular; some of them are vesicular augite-andesites, with a vitreous base. In addition there were other fragments covered with and cemented by manganese; these consist of lapilli, brown in colour and much decomposed.	Marion Island to Crozet Islands—*continued.*
63·66	(20·00 %), Radiolaria, casts of calcareous organisms, Diatoms.	(25·00 %), m. di. 0·12 mm., angular and rounded; felspar, plagioclase, black mica, hornblende, augite, magnetite, olivine, glassy volcanic particles, red mammillated fragments.	(18·66 %), amorphous matter, very many fragments of Diatoms, and minute mineral particles.	There are in this deposit very fine and perfect casts of Foraminifera, fragments of Echini, &c. The carbonate of lime organisms are white or of a pale straw colour; with reflected light they are shining and homogeneous; with transmitted light some are opaque, some transparent and yellow-brown. There are no green casts or glauconitic particles in the deposit. It is unusual to find such perfect casts in the deposit off a volcanic island. Some of these casts show aggregate polarization.	Off Crozet Islands.
...	...	...	...	There were two dredgings; many animals, but no deposit, were obtained. The bottom seemed to be hard and composed of gravel, Polyzoa, and shells.	
...	...	...	...	The dredge brought up a few specimens of *Aphrocallistes.* The bottom appeared to be of the same nature as that at the previous station.	
99·00	(50·00 %), Sponge spicules, Lituolidæ, frustules of Diatoms.	(20·00 %), m. di. 0·15 mm., angular; plagioclase, augite, magnetite, hornblende, olivine (in some cases altered), lapilli, pumice, brown volcanic glass.	(29·00 %), a small quantity of amorphous matter, flocculent organic matter, many fine mineral particles, fragments of Sponge spicules and Diatoms.	During the month of January 1874 the Challenger took many soundings and dredgings in the bays, and several miles off the coast, of Kerguelen, in depths varying from 20 to 150 fathoms. In all cases the deposit was a Green Mud, with a strong smell of sulphuretted hydrogen, composed principally of mineral particles and the skeletons of siliceous organisms. Generally these muds did not effervesce with acid; sometimes a few spots were observed. The carbonate of lime never appeared to make up more than 1 per cent. The larger sized mineral particles were found in the soundings nearest the coast, while siliceous organisms seemed to be most abundant in the soundings furthest from the coast. In some cases the deposit was almost entirely made up of the basal portions of siliceous sponges, *e.g.*, *Rossella antarctica.* The dredgings along this coast gave many animals.	Off Kerguelen Island.
[80·00]	(15·00 %), many Sponge spicules and Radiolaria.	(60·00 %), volcanic and other pebbles.	(5·00 %), amorphous matter and fragments of siliceous organisms.	A large number of stones were brought up in the dredge. These are fragments of rocks of irregular form and varying in diameter from 1 to 7 cm. They are blue-black and much overgrown by Sponges, *Serpula*, Polyzoa, Foraminifera, &c.; some of the pebbles are granite, augite-andesite, basalt filled with delessite.	Off Heard Island.
97·42	(5·00 %), Radiolaria, Sponge spicules, and Diatoms.	(80·00 %), m. di. 0·30 mm., angular; fragments of brown and reddish volcanic glass often enclosing microliths of olivine, plagioclase, augite, magnetite.	(12·42 %), many fine mineral particles, a small quantity of amorphous matter, fragments of Sponge spicules and Diatoms.	This deposit is essentially composed of black volcanic sand and remains of organisms. The fragments of glass are vesicular, and often decomposed. The dredge was used three times and brought up many animals.	

See Charts 23 and 24, and Diagrams 9 and 10.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water. (Fahr.) Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
		1874	° ′ ″		°	°				
In Vicinity of Antarctic Ice.	152	Feb. 11	60 52 0 S. 80 20 0 E.	1260	...	34·5	DIATOM OOZE, pale straw-coloured when wet, when dry white and presenting the appearance of flour, very fine. **Residue** white or pale rose, very slightly plastic.	22·47	(20·00 %), Globigerinidæ. (1·00 %), Miliolidæ, Rotalidæ.	(1·47 %), Gasteropods, Lamellibranchs (rare).
	153	„ 14	65 42 0 S. 79 49 0 E.	1675	...	29·5	BLUE MUD, grey when dry, unctuous, sticky, coherent, containing many hard particles. **Residue** grey.	3·50	(2·00%), Globigerinidæ, a few Textularidæ, Lagenidæ, Rotalidæ.	(1·50 %), Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
	154	„ 19	64 37 0 S. 85 49 0 E.	1800	...	32·0	BLUE MUD, grey when dry, coherent, sublustrous streak, presenting hard particles to the touch. **Residue** dark grey.	1·00	Globigerinidæ and *Miliolina*.	...
	155	„ 23	64 18 0 S. 94 47 0 E.	1300	...	31·0	BLUE MUD, grey when dry, unctuous, coherent, sublustrous streak, earthy. **Residue** brown.	11·84	(9·00 %), Globigerinidæ. (1·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(1·84 %), fragments of Echini spines.
	156	„ 26	62 26 0 S. 95 44 0 E.	1975	...	33·0	DIATOM OOZE, brown when wet, white or dirty white when dry, soft to the touch, resembling flour. **Residue** yellow-white.	2·08	Chiefly *Globigerina*, a few *Truncatulina*.	...
Termination Land to Melbourne.	*157	Mar. 3	53 55 0 S. 108 35 0 E.	1950	32·1	37·2	DIATOM OOZE, straw coloured when wet, white when dry, very light, extremely fine particles, soft to the touch, coherent under pressure, and resembling flour in many respects. **Residue** white.	19·29	(10·00 %), Globigerinidæ. (4·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(5·29 %), Otoliths and teeth of fish, worm tubes, Gasteropods, Lamellibranchs, Ostracodes, fragments of Echini, Polyzoa.
	†158	„ 7	50 1 0 S. 123 4 0 E.	1800	33·5	45·0	GLOBIGERINA OOZE, white with slight rose tint, granular, pulverulent. **Residue** yellow.	85·31	(75·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·31 %), Scales of fish, worm tubes, Ostracode valves, Echinoderm fragments, Coccoliths.
	159	„ 10	47 25 0 S. 130 22 0 E.	2150	34·5	51·5	GLOBIGERINA OOZE, grey with a red tinge, granular, slightly coherent. **Residue** brown.	87·90	(75·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(11·90 %), Ostracode valves, Echini spines, Coccoliths, Rhabdoliths.

* See anal. 31, 32; Pl. XV. figs. 1*a*, 1*b*.   † See Pl. XII. fig. 4.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
77·53	(50·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, numerous Diatoms.	(15·00 %), m. di. 0·10 mm., angular; quartz sometimes coloured red, monoclinic and triclinic felspars, mica, hornblende, tourmaline, garnet, magnetite, zircon, glassy volcanic particles, glauconite.	(12·53 %), a little amorphous matter, a few mineral particles, but principally fragments of Diatoms.	The trawl came up fouled, but contained a few animals and pebbles, the latter varying in diameter from 5 mm. to 1 cm.; one of the pebbles is a granitite, containing quartz, plagioclase, orthoclase, hornblende, black or green mica; another is a fine-grained chloritic sandstone with felspar. The minerals, as well as the rock fragments obtained at this station, appear to indicate that they come from rocks belonging to older formations.	In Vicinity of Antarctic Ice.
96·50	(15·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(20·00 %), m. di. 0·10 mm., angular; quartz, felspar, plagioclase, hornblende, glauconite, garnet.	(61·50 %), amorphous matter, minute fragments of minerals and Diatoms.	The dredge brought up many rocks and pebbles, to which an Ascidian and an Actinian were attached, and a few animals. The quartz grains are sometimes rounded and covered with limonite. Among the pebbles are granitic rocks, containing orthoclase, plagioclase, quartz, and black mica; amphibolite with large grains of green hornblende and quartz; metamorphic quartzite speckled with black mica; fine grained micaceous sandstone passing to a schist; and red sandstone.	
99·00	(3·00 %), Radiolaria, Sponge spicules, Diatoms.	(20·00 %), m. di. 0·10 mm., angular; quartz, felspar, hornblende, mica, epidote, garnet, glauconite.	(76·00 %), amorphous matter, fine mineral particles and Diatom remains.	Some particles of minerals attain a diameter of 1 or 2 mm.	
88·16	(3·00 %), Radiolaria, Sponge spicules, Lituolidæ, Diatoms.	(20·00 %), m. di. 0·30 mm., angular; quartz, plagioclase, hornblende, augite, magnetite, mica, garnet, tourmaline, glauconite, fragments of granitic and amphibolic rocks.	(65·16 %), amorphous matter, minute mineral particles, fragments of Radiolaria and Diatoms.	The dredge came up without showing any signs of having been at the bottom. It had to be hauled in soon, on account of a strong wind rising, and the ship being surrounded by icebergs. Some of the fragments of granitic and amphibolic rocks attain a diameter of 2 cm.	
97·92	(60·00 %), many Radiolaria, a few Lituolidæ, chiefly Diatoms.	(10·00 %), m. di. 0·20 mm., angular and rounded; quartz, orthoclase, rarely plagioclase, hornblende, mica, magnetite, a few small glassy volcanic fragments.	(27·92 %), essentially composed of Diatom fragments, with a little amorphous matter and a few minute mineral particles.	The trawl brought up a number of animals, rocks, and pebbles. The rocks and pebbles include granite, containing orthoclase, plagioclase, quartz, hornblende, and mica; gneiss composed of quartz, black and white mica, and garnet; chloritic quartzite; fine-grained micaceous sandstone; slate formed of sericite with microliths of rutile; trachytic pumice with sanidine and augite; limburgite partially transformed into palagonite; and some other ancient and recent volcanic rocks all very much altered.	
80·71	(50·00%), many Radiolaria, some Sponge spicules, Astrorhizidæ, Lituolidæ, principally Diatoms.	(3·00 %), m. di. 0·07 mm., angular; quartz, felspar, hornblende, a few magnetic particles, small fragments of palagonite, pumice, much altered volcanic rock with ophitic structure.	(27·71 %), composed essentially of fragments of Diatoms, a small quantity of amorphous matter and minute mineral particles.	Only a small quantity of the deposit came up in the sounding tube. In the trawl there were several pebbles and one large piece of rock along with many animals. One fragment of grey gneiss weighed 20 kilogrammes, and some similar fragments had glacial markings; there was a basaltic fragment 6 cm. in diameter, and thirty pieces of pumice from 1 to 3 cm. in diameter.	Termination Land to Melbourne.
14·69	(10·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, chiefly Diatoms.	(1·00 %), m. di. 0·07 mm., angular; quartz, felspar, pumice, glassy volcanic particles.	(3·69 %), a little amorphous matter, with minute mineral particles and fragments of siliceous organisms.	The trawl brought up pumice stones, pebbles, and many animals. There were fifteen fragments of pumice, generally all rounded, and varying in diameter from 2 to 5 cm., and also one flattened angular fragment of palagonite, 3 or 4 cm. in width, and 1 cm. in thickness. Some of the quartz grains are covered with limonite.	
12·10	(2·00 %), Radiolaria, Sponge spicules, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; felspar, hornblende, magnetite, pumice, red glassy volcanic fragments, manganese grains, quartz grains (rare).	(9·10 %), amorphous matter, fine mineral particles, and fragments of siliceous organisms.	The trawl was put over, but came up without any of the deposit or any bottom-living animals to show that it had ever touched the bottom. The presence of Coccoliths and Rhabdoliths in this deposit is worthy of notice, as they have been absent in those to the south of lat. 55°. The greater abundance of Orbulinas and Pulvinulinas in the last two stations should also be remarked.	

See Charts 24, 25, and 26, and Diagrams 10 and 11.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Percent.	Foraminifera.	Other Organisms.
Termination Land to Melbourne—*continued.*	*160	1874 Mar. 13	° ′ ″ 42 42 0 S. 134 10 0 E.	2600	° 33·9	° 55·0	Red Clay, when wet chocolate coloured, reddish when dry, coherent, breaking up with difficulty in water. **Residue** reddish.	13·56	(12·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(5·56 %), Teeth of fish and some pieces of bone, Brachiopods, Ostracodes, Echinoderm fragments, Polyzoa, a few Coccoliths.
Melbourne to Sydney.	161	Apr. 1	38 22 30 S. 144 36 30 E.	33	...	63·5	Shelly Sands, mottled yellow and brown. **Residues** dark and pale brown.	82·22	(10·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(72·22 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
	162	,, 2	39 10 30 S. 146 37 0 E.	38	...	63·2				
	163	,, 4	36 57 0 S. 150 34 0 E.	2200	34·5	72·0	Globigerina Ooze, grey, plastic, green when dry, coherent, fine grained. **Residue** dark green.	61·77	(25·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(31·77 %), *Serpula*, Pteropods, Ostracodes, Echinoderm fragments, Alcyonarian spicules, Coccoliths, Coccospheres.
	163A	,, 4	36 59 0 S. 150 20 0 E.	150	...	71·0	Green Mud (?).	...	...	...
Off Sydney.	...	,, 4	Port Jackson.	2–10 6–15 7	...	...	Blue Sandy Muds, with fragments of shells, in other cases a shelly deposit with many sandy particles. **Residues** mottled brown.	42·36	(1·00 %), Globigerinidæ. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(36·36 %), *Serpula*, Brachiopods, Gasteropods, Lamellibranchs, fragments of Echinoderms, calcareous Algæ.
	163B	June 3	33 51 15 S. 151 22 15 E.	35	63·0	69·0	...	...	...	...
	163C	,, 12	33 55 0 S. 151 35 0 E.	85	62·2	67·5	Hard Ground, shells.	...	...	...
	163D	,, 12	33 57 30 S. 151 39 15 E.	120	...	68·0	Green Sand.	...	Globigerinidæ, *Pulvinulina.* Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	Gasteropods, Pteropods, fragments of Echinoderms.
	163E	,, 12	34 0 15 S. 151 44 15 E.	290	...	70·2	Green Sand.	...	...	...
	163F	,, 12	34 3 15 S. 151 51 30 E.	650	40·8	70·2	Green Mud, green, coherent, granular, earthy. **Residue** dark green.	47·32	(35·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(10·32 %), Otoliths of fish, fragments of Gasteropods, Lamellibranch shells, Echinoderm fragments, Coccoliths, Coccospheres, Rhabdoliths.

* See anal. 12, 99, 100, 101; Pl. II. figs. 3, 3*a*, 3*b*; Pl. VIII. figs. 10, 11; Pl. XVI. fig. 2; Pl. XVII. fig. 3; Pl. XXVIII. figs. 1, 2, 4, 5.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
81·44	(1·00 %), a few Radiolaria, Astrorhizidæ, Lituolidæ, one or two Diatoms.	(1·00 %), m. di. 0·08 mm., angular and rounded; felspar, quartz, black mica, augite, magnetite, pumice, many fragments of volcanic glass, magnetic spherules, manganese grains; there is a large number of minute fragments of quartz covered with limonite, apparently windborne from Australia.	(79·44 %), amorphous matter, minute particles of minerals, fragments of volcanic glass.	The sounding tube brought up about half a litre of the deposit. The trawl came up with the netting much torn, but in the bag there were a large quantity of red or chocolate clay, many manganese nodules and animals. The nuclei of the nodules are in some cases fragments of felspathic basalt, black and opaque; in others they are pieces of basalt-glass coated with a palagonitic reddish or yellowish zone of decomposition. The upper layers of the deposit from the sounding tube contained apparently many more Foraminifera than the lower. The clay mixed up with the nodules, most probably came from the surface layers on account of the large quantity of carbonate of lime as found by the analysis of a sample taken from the trawl.	Termination Land to Melbourne—*continued.*
17·78	(3·00 %), a few fragments of Sponge spicules, casts.	(5·00 %), m. di. 0·70 mm., rounded; quartz, mica, monoclinic and triclinic felspars, augite, hornblende, magnetite.	(9·78 %), a small quantity of amorphous matter, much brown flocculent organic matter, a few minute mineral particles, and fragments of Sponge spicules.	The major part of these deposits is made up of fragments of Polyzoa with fewer of the other organisms mentioned, the majority of the fragments being a little more than 5 mm. in diameter. There were a few greenish casts of the carbonate of lime shells.	Melbourne to Sydney.
38·23	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ, Diatoms.	(5·00 %), m. di. 0·12 mm., angular and rounded; quartz, felspar, volcanic glass, hornblende, magnetite.	(32·23 %), amorphous matter, minute fragments of minerals and siliceous organisms.	Only a small quantity of the deposit came up in the sounding tube.	
...	...	...	...	...	
57·64	(1·00 %), Lituolidæ, a few Diatoms.	(50·00 %), m. di. 0·80 mm., rounded; quartz, felspar, fragments of mica-schist, hornblende, magnetite, augite, olivine.	(6·64 %), a small quantity of amorphous matter, minute mineral fragments and coal dust, some flocculent organic matter.	The carbonate of lime in these deposits is chiefly composed of the fragments of Molluscan shells. The mineral particles consist chiefly of rounded fragments of quartz and particles of felspar.	Off Sydney.
...	...	...	...	...	
...	...	...	...	A small piece of shell was all that came up in the sounding tube.	
...	Sponge spicules, glauconitic casts of Foraminifera.	Quartz, felspar, glauconite.	...	A small quantity of mud came up on the grease of the sounding tube, and gave the organisms mentioned, but there was insufficient for analysis.	
...	...	...	...	A small quantity came up attached to the grease of the sounding tube, much the same as that obtained at the last station, but it contained more Foraminifera and many more glauconitic casts and glauconite particles of a dark green colour. There was insufficient for analysis.	
52·68	(5·00 %), Sponge spicules, one or two Radiolaria, pale casts of Foraminifera, Astrorhizidæ, Lituolidæ, Diatoms.	(25·00 %), m. di. 0·12 mm., angular and rounded; quartz, felspar, mica, hornblende, magnetite, augite, glauconite.	(22·68 %), fine mineral particles, with fragments of siliceous organisms and amorphous matter.	The pelagic Foraminifera are very abundant in this deposit, a great many of them being filled with pale yellow and green glauconite. Some of the Foraminifera are macroscopic.	

See Charts 26 and 27, and Diagram 11.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
		1874	° ′ ″		°	°				
Off Sydney—*continued.*	164	June 12	34 8 0 S. 152 0 0 E.	950	36·5	69·5	GREEN MUD, grey-green when wet, coherent, granular, earthy. **Residue green.**	48·15	(35·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(11·15 %), Otoliths of fish, fragments of Lamellibranch shells, Ostracodes, Echinoderm fragments, Coccoliths, Coccospheres, Rhabdoliths.
	164A	" 13	34 9 0 S. 151 55 0 E.	1200	...	70·2	GREEN MUD, grey-green, granular, slightly coherent. **Residue green.**	46·59	(35·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(9·59 %), fragments of Pteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	*164B	" 13	34 13 0 S. 151 38 0 E.	410	...	69·0	GREEN MUD, green when wet, greenish grey when dry, pulverulent. **Residue green.**	50·31	(35·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(10·31 %), Otoliths of fish, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Corals, Coccoliths, Rhabdoliths.
Sydney to New Zealand.	165	" 17	34 50 0 S. 155 28 0 E.	2600	34·5	64·5	RED CLAY, plastic, homogeneous, drying into hard lumps, lustrous streak, breaking up with difficulty in water. **Residue red-brown.**	6·54	(2·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), *Miliolina*, Lagenidæ, Rotalidæ, Nummulinidæ.	(1·54 %), Teeth of fish, Echini spines, Coccoliths.
	†165A	" 19	36 41 0 S. 158 29 0 E.	2600	34·4	62·5	RED CLAY, homogeneous, plastic, drying into lumps, which break up with difficulty in water, lustrous streak. **Residue red.**	19·13	(10·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(6·13 %), a few small teeth of fish, Ostracodes, Echini spines, fragments of Polyzoa, Coccoliths, a few Rhabdoliths.
	165B	" 21	37 53 0 S. 163 18 0 E.	1975	34·7	59·5	GLOBIGERINA OOZE, white with rose tinge, slightly coherent, chalky. **Residue grey-white.**	76·59	(65·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(10·59 %), Otoliths of fish, Echini spines, Coccoliths, Coccospheres, Rhabdoliths.
	165C	" 22	38 36 0 S. 166 36 0 E.	1100	36·4	58·2	GLOBIGERINA OOZE, white, fine grained, giving an almost impalpable powder, very slightly coherent, chalky. **Residue red-brown.**	84·89	(75·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·89 %), Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	‡166	" 23	38 50 0 S. 169 20 0 E.	275	50·8	58·5	GLOBIGERINA OOZE.	88·45	Miliolidæ, Textularidæ, Lagenidæ, Globigerinidæ, Rotalidæ.	Fragments of Pteropods, Gasteropods, and Lamellibranchs, Ostracodes, Echinoderm fragments, Coccoliths, Coccospheres, Rhabdoliths.
	166B	" 23	39 8 0 S. 170 43 0 E.	400	...	58·5	} GLOBIGERINA OOZES, dirty white, granular, very slightly coherent, soiling the fingers. **Residues dirty white.**	82·20	(50·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(27·20 %), fragments of Gasteropods and Lamellibranchs, Ostracodes, Echini spines, Coccoliths, Coccospheres, Rhabdoliths.
	166C	" 24	39 21 0 S. 171 28 0 E.	400	...	58·0				

* See anal. 67, 84, 85, 86, 87; Pl. XXIV. fig. 2; Pl. XXV. fig. 1. † See Pl. XXVI. fig. 3. ‡ See Pl. XI. fig. 3.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
51·85	(2·00 %), Sponge spicules, one or two Radiolaria, pale casts of Foraminifera, Astrorhizidæ.	(10·00 %), m. di. 0·12 mm., angular and rounded; quartz, felspar, hornblende, augite, magnetite, volcanic glass, glauconite.	(39·85 %), amorphous matter, with minute fragments of minerals and siliceous organisms.	This deposit is much like that obtained at Station 163 F, but there is considerably more amorphous clayey matter.	Off Sydney—*continued.*
53·41	(2·00 %), Sponge spicules, a few Radiolaria, casts of Foraminifera, Astrorhizidæ.	(10·00 %), m. di. 0·12 mm., angular; quartz, monoclinic and triclinic felspars, augite, hornblende, mica, glassy volcanic fragments, magnetite, epidote, glauconite.	(41·41 %), fine greenish coloured amorphous matter, fragments of minerals, Radiolaria, and Diatoms.	This deposit, except for the glauconite and other mineral particles, might be called a Globigerina Ooze.	
49·69	(15·00 %), Radiolaria, many casts of Foraminifera and other organisms, Astrorhizidæ, Lituolidæ, Diatoms.	(25·00 %), m. di. 0·15 mm., angular; quartz, felspar, plagioclase, glauconite, hornblende, augite, white or green mica, epidote, tourmaline, glassy volcanic fragments, magnetite.	(9·69 %), amorphous matter and fine mineral particles, with a green-brown substance often cementing the particles together.	The trawl brought up a quantity of mud, some pumice, pebbles, and animals. Six pieces of pumice are rounded, and a rounded fine-grained fragment of sandstone is 2 cm. in diameter. Glauconitic particles are numerous.	
93·46	(1·00 %), a few Sponge spicules, Radiolaria, Lituolidæ.	(20·00 %), m. di. 0·10 mm., angular; quartz, felspar, hornblende, mica, magnetite, glassy volcanic fragments, pumice, grains of manganese.	(72·46 %), amorphous matter, with minute mineral particles and some siliceous fragments.	This deposit contains a great amount of amorphous matter; the pelagic Foraminifera are chiefly in a fragmentary condition.	Sydney to New Zealand.
80·87	(1·00 %), Radiolaria, a few Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·08 mm., angular; quartz, felspar, hornblende, mica, glassy volcanic fragments, magnetite, manganese grains, zircon, glauconite.	(78·87 %), amorphous matter, with many minute fragments of minerals and some fragments of siliceous organisms.	Among the minerals there are many small rounded particles of quartz the same as at Station 160, probably wind-borne. Most of the pelagic Foraminifera are fragmentary, as at Station 165.	
23·41	(1·00 %), Radiolaria, Sponge spicules, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; fragments of pumice, felspar, magnetite, augite.	(21·41 %), amorphous matter, with minute fragments of minerals, Radiolaria, and Diatoms.	This deposit contains a considerable quantity of fine amorphous calcareous matter, and relatively little clayey matter. Note the increase of carbonate of lime with decreasing depth.	
15·11	(1·00 %), Radiolaria, Lituolidæ, one or two imperfect white casts of Foraminifera, a few Diatoms.	(1·00 %), m. di. 0·06 mm., angular; pumice, augite, felspar, plagioclase, green mica, magnetite, quartz.	(13·11 %), amorphous matter and small fragments of minerals and siliceous organisms.	The quartz particles are few in number, small, rounded, and wind-borne. The volcanic mineral particles have often a vitreous coating. The small lapilli are basaltic, much altered, and filled with delessite; some are vesicular, others quite massive.	
11·55	Lituolidæ.	...	...	A small quantity of the deposit which came up in the sounding tube indicated a Globigerina Ooze, and contained the organisms mentioned. The trawl brought up a small quantity of the deposit, with the finer parts washed away, from which the analysis was made.	
17·80	(3·00 %), white and pale green casts of the Foraminifera, Lituolidæ, a few Radiolaria, one or two Diatoms.	(1·00 %), m. di. 0·12 mm., angular; pumice, felspar, plagioclase, augite, magnetite, glauconite, quartz, garnet, manganese grains.	(13·80 %), amorphous matter and small fragments of minerals and siliceous organisms.	These deposits are somewhat remarkable for the large number of Coccoliths and Coccospheres they contain. The average diameter of the Coccoliths is 0·015 mm., and that of the Coccospheres 0·025 mm. We estimate that these organisms and their broken parts make up from 15 to 20 per cent. of the deposit. The shallow depth and relative absence of land debris probably account in some measure for the abundance of these organisms in this place. Although the white and pale green casts of Foraminifera are numerous, true glauconitic particles are exceedingly rare.	

See Charts 27 and 28, and Diagrams 11 and 12.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Sydney to New Zealand—*continued.*	167	1874 June 24	° ′ ″ 30 32 0 S. 171 48 0 E.	145–150	° ...	° 58·5	Blue Mud, coherent, earthy, homogeneous, finely granular, marly, drying into light grey lumps with sublustrous streak. **Residue** blue-green.	26·71	(10·00 %), Globigerinidæ, *Pulvinulina.* (10·00%), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(6·71 %), Otoliths of fish, Lamellibranchs, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	...	„ 25	Off D'Urville Island.	32–52	...	...	Blue Muds, sandy, slightly coherent, granular, the sandy particles becoming more numerous and coarser in the shallower depths near to the shore. **Residue** green-grey.	8·71	(1·00 %), Globigerinidæ. (4·00 %), Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(3·71 %), fragments of Lamellibranch shells, Echini spines, Coccoliths.
Off New Zealand.	168	July 8	40 28 0 S. 177 43 0 E.	1100	37·2	57·2	Blue Mud, green-blue when wet, grey-blue when dry, fine grained, coherent, breaking up with difficulty in water, sublustrous streak. **Residue** blue.	10·71	(5·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(3·71 %), Otoliths and vertebræ of fish, worm tubes, Gasteropods, Lamellibranchs, Pteropods, Echinoderm fragments.
	169	„ 10	37 34 0 S. 179 22 0 E.	700	40·0	58·2	Blue Mud, blue-grey when dry, slightly coherent, fine grained, earthy, sublustrous streak. **Residue** blue.	4·36	(1·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(1·36 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths (rare).
New Zealand to Tongatabu.	170	„ 14	29 55 0 S. 178 14 0 W.	520	43·0	65·0	Volcanic Muds.	...	...	...
	171	„ 15	28 33 0 S. 177 50 0 W.	600	39·5	66·5	(Volcanic Muds.)			
	171A	„ 17	25 5 0 S. 172 56 0 W.	2900	34·3	72·0	Red Clay, plastic when wet, light brown when dry, earthy fracture, breaking up with difficulty in water, sublustrous streak.	...	...	...
Off Tongatabu.	*172	„ 22	20 58 0 S. 175 9 0 W.	18	...	75·0	Coral Sand, white with red coloured fragments. **Residue** red.	90·70	(5·00 %), Globigerinidæ, *Pulvinulina.* (40·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(45·70 %) Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Corals, Polyzoa, calcareous Algæ.

* See anal. 71; Pl. XIV. fig. 2.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
73·29	(1·00 %), a few small fragments of Sponge spicules, Astrorhizidæ, Lituolidæ, a few pale and dark green casts.	(2·00 %), m. di. 0·08 mm., angular and rounded; felspar, quartz, augite, magnetite, olivine, mica, many grains of glauconite.	(70·29 %), amorphous matter, with many minute mineral particles.	This deposit contains a great many glauconite grains, which are mostly irregular in form, but would appear to have been at one time perfect casts of Foraminifera and other organisms. In some cases the transition can be traced by microscopic examination.	Sydney to New Zealand.—*continued.*
91·29	(2·00 %), a few fragments of Sponge spicules and Diatoms.	(60·00 %), m. di. 0·15 mm., angular and rounded; quartz, mica, magnetite, felspar, augite, many fragments of clastic rocks.	(29·29 %), amorphous matter, many fine mineral particles, and a few fragments of siliceous organisms.	A few of the mineral particles measure 1 or 2 mm., and several rounded pebbles 2 to 4 cm. in diameter.	
89·29	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(2·00 %), m. di. 0·10 mm., angular; monoclinic and triclinic felspars, quartz, augite, hornblende, magnetite, olivine, very many small fragments of pumice and volcanic glass.	(86·29 %), amorphous matter, many minute fragments of minerals and siliceous organisms.	The bag of the trawl was nearly filled with a brownish mud, in which were many large lumps of stiff blue clay, and several pumice stones more or less rounded and of the light coloured fibrous variety. The beam of the trawl had many lumps of stiff blue clay attached to it. There was a thin watery red coloured layer in which the calcareous organisms appeared to be more abundant than in the stiff blue layers beneath. Many of the bottom-living Foraminifera are macroscopic. The fragments of pumice and volcanic glass have sometimes a diameter of 1 mm., some felspar and quartz fragments also attain nearly the same size.	Off New Zealand.
95·64	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Sponge spicules, a few Diatoms.	(25·00 %), m. di. 0·10 mm., angular, but some rounded; quartz, felspar, plagioclase, green mica, hornblende, glauconite, pumice, magnetite.	(69·64 %), amorphous matter, many minute fragments of minerals, a few siliceous fragments.	The trawl brought up a large quantity of the mud, some pumice stones and animals. The surface layer was red and not so compact as the stiff blue layer beneath. The washings of the mud were chiefly made up of arenaceous Foraminifera, many of which were macroscopic.	New Zealand to Tongatabu.
...	...	...	...	Only a small quantity of these deposits was obtained in the sounding tube. In the trawl there were several large pieces of pumice.	
100·00	(1·00 %), Radiolaria and one or two Diatoms.	(5·00 %), m. di. 0·07 mm., angular; plagioclase, magnetite, hornblende, quartz, pumice, red glassy particles, fragments of basaltic rocks, manganese grains.	(94·00 %), amorphous matter, small fragments of minerals and siliceous organisms.	There were several pieces of pumice stone in the clay brought up by the sounding tube, one of which was 1 cm. in diameter. Before the blow-pipe the deposit fuses into a grey magnetic bead. No effervescence is observed when treated with acids. The fine washings are chiefly composed of minute fragments of pumice.	
9·30	(1·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ.	(3·00 %), m. di. 0·50 mm., angular; monoclinic and triclinic felspars, augite, hornblende, magnetite, pumice, glassy volcanic fragments, lapilli of basaltic and trachytic rocks, red-brown granules.	(5·30 %), a small quantity of amorphous matter, associated with flocculent organic matter derived from the Foraminifera, Algæ, &c.	The dredge brought up a large quantity of the Coral Sand with some large fragments of Corals, many *Orbitolites*, shells, &c. The diameter of some of the particles making up the sand exceeded 1 cm. The mineral particles are remarkable for the perfection of their crystallographic form; the felspar often has the form of rhombic tables.	Off Tongatabu.

See Charts 27, 28, 29, and 30, and Diagrams 12 and 13.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Off Tongatabu—*continued.*	*172A	1874 July 22	° ′ ″ 20 56 0 S. 175 11 0 W.	240	° ...	° 75·0	CORAL SAND, yellow-grey, slightly coherent when dry, fine grained. **Residue** light yellow-brown.	86·44	(25·00 %), Globigerinidæ, *Pulvinulina.* (35·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(26·44 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Echinoderm fragments, Polyzoa, Coral fragments, Alcyonarian spicules, calcareous Algæ, a few Coccoliths.
Off Fiji Islands.	173	„ 24	19 9 35 S. 179 41 50 E.	315	...	76·0	CORAL MUDS.	...	...	...
	173A	„ 24	19 9 32 S. 179 41 55 E.	310	...	77·0	CORAL MUDS.			
		„ 29	Off Levuka.	12	...	...	CORAL SAND, coarse, chiefly composed of large white and yellow *Orbitolites* and other Foraminifera. **Residue** yellow-brown.	90·30	(50·00 %), Miliolidæ, Textularidæ, Nummulinidæ.	(40·30 %), *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, carapace and other parts of Crustaceans, fragments of Echinoderms, Alcyonarian spicules, Polyzoa, Corals, calcareous Algæ.
	174	Aug. 3	19 6 0 S. 178 14 20 E.	140	...	77·0	CORAL MUD, cream-white with rose tinge, slightly coherent, fine grained, presenting no macroscopic elements. **Residue** yellow-brown.	86·41	(25·00 %), Globigerinidæ, *Pulvinulina.* (35·00 %), Miliolidæ, Textularidæ, Lagenidæ.	(26·41 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coral fragments, calcareous Algæ, a few Coccoliths.
	174A	„ 3	19 6 32 S. 178 16 20 E.	160	...	77·0	CORAL MUD.	...	...	...
	174B	„ 3	19 6 45 S. 178 17 0 E.	255	...	77·7	CORAL MUD, cream-white with rose tinge, slightly coherent, fine grained, presenting no macroscopic elements. **Residue** yellow-brown.	86·31	(25·00 %), Globigerinidæ, *Pulvinulina.* (35·00%), Miliolidæ, Textularidæ, Lagenidæ.	(26·31 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coral fragments, calcareous Algæ, a few Coccoliths.
	†174C	„ 3	19 7 50 S. 178 19 35 E.	610	39·0	78·0	GLOBIGERINA OOZE, with rosy tinge, fine grained, plastic when wet, pulverulent when dry. **Residue** light brown.	79·65	(40·00 %), Globigerinidæ, *Pulvinulina.* (10·00%), Miliolidæ, Textularidæ.	(29·65 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Echini spines, fragments of Corals, Coccoliths, Rhabdoliths.
	174D	„ 3	19 5 50 S. 178 16 20 E.	210	...	77·7	CORAL MUD, cream coloured, slightly coherent, fine grained. **Residue** brown.	86·97	(10·00 %) Globigerinidæ, *Pulvinulina.* (40·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(36·97 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coral fragments, Alcyonarian spicules, calcareous Algæ, Coccoliths.
Fiji Islands to New Hebrides.	‡175	„ 12	19 2 0 S. 177 10 0 E.	1350	36·0	77·5	GLOBIGERINA OOZE, with much clayey matter, red when wet, red-brown when dry, coherent, earthy. **Residue** chocolate coloured.	44·43	(35·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(7·43 %), Otoliths and small teeth of fish, Ostracode shells, Echini spines, Coccoliths, Rhabdoliths. It is remarkable that no shells of Pteropods, Heteropods, or other pelagic Molluscs, are found in this deposit, although they were apparently more abundant than the Globigerinidæ in the surface water.

* See Pl. XIV. fig. 1. † See Pl. XIV. figs. 3*a*, 3*b*. ‡ See Pl. XIV. figs. 4*a*, 4*b*.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
13·56	(2·00 %), Sponge spicules, Lituolidæ.	(3·00 %), m. di. 0·40 mm., angular; felspar, plagioclase, augite, magnetite, fragments of brown and black volcanic glass.	(8·56 %), a small quantity of fine amorphous matter and minute fragments of minerals and siliceous organisms.	Here also the mineral particles are remarkable for the perfection of their crystallographic form.	Off Tongatabu—*continued.*
...	...	...	...	There was insufficient for subsequent examination.	Off Fiji Islands.
9·70	(1·00 %), Sponge spicules, Lituolidæ.	(3·00 %), m. di. 0·50 mm., angular; felspar, plagioclase, augite, magnetite, fragments of volcanic rocks.	(5·70 %), amorphous clayey and other matter (organic), minute mineral particles, and some fine siliceous remains.	This deposit is composed of very large shells of *Orbitolites complanata*, with fragments of Molluscs, Corals, &c.	Off Fiji Islands.
13·59	(2·00 %). Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; fragments of altered volcanic glass, felspar, hornblende, augite, magnetite, black mica.	(10·59 %), small quantity of amorphous matter, with a considerable number of fragments of siliceous organisms.	The Sponge spicules are derived chiefly from the genus *Geodia*.	Off Fiji Islands.
...	...	...	...	There was insufficient for examination.	Off Fiji Islands.
13·69	(2·00 %), Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; fragments of altered volcanic glass, pumice, plagioclase, olivine, hornblende, black mica, augite, magnetite.	(10·69 %), amorphous matter, with a few mineral fragments and remains of siliceous organisms.	...	Off Fiji Islands.
20·35	(3·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, Lituolidæ, brown casts.	(2·00 %), m. di. 0·08 mm., angular; hornblende, felspar, magnetite, black mica, white and black glassy volcanic particles.	(15·35 %), amorphous matter, minute mineral particles, and small fragments of siliceous organisms.	A few imperfect brown coloured casts of some of the calcareous organisms were observed. There are large pieces of pumice present in the deposit. The percentage of particles from the reefs is much less than in the other soundings nearer the reefs.	Off Fiji Islands.
13·03	(2·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·08 mm., angular; felspar, plagioclase, hornblende, magnetite, pumice.	(10·03 %), flocculent amorphous matter, minute fragments of minerals and siliceous spicules.	In the dredge there were several pieces of grey pumice stone overgrown with *Carpenteria* and *Serpula*. One of these pieces of pumice was as large as a hen's egg.	Off Fiji Islands.
55·57	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; felspar, plagioclase, black mica, augite, hornblende, magnetite, many fragments of pumice, glassy volcanic particles, lapilli of basaltic rocks, manganese.	(53·57 %), amorphous matter, with small fragments of minerals and siliceous organisms.	The trawl brought up a branch of a tree which was in parts carbonised, also many fragments of pumice and some animals; most of the animals were found on the piece of wood. The felspar and augite have sometimes vitreous inclusions and are covered with glassy scoriaceous matter. The pumice stones are all more or less rounded and vary much in size, the largest being 6 to 8 cm. in diameter, and are all covered with a layer of hydroxides of iron and manganese which penetrate them more or less deeply. The pumice is to be referred to augite-andesite; it contains plagioclase and augite.	Fiji Islands to New Hebrides.

See Chart 27, and Diagram 18.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Fiji Islands to New Hebrides—*continued.*	*176	1874 Aug. 15	18° 30′ 0″ S. 173 52 0 E.	1450	36°·2	77°·5	GLOBIGERINA OOZE, reddish when wet, red-brown when dry, slightly coherent, breaking up in water. **Residue** chocolate coloured.	62·41	(55·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(6·41 %), Otoliths of fish, Ostracode valves, Echini spines, Coccoliths, Rhabdoliths.
New Hebrides to Raine Island.	177	,, 18	16 45 0 S. 168 7 0 E.	130	...	78·7	VOLCANIC SAND, with concretionary masses of a dark brown colour, coherent, gritty. **Residue** brown, with red tinge.	13·14	(2·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·14 %), *Serpula*, Gasteropods, Pteropods, *Balanus*, Echinoderm fragments, Polyzoa, Corals, Alcyonarian spicules.
	†178	,, 19	16 47 0 S. 165 20 0 E.	2650	35·8	79·0	RED CLAY, chocolate coloured when wet, yellow-brown when dry, coherent, breaking up in water, fusing easily before the blowpipe, sublustrous streak.	...	...	...
	179	,, 21	15 58 0 S. 160 48 0 E.	2325	36·0	79·0	GLOBIGERINA OOZE, pale yellow-brown, slightly coherent, homogeneous, fine grained. **Residue** red-brown.	32·29	(27·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Biloculina*, Rotalidæ.	(4·29 %), small teeth of fish, Echini spines, Coccoliths, Rhabdoliths.
	180	,, 24	14 7 0 S. 153 43 0 E.	2450	36·0	80·0	RED CLAY, grey-brown, plastic, homogeneous, fine grained. **Residue** red-brown.	[1·00]	Fragments of Globigerinidæ and Rotalidæ.	...
	181	,, 25	13 50 0 S. 151 49 0 E.	2440	35·8	80·0	RED CLAY (*top layer*), light red-grey when dry, coherent, fine grained, lustrous streak, plastic, unctuous, brown when wet. **Residue** brown.	6·42	Mostly broken fragments of Globigerinidæ, one or two *Truncatulina pygmæa.*	...
							(*Bottom layer*), light red-grey, somewhat coherent, breaking up readily in water, brown (but lighter shade than the upper) when wet. **Residue** brown.	32·28	(28·00 %), Globigerinidæ, *Pulvinulina*, very many more perfect shells than in the upper layer; one or two *Lagena orbignyana.*	(4·28 %), Coccoliths, Rhabdoliths.
	182	,, 27	13 6 0 S. 148 37 0 E.	2275	35·8	78·5	GLOBIGERINA OOZE, yellow-grey, chalky, slightly coherent, fine grained, breaking up readily in water. **Residue** red-brown.	49·90	(40·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Bolivina dilatata*, Nummulinidæ.	(7·90 %), Pteropod fragments, Ostracodes, Echini spines, Alcyonarian spicules, Coccoliths, Rhabdoliths.

* See anal. 44, 56; Pl. XI. fig. 1; Pl. XXIV. fig. 4. † See Pl. XXVII. fig. 2.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
37·59	(10·00 %), a few Radiolaria, principally red coloured casts of pelagic Foraminifera, Lituolidæ, a few Diatoms.	(10·00 %), m. di. 0·10 mm., angular; felspar, augite, olivine, many fragments of pumice, lapilli, volcanic glass transformed into palagonite, manganese grains.	(17·59 %), minute pumice and other mineral fragments, amorphous matter, and remains of siliceous organisms.	The Foraminifera of this sounding are worthy of notice, as while some of them are quite white and rose coloured, others are deep brown or black and have in some cases a deposit of manganese on their surfaces. Very many of them are filled and covered with a red siliceous matter, which remains as external and internal casts on removal of the carbonate of lime. On breaking one of these shells three distinct zones are observed: internal cast, shell, and external cast.	Fiji Islands to New Hebrides—*continued.*
86·86	(3·00 %), Sponge spicules, a few glauconitic-like casts of calcareous organisms.	(65·00 %), m. di. 0·30 mm., angular; black vesicular glassy fragments, pumice, plagioclase, augite, magnetite, more or less altered lapilli.	(18·86 %), amorphous ferruginous matter, very many mineral particles, and a few fragments of siliceous spicules.	Amongst the mineral particles are fragments of rocks and pumice from 0·5 to 1 cm. in diameter. Of the mineral particles many are often surrounded with volcanic glass. Casts of some of the organisms in a green matter remain after treatment with acid. The concretions are overgrown with Corals, *Serpula*, Polyzoa, and *Carpenteria*.	New Hebrides to Raine Island.
100·00	(5·00 %), Radiolaria, Sponge spicules, a few *Ammodiscus incertus*, Diatoms.	(20·00 %), m. di. 0·06 mm., angular; felspar, plagioclase, augite, hornblende, pumice, small particles of manganese.	(75·00 %), amorphous matter, with many minute particles of pumice and other minerals, fragments of Diatoms and Sponge spicules.	This deposit does not show any sensible effervescence with acids and no carbonate of lime organisms have been observed. There are many fragments of pumice, some of which are dark coloured. It would appear that this deposit has its origin chiefly from volcanic debris.	
67·71	(2·00 %), Radiolaria and Sponge spicules.	(5·00 %), m. di. 0·06 mm., angular; plagioclase, augite, magnetite, pumice, brown glassy vesicular lapilli.	(60·71 %), much amorphous matter, many minute mineral particles, pumice debris, and fragments of siliceous organisms.	The larger Foraminifera are much broken and decomposed. Many small fragments of pumice, much decomposed, were observed among the minerals.	
[99·00]	(1·00 %), Sponge spicules, fragments of Radiolaria, *Haplophragmium*, a few Diatoms.	(2·00 %), m. di. 0·06 mm., angular; felspar, plagioclase, augite, hornblende, pumice, volcanic glass, magnetite.	(96·00 %), amorphous matter, minute mineral particles, and fine fragments of siliceous spicules.	*Truncatulina pygmæa* is the only perfect representative of the bottom-living calcareous Foraminifera observed; the pelagic Foraminifera are nearly all fragmentary. At the bottom part of the sounding tube there appeared to be a stratification, evidenced by very thin dark and light coloured layers.	
93·58	(1·00 %), a few fragments of Sponge spicules, Lituolidæ, casts of Foraminifera.	(1·00 %), m. di. 0·07 mm., angular; felspar, volcanic glass, manganese grains.	(91·58 %), much amorphous matter, mineral and siliceous remains.	The sounding tube was full of mud in two layers, the upper layer, about three inches deep, being a Red Clay very like that obtained at the last station. Very little effervescence was noticed on treating a portion with acid.	
67·72	(1·00 %), fragments of Sponge spicules, a few casts.	(1·00 %), m. di. 0·06 mm., angular; felspar, plagioclase, augite, magnetite, palagonite, glassy volcanic particles, manganese grains.	(65·72 %), much brown amorphous matter and fine mineral particles.	Separated from the upper layer by a distinct line was a lighter coloured deposit which effervesced readily with acids, leaving a residue similar to the upper layer. The minerals are the same in each layer. Coccoliths and Rhabdoliths are present, but only a few are perfect. The Globigerinidæ are chiefly fragmentary. A piece of pumice about 3 mm. in diameter was observed. In the trawl were many pieces of pumice from the size of a pea to that of a hen's egg.	
50·10	(2·00 %), Sponge spicules, a few Radiolaria, *Rhabdammina*, *Haplophragmium*.	(2·00 %), m. di. 0·07 mm., angular; felspar, plagioclase, quartz, augite, magnetite.	(46·10 %), amorphous matter, fine mineral particles, and minute siliceous remains.	Very little of the deposit was obtained, and considerable washing may have taken place in the sounding tube. A relatively large number of calcareous spicules of Alcyonaria are present. The pelagic Foraminifera are nearly all fragmentary.	

See Charts 27 and 31, and Diagram 13.

Region	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
New Hebrides to Raine Island—*continued.*	183	1874 Aug. 28	° ′ ″ 12 42 0 S. 146 46 0 E.	1700	° 36·0	° 78·0	GLOBIGERINA OOZE, cream-coloured with rose tinge, slightly coherent, fine grained, breaking up readily in water. **Residue** red-brown.	53·75	(50·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Biloculina*, Textularidæ, Lagenidæ, Rotalidæ.	(2·75 %), Ostracodes, Echini spines, a few Coccoliths and Rhabdoliths.
	*184	,, 29	12 8 0 S. 145 10 0 E.	1400	36·0	77·5	GLOBIGERINA OOZE, yellowish when dry, coherent, breaking up readily in water. **Residue** reddish.	52·64	(40·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(10·64 %), *Serpula*, fragments of Lamellibranchs, Brachiopods, Cirripeds, Echini spines, Coccoliths, Rhabdoliths.
Off Raine Island.	185	,, 31	11 35 25 S. 144 2 0 E.	135	...	77·0	CORAL SANDS, composed of white and brownish fragments of calcareous organisms. **Residue** yellow-red.	86·97	(40·00 %), Globigerinidæ, *Pulvinulina.* (15·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(31·97 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, calcareous Algæ.
	185A	,, 31	11 36 20 S. 144 1 50 E.	150	...	77·0				
	†185B	,, 31	11 38 15 S. 143 59 38 E.	155	...	77·0				
	...,	...	Beach, Raine Island.	...	...	...	CORAL SAND, yellow-white. **Residue** a few dark mineral particles and some red amorphous material.	89·14	(35·00 %), Miliolidæ, Rotalidæ, Nummulinidæ.	(54·14 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Alcyonarian spicules, Polyzoa, Corals, calcareous Algæ.
Cape York to Arrou Islands.	...	Sept. 7	Torres Strait.	3–11	...	...	DEPOSIT composed of coarse sand, shells, and gravel. **Residue** white, red, and black particles.	62·15	(15·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(47·15 %), *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Ostracodes, *Balanus*, Echinoderm fragments, Alcyonarian spicules, Polyzoa, Corals, calcareous Algæ, calcareous concretions.
	186	,, 8	10 30 0 S. 142 18 0 E.	8	...	77·2	DEPOSIT composed of coarse sand, shells, and gravel. **Residue** yellow-brown.	59·66	(20·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(39·66 %), *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs, Ostracodes, *Balanus*, Echinoderm fragments, Alcyonarian spicules, Corals, Polyzoa, calcareous Algæ.

* See anal. 79. † See anal. 88; Pl. XXIV. fig. 3.

	Residue.			Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
46·25	(2·00 %). Sponge spicules, *Ammodiscus incertus*, a few brown casts.	(2·00 %), m. di. 0·06 mm., angular; felspar, plagioclase, augite, mica, hornblende, magnetite, volcanic glass splinters, pumice, glauconite.	(42·25 %), a considerable quantity of fine clayey and other matter, coloured red by iron, minute mineral particles, and remains of siliceous organisms.	There was a large quantity of this deposit, of a uniform character throughout, in the sounding tube. The Foraminifera are large and very perfect and include a few *Textularia* and *Rotalia*, as well as *Pulvinulina favus*. All the pelagic forms are typical of a tropical Globigerina Ooze. The volcanic glass in some cases has been highly altered.	New Hebrides to Raine Island—*continued*.
47·36	(2·00 %), Radiolaria, casts of Foraminifera in manganese and iron, Sponge spicules, Astrorhizidæ, Lituolidæ, a few Diatoms.	(2·00 %), m. di. 0·06 mm., angular; felspar, quartz, mica, hornblende, augite, magnetite, fragments of pumice.	(43·36 %), amorphous matter, with many small fragments of minerals and siliceous organisms.	In the trawl there were many pumice stones, several cocoa-nuts, and other fruits. To these were attached Hydroids, Brachiopods, Annelids, and Cirripeds. Some of the largest pumice stones have a diameter of about 5 cm., all more or less rounded, some porous, some homogeneous, some filamentous, some scoriaceous; others have a greenish tinge, with a thin coating of manganese, and are rather hard, but not so much altered as those at Station 175.	
13·03	(6·00 %), many casts of Foraminifera of a reddish colour, Astrorhizidæ, Lituolidæ.	(4·00 %), m. di. 0·07 mm., angular and rounded; quartz, felspar, mica, magnetite, augite, glauconite, olivine.	(3·03 %), flocculent amorphous matter, some fine mineral particles.	This deposit contains very many casts of Foraminifera which are nearly all of a brick-red colour although a few have a greenish tinge; there was, however, no typical glauconite observed. Many of the organisms are macroscopic. The number of pelagic forms varies greatly in different samples.	Off Raine Island.
10·86	(1·00 %), Sponge spicules, a few brown casts of calcareous organisms.	(6·00 %), m. di. 0·30 mm., rounded, smallest particles angular; quartz, plagioclase, augite, hornblende, felspar, mica, tourmaline, glauconite grains, magnetite.	(3·86%), a small quantity of flocculent organic matter and fine mineral particles.	This deposit is made up for the most part of Corals, fragments of Lamellibranchs and Gasteropods, *Orbitolites*, *Amphistegina*, *Heterostegina*, and *Rotalia*. The grains making up the "sand" measure from 1 to 10 mm. in diameter.	
37·85	(2·00 %), Sponge spicules, Lituolidæ.	(30·00 %), m. di. 0·50 mm., rounded; quartz, olivine, felspar, magnetite, glauconite.	(5·85 %), flocculent amorphous matter, and fine mineral particles.	A large percentage of the carbonate of lime comes from fragments of calcareous rocks and concretions. These fragments average in diameter about 1 cm. In addition there are a few conglomerated masses about 1 cm. in diameter, and quartz and other mineral particles cemented together by a reddish material. Worm tubes composed of grains of quartz are also present, and shell fragments cemented together.	Cape York to Arrou Islands.
40·34	(5·00 %), Lituolidæ, Textularidæ, Sponge spicules, casts of calcareous organisms, Diatoms.	(25·00 %), m. di. 1·00 mm., rounded, finer grains angular and often coated with limonite; chiefly quartz, some grains of milky quartz.	(10·34 %), amorphous ferruginous matter, fine minerals, and siliceous remains.	The sandy and calcareous concretions of the bottom measure from one to many centimetres in diameter, and on treatment with acid leave a considerable quantity of yellow-red residue, chiefly made up of casts of organisms. A second dredging, obtained near the first, was found to be finer but otherwise similar. Nearly all the organisms are impregnated with red oxide of iron, giving a decided colour to the deposit.	

See Charts 31 and 32, and Diagram 14.

Route	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water. (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
		1874	° ′ ″		°	°				
Cape York to Arrou Islands.—*continued.*	187	Sept. 9	10 36 0 S. 141 55 0 E.	6–8	...	77·7	Deposit composed of sand and shells. **Residue** green-brown.	77·90	(45·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(32·90 %), *Serpula*, Gasteropods, Lamellibranchs, Pteropod fragments, Echinoderm fragments, Polyzoa, calcareous Algæ.
	188	,, 10	9 59 0 S. 139 42 0 E.	28–30	...	78·5	Deposit composed of sand and shells, green-grey. **Residue** pale grey.	38·70	(15·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(23·70 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, fragments of Echinoderms, Alcyonarian spicules, Polyzoa, one or two Coccoliths.
	*189	,, 11	9 36 0 S. 137 50 0 E.	28	...	79·0	Green Mud, pale green-grey, gritty, coherent when dry, containing shell fragments and calcareous concretions. **Residue** green-grey.	31·13	(10·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(21·13 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
	190	,, 12	8 56 0 S. 136 5 0 E.	49	...	79·2	Green Mud, green-grey, coherent, breaking up with difficulty in water, containing large fragments of Lamellibranchs and large calcareous concretionary nodules. **Residue** green.	23·04	(1·00 %), *Globigerina rubra*. (3·00 %), Miliolidæ, Lagenidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(19·04 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, valves of *Balanus*, Echinoderm fragments, Polyzoa, Corals.
Arrou Islands to Banda.	...	,, 16	Arafura Sea.	65	...	...	Green Mud, green-grey, slightly coherent, breaking up in water. **Residue** dark green.	41·60	(10·00 %), Globigerinidæ, *Pulvinulina*. (10·00 %), Miliolidæ, Lagenidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(21·60 %), *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echini spines, Alcyonarian spicules, Polyzoa.
	191	,, 23	5 41 0 S. 134 4 30 E.	800	39·5	82·2	Green Mud, very plastic when wet, soft to the touch, coherent when dry. **Residue** green with brown tinge.	13·95	(8·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(3·95 %), Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, calcareous Algæ.
	191A	,, 24	5 26 0 S. 133 19 0 E.	580	40·7	81·5	Green Mud, dark grey with green tinge, coherent when dry, plastic when wet. **Residue** dark green.	40·20	(30·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(7·20 %), Otoliths of fish, Pteropods, Ostracodes, Echini spines, one or two Coccoliths.
	192	,, 26	5 49 15 S. 132 14 15 E.	140	...	82·0	Blue Mud, green-grey when dry, plastic, coherent, breaking up with difficulty in water, lustrous streak. **Residue** dark green.	8·30	(4·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(2·30 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Alcyonarian spicules.

* See Pl. XXVII. fig. 6.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
22·10	(2·00 %), Sponge spicules, Lituolidæ, Textularidæ, glauconitic casts, Diatoms.	(15·00 %), m. di. 0·50 mm., angular and rounded; quartz often covered with limonite, tourmaline, felspar, glauconite.	(5·10 %), flocculent amorphous matter, fine mineral particles, fragments of Diatoms.	Two dredgings were taken, one in 6 and another in 8 fathoms. The characters were similar in both cases, and also similar to the deposits taken on the previous day. There is less red coloured material than at the previous station, but on the other hand the glauconite is more abundant. The red material of these and the preceding stations, on treatment with acid, breaks up readily, only a few of the organisms retaining their characteristic outlines. Calcareous concretionary nodules were also observed. Quartz is the chief mineral.	Cape York to Arrou Islands—*continued.*
61·30	(3·00 %), Sponge spicules, Lituolidæ, casts of Foraminifera, Diatoms.	(45·00 %), m. di. 0·20 mm., rounded; quartz, glauconite, felspar, hornblende, fragments of rocks.	(13·30 %), ferruginous amorphous matter and small fragments of minerals.	One or two casts of the Foraminifera of a yellow colour remained after treatment with acid. Calcareous concretionary nodules about 3 cm. in diameter were observed here as in the preceding deposits.	
68·87	(3·00 %), glauconitic casts, Textularidæ, Sponge spicules, a few Diatoms.	(25·00 %), m. di. 0·20 mm., rounded; quartz, glauconite, green mica, tourmaline, zircon.	(40·87 %), amorphous green-grey and other matter, fine mineral particles, and a few siliceous remains.	In this deposit there were calcareous nodules as at Stations 186 and 187, but much smaller in size and in some cases dark in colour, due to the impregnation with black oxide of manganese. The glauconite is more abundant than in the four preceding stations.	
76·96	(2·00 %), Sponge spicules, *Hyperammina*, a few casts.	(50·00 %), m. di. 0·10 mm., angular; quartz, glauconite, large fragments of felspar.	(24·96 %), fine mineral particles, flocculent green amorphous matter.	The calcareous nodules in this deposit are about 6 inches long in some cases, and are covered with *Serpula*, Corals, Polyzoa, *Polytrema*, *Carpenteria*, and *Hyperammina*. After acid there remained a greenish red residue of imperfect casts of organisms, minerals, &c. There is much amorphous matter in this deposit, some of which is transparent, with a green tint; it shows aggregate polarisation. This matter is probably to be referred to glauconite. There are also present some small fragments of calcite.	
58·40	(2·00 %), Radiolaria, Sponge spicules, a few pale green casts of Foraminifera.	(30·00 %), m. di. 0·10 mm., rounded and angular; quartz, felspar, tourmaline, glauconite, zircon.	(26·40 %), amorphous matter, fine mineral particles, and a few fragments of siliceous organisms.	This deposit is similar to the last. There are more pelagic Foraminifera here than in the five previous deposits. No calcareous concretionary nodules were found.	Arrou Islands to Banda.
86·05	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; quartz, felspar, hornblende, glauconite, zircon.	(84·05 %), much fine green amorphous and clayey matter, with small fragments of minerals and siliceous organisms.	Among the organisms in this deposit there were worm-tubes formed of the clayey material. Fragments of wood, twigs, and seeds, were also present.	
59·80	(1·00 %), Sponge spicules, glauconitic casts.	(1·00 %), m. di. 0·06 mm., angular; quartz, felspar, glauconite, pumice.	(57·80 %), amorphous green coloured matter, fine mineral particles, and a few fragments of Sponge spicules.	There was a large quantity of mud in the sounding tube; that on the top was of a green colour tinged with brown, while at the bottom it was more clayey with a blue tinge. After treatment with acid there remained pale and dark green glauconitic grains and casts. There were some concretions of Globigerina Ooze cemented into a fine almost opaque paste of carbonate of calcium. In the concretions some of the Globigerinidæ are filled with glauconite.	
91·70	(1·00 %), a few Sponge spicules, casts of Foraminifera, Lituolidæ.	(1·00 %), m. di. 0·08 mm., angular; glauconite (irregular or spherical grains), quartz, felspar, rarely thin greenish scales of a chloritic mineral, green pyroxene.	(89·70 %), amorphous matter, a few small fragments of minerals.	Several soundings were taken, at two of which there were traces of Coral Sand on the lead. At 3.30 p.m., south of the Tionfolokker Islands, the Blue Mud described was obtained. Near the same place two hauls of the trawl were taken, and the deposit obtained was a Coral Sand with large perforated fragments of calcareous rock.	

See Charts 31 and 33, and Diagram 14.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Arrou Islands to Banda—*continued.*	*192A	1874 Sept. 26	° ′ ″ 5 49 15 S. 132 14 15 E.	129	° ...	° ...	GLOBIGERINA OOZE, hard honey-combed Globigerina rock. Residue green.	79·56	(60·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(14·56 %), *Serpula*, *Dentalium*, fragments of Gasteropods (rare) and Lamellibranchs, limbs and carapaces of Crustaceans, Pteropods, Ostracodes, Echinoderm fragments, Corals (*Caryophyllia*), Alcyonarian spicules.
	193	„ 28	5 24 0 S. 130 37 15 E.	2800	38·0	83·5	VOLCANIC MUD, blue, pulverulent, fine grained.	trace	*Pulvinulina.*	...
	194	„ 29	4 31 0 S. 129 57 30 E.	200	...	83·0	} VOLCANIC MUDS.	...	...	...
	194A	„ „	4 31 0 S. 129 57 20 E.	360	...	82·5				
	...	Oct. 1	Off Banda.	17	...	...	VOLCANIC SAND or gravel, made up of red, white, and black particles. Residue black.	52·09	(20·00 %), Miliolidæ, Rotalidæ, Nummulinidæ.	(32·09 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Echinoderm fragments, Polyzoa, Corals, calcareous Algæ.
Banda to Amboina.	195	„ 3	4 21 0 S. 129 7 0 E.	1425	38·0	82·0	BLUE MUD, blue-grey, coherent, homogeneous, fine grained, plastic when wet. Residue blue-grey.	31·36	(15·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(13·36 %), Gasteropod fragments, Lamellibranchs, Pteropods, Ostracodes, Alcyonarian spicules, Coccoliths.
	...	„ 6	Off Amboina.	15–20	...	...	Deposit composed of SHELLS and SAND, principally Gasteropod and Lamellibranch fragments, *Heterostegina complanata.* Residue dark grey.	59·26	(9·00 %), Globigerinidæ, *Pulvinulina menardii.* (25·00 %), Miliolidæ, Lagenidæ, Nummulinidæ.	(25·26 %), Otoliths of fish, *Serpula*, *Dentalium*, Gasteropods, Lamellibranchs (oyster), Pteropods, Ostracodes, *Balanus*, Echinoderm fragments, Corals (free), Polyzoa.

* See Pl. XII. fig. 2.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
20·44	(5·00 %), Sponge spicules, Textularidæ, casts of calcareous organisms.	(1·00 %), m. di. 0·10 mm., rounded; glauconite, quartz, felspar, zircon, olivine, hornblende.	(14·44 %), amorphous matter, fine mineral particles, and siliceous remains.	In the trawl were several large pieces of honeycombed rock, and many rounded more or less hardened nodules. These nodules, when examined, were found to be composed entirely of the shells of *Globigerina*, *Pulvinulina*, and *Orbulina*,—in short, a Globigerina Ooze more or less hardened. The large pieces of rock are very hard, requiring heavy strokes of a hammer to break them, and are overgrown with *Serpula*, *Carpenteria*, *Polytrema*, Sponges, Corals, Polyzoa, &c.	Arrou Islands to Banda—*continued*.
100·00	(5·00 %), Sponge spicules, Radiolaria, Diatoms.	(60·00 %), m. di. 0·20 mm., angular; felspar, plagioclase, volcanic glass, augite, magnetite, andesitic lapilli.	(35·00 %), fine amorphous matter, fine mineral particles, and siliceous remains.	Only traces of the deposit came up in the sounding tube; it had evidently been washed out. In the water-bottle, however, there was a small quantity of a red-green colour. No Foraminifera were observed in this latter, but in that obtained in the sounding tube three *Pulvinulina* shells were observed.	
...	...	...	...	Some pebbles and mineral particles came up in the tube. Mixed with these were some pelagic Foraminifera. The minerals were generally volcanic, and attached to one was a piece of coral. In the dredge were several fragments of volcanic rocks and pumice, measuring from 1 to 4 inches (25 mm. to 10 cm.) in diameter, Corals, siliceous Sponges (*Aphrocallistes*, &c.), and calcareous Algæ.	
47·91	...	(47·91 %), angular; lapilli of volcanic rocks, plagioclase, augite, hornblende, magnetite, black glassy volcanic particles, olivine.	A small quantity of fine amorphous matter.	A large proportion of the deposit is made up of calcareous Algæ encrusting nuclei of various materials, such as rock fragments, Corals, &c., and forming nodules from ¼ to 4 inches (6 mm. to 10 cm.) in diameter. The rock fragments are from 1 to 5 cm. in diameter, with a few smaller mineral particles. The volcanic minerals are very often surrounded with black volcanic glass; they may be considered as splinters or products of disintegration of a basaltic rock or as a volcanic ash.	
68·64	(3·00 %), Sponge spicules, a few Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(10·00 %), m. di. 0·10 mm., angular; magnetite, brownish vesicular volcanic glass, pumice, plagioclase, hornblende, augite.	(55·64 %), fine amorphous matter, with minute mineral particles and remains of siliceous organisms.	A large quantity of the mud came up in the sounding tube. There was a watery brown layer on the top, whereas the remainder was a compact Blue Mud; both, however, were of the same composition. In the dredge there were a number of pumice nodules, varying from ½ to 4 inches (12 mm. to 10 cm.) in diameter, slightly impregnated with manganese. To several of the smaller ones there were attached specimens of *Antipathes*. One or two twigs and seeds were also found in the dredge.	Banda to Amboina.
40·74	(2·00 %), Sponge spicules, Lituolidæ, Diatoms.	(15·00 %), m. di. 0·20 mm., angular and rounded; plagioclase, sanidine, pyroxene, magnetite, quartz, altered olivine, pumice, particles of volcanic rocks (some altered).	(23·74 %), flocculent amorphous matter, minute mineral particles, and fine siliceous remains.	Pieces of twigs and leaves were present. A piece of volcanic tufa about an inch (25 mm.) in diameter was also obtained. Small fragments of rocks 3 or 4 mm. in diameter were found among the minerals. *Heterostegina complanata*, var. *granulosa*, is largely represented.	

See Chart 31, and Diagram 14.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Amboina to Samboangan.	196	1874 Oct. 13	° ′ ″ 0 48 30 S. 126 58 30 E.	825	° 36·9	° 83·0	Hard Ground, hard conglomerate, yellow-white. Residue yellow-white.	93·70	*Miliolina*, *Orbitolites*, *Globigerina*, *Carpenteria*, *Polytrema*.	*Serpula*, fragments of Gasteropods, Lamellibranchs, Echinoderm fragments, Polyzoa, calcareous Algæ.
	197	„ 14	0 41 0 N. 126 37 0 E.	1200	35·9	82·5	Blue Mud.	...	...	...
	198	„ 20	2 55 0 N. 124 53 0 E.	2150	38·9	85·0	Volcanic Mud, red-brown, coherent, fine grained, breaking up in water, plastic and dark brown when wet.	...	...	...
	199	„ 22	5 44 0 N. 123 34 0 E.	2600	38·6	83·0	Volcanic Mud, red-brown, coherent, fine grained, breaking up in water, plastic and dark brown when wet.	...	...	...
	200	„ 23	6 47 0 N. 122 28 0 E.	250	...	85·5	Green Mud.	...	..	...
Samboangan to Manila.	201	„ 26	7 3 0 N. 121 48 0 E.	82	...	83·0	Stones, Gravel.	...	...	..
	202	„ 27	8 32 0 N. 121 55 0 E.	2550	50·5	83·0	Blue Mud, dark brown, fine grained, unctuous, plastic, homogeneous, coherent.	trace	*Globigerina bulloides*, *Textularia dilatata*.	Echini spines, a few Coccoliths.
	203	„ 31	11 6 0 N. 123 9 0 E.	20	...	85·0	Mud, Sand, and Shells.	...	...	...

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
6·30	(1·00 %), Sponge spicules.	(1·00 %), m. di. 0·08 mm., angular; felspar, pyroxene or hornblende, pumice.	(4·30 %), fine amorphous matter and a few fine mineral particles.	Nothing was obtained in the sounding tube, but in the trawl there were fragments of a hard, irregular, honeycombed conglomerate of a yellow-white colour, coated in parts with manganese and overgrown with *Serpula*, Polyzoa, and Sponges. The largest fragment measured 12 by 8 inches (30 by 20 cm.), and was not unlike those obtained on September 26, but much harder and the organisms were less apparent. Microscopic sections show the whole mass to be composed for the most part of Foraminifera and calcareous Algæ, transformed into a crystalline limestone. Microscopic crystals of carbonate of lime have been formed in all the hollows of these concretions, and the cement is also crystalline. From consideration of the organisms, this deposit, unlike that at Station 192A, has been formed in comparatively shallow water. In addition to the rock fragments, there were also pieces of Corals. In the residue after acid there were observed a number of small rounded bodies, isolated or grouped, yellow and transparent; these must be organic.	Amboina to Sambangan.
...	...	...	...	Only a trace of the bottom came up in the sounding tube, and this was a fine sandy mud formed of red, white, and black mineral particles, mixed with a few small Foraminifera and Radiolaria. There was also an angular pebble of augite-andesite, much decomposed and coated with manganese.	
100·00	(3·00 %), Sponge spicules, Lituolidæ.	(45·00 %), m. di. 0·20 mm., angular; felspar, plagioclase, pyroxene, hornblende, magnetite, pumice, palagonite, lapilli.	(52·00 %), amorphous matter of a brown colour and many fine mineral particles.	In the trawl there came up one or two pieces of rock about an inch in diameter, volcanic conglomerate the same as found off Goonong Api, several palm fruits, and pieces of wood and bark.	
100·00	(2·00 %), Sponge spicules, *Reophax nodulosa*, *Gaudryina siphonella*, Diatoms.	(48·00 %), m. di. 0·10 mm., angular; plagioclase, pyroxene, hornblende, magnetite, pumice, vitreous lapilli.	(50·00 %), fine amorphous brown coloured matter, many fine mineral particles, and a few siliceous remains.	There were many small fragments of pumice.	
...	...	...	...	Only a small quantity of mud was brought up. It was green in colour and contained Diatoms, Coccoliths, *Globigerina*, Radiolaria, and small mineral particles.	
...	...	...	...	Four or five small pebbles came up in the sounding tube, some basaltic, others limestone. The former were covered with attached Foraminifera of various kinds.	Sambangan to Manila.
100·00	(1·00 %), Radiolaria and a few Diatoms.	(5·00 %), m. di. 0·08 mm., angular; magnetite, felspar, plagioclase, quartz, augite, hornblende, pumice, coloured altered particles, brown volcanic glass, small basaltic lapilli.	(94·00 %), amorphous matter.	The deposit which came up in the tube and water-bottle was exceedingly soft and of a slate blue colour, with here and there a tinge of red.	
...	...	...	...	...	

See Chart 31, and Diagram 14.

Route	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
			° ′ ″		°	°				
Samboangan to Manila—*continued.*	204	1874 Nov. 2	12 28 0 N. 122 15 0 E.	705	...	84·0	Blue Mud, green-grey when dry, fine grained, coherent, green when wet. **Residue** green.	11·31	(6·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(4·31 %), Lamellibranch fragments, Pteropods, Ostracodes, Echini spines, Coccoliths.
	204A	„ 2	12 43 0 N. 122 9 0 E.	100	...	84·0	Green Mud, green, slightly coherent. **Residue** green.	56·18	(20·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(31·18 %), Otoliths of fish, Gasteropods, Lamellibranchs (larval), Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa.
	204B	„ 2	12 46 0 N. 122 10 0 E.	115	...	84·0	Green Mud, same as 204A. **Residue** green.	50·40	(20·00 %), Globigerinidæ. (4·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(26·40 %), Otoliths of fish, Gasteropods, Lamellibranchs (larval), Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa.
Manila to Hong Kong and back.	...	„ 11	Manila Harbour.	4	...	...	Blue Mud, blue-grey, plastic, fine grained, unctuous, coherent.	trace	*Miliolina*, *Bulimina aculeata*, *Rotalia*.	Gasteropods, Lamellibranchs, Pteropods, Coccoliths.
	205	„ 13	16 42 0 N. 119 22 0 E.	1050	37·0	82·0	Blue Mud, light grey, homogeneous, fine grained, coherent. **Residue** brown.	22·11	(15·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Cassidulina subglobosa*, *Sphæroidina bulloides*, Rotalidæ.	(6·11 %), *Serpula*, Gasteropods, Lamellibranchs, a few Pteropod fragments, Echinoderm fragments, free Corals (*Bathyactis*), Coccoliths, Rhabdoliths.
	...	1875 Jan. 6	Hong Kong Harbour.	7	...	...	Mud and Shells, green-grey, coherent, breaking up readily in water. **Residue** green-grey.	53·52	(5·00 %), Miliolidæ, Rotalidæ, Nummulinidæ.	(48·52 %), Otoliths of fish, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.
	206	„ 8	17 54 0 N. 117 14 0 E.	2100	36·5	75·2	Blue Mud, green, somewhat plastic, coherent, unctuous, homogeneous, fine grained.	trace	Globigerinidæ, *Pulvinulina*.	...
Manila to Samboangan.	207	„ 16	12 21 0 N. 122 15 0 E.	700	51·6	80·0	Blue Mud, light green-grey, coherent, homogeneous, fine grained, sublustrous streak, breaking up with difficulty in water. **Residue** dark green.	3·22	*Textularia*, *Uvigerina*, *Globigerina sacculifera*, *Pulvinulina menardii*, *Rotalia*.	A few fragments of Lamellibranchs and Pteropods, one or two Coccoliths.
	208	„ 17	11 37 0 N. 123 31 0 E.	18	...	81·0	Blue Mud.	...	..	...

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
88·69	(5·00 %), Radiolaria, Sponge spicules, Diatoms.	(60·00 %), m. di. 0·10 mm., angular; plagioclase, quartz, pyroxene, hornblende, mica, magnetite, pumice, altered volcanic particles, glauconite.	(23·69 %), green amorphous matter, fine mineral particles, and siliceous fragments.	...	Samboangan to Manila—*continued.*
43·82	(3·00 %), Sponge spicules, Radiolaria, Textularidæ, casts of calcareous organisms.	(30·00 %), m. di. 0·13 mm., angular; felspar, plagioclase, augite, magnetite, volcanic glass splinters, glauconite.	(10·82 %), many fine mineral particles, a little amorphous matter, and a few siliceous remains.	After treatment with acid, there remain a good many pale and dark green casts of the Foraminifera and other shells.	
49·60	(4·00 %), Sponge spicules, Radiolaria, arenaceous Textularidæ, glauconitic casts.	(30·00 %), m. di. 0·10 mm., angular; felspar, plagioclase, quartz, hornblende, augite, mica, magnetite, glassy volcanic particles, glauconite.	(15·60 %), many fine mineral particles, a little amorphous matter, and a few siliceous remains.	The deposit is similar in every respect to that obtained at the previous station. Pteropods are fewer. A great many casts of the organisms remain after treatment with acid.	
100·00	(3·00 %), Sponge spicules and Diatoms.	(25·00 %), m. di. 0·08 mm., angular; felspar, plagioclase, hornblende, augite, glassy volcanic particles more or less altered, quartz.	(72·00 %), fine amorphous matter of a blue colour, fine mineral particles, and a few remains of siliceous organisms.	The deposit was obtained from the anchor. A number of small coprolite-like bodies are present.	Manila to Hong Kong and back.
77·89	(5·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, *Haplophragmium*, Diatoms.	(10·00 %), m. di. 0·13 mm., angular; quartz, plagioclase, felspar, hornblende, augite, magnetite, palagonite, pumice.	(62·89 %), fine amorphous and clayey matter, minute mineral particles, and some siliceous remains.	In the trawl were two or three rounded nodules of pumice, from ½ to 1 inch (12 to 25 mm.) in diameter, a few cinders, and fragments of wood and leaves. The nodules and pieces of wood were overgrown with *Serpula*. In addition to these there were a dead Coral (*Bathyactis*) and a Gasteropod.	
46·48	(5·00 %), Sponge spicules, a few fragments of Diatoms.	(25·00 %), m. di. 0·50 mm., rounded and angular; quartz, plagioclase, felspar, pyroxene, hornblende, epidote, magnetite particles, glauconite.	(16·48 %), fine mineral particles, a small quantity of amorphous matter, a few fine fragments of Sponge spicules, one or two fragments of Diatoms.	The deposit was obtained from the anchor and consists of fragments of shells, &c., cemented together by mud. It is curious to note that although the surface waters were full of Diatoms none or only a few fragments were observed in the deposit from the bottom. The felspar is sometimes kaolinised.	
100·00	(10·00 %), Sponge spicules, Radiolaria, *Rhizammina*, Lituolidæ, *Clavulina communis*, Diatoms.	(5·00 %), m. di. 0·20 mm., angular; quartz, a great number of small particles of brown vesicular volcanic glass, plagioclase, augite, manganese grains, magnetite.	(85·00 %), much green-brown clayey and amorphous matter, some fine mineral particles, and minute remains of siliceous organisms.	When brought up in the sounding tube the mud was reddish at the top and of a slate-blue colour at the bottom. Small pellets of amorphous matter are observed in the larger washings of the residue, probably excreta of Echinoderms.	
96·78	(3·00 %), a few Radiolaria, Sponge spicules, and Diatoms.	(5·00 %), m. di. 0·06 mm., angular; very small particles, among which felspar and augite predominate, quartz, glassy volcanic particles, lumps of disintegrating volcanic matter black and somewhat opaque, probably volcanic matter altering into clayey substances, glauconite.	(88·78 %), much green clayey and amorphous matter, many fine mineral particles, and a few remains of siliceous organisms.	The calcareous organisms are fragmentary.	Manila to Samboangan.
...	...	...	...	A small quantity of deposit was obtained from the stomach of a Holothurian. It was green in colour and contained broken shells of all kinds, Echinoderm spines, many varieties of Foraminifera, but no *Globigerina* or *Pulvinulina*.	

See Chart 31, and Diagram 14.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Manila to Samboangan—*continued.*	209	1875 Jan. 22	° ′ ″ 10 14 0 N. 123 54 0 E.	95	° 71·0	° 81·0	BLUE MUD, green, slightly coherent, somewhat plastic when wet. Residue green.	35·82	(13·00 %), Globigerinidæ, *Pulvinulina.* (13·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(9·82 %), Otoliths of fish, Gasteropods, Lamellibranch fragments, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Alcyonarian spicules, Coccoliths, Coccospheres.
	209A	,, 24	...	85	...	...	BLUE MUD.	...	...	...
	210	,, 25	9 26 0 N. 123 45 0 E.	375	54·1	80·2	GREEN MUD, light green-brown, coherent, fine grained, dark green when wet. Residue green.	36·06	(25·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina*, Textularidæ, Lagenidæ, *Rotalia.*	(9·06 %), Otoliths of fish, Lamellibranchs, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	210A	,, 26	9 15 0 N. 124 38 0 E.	185	57·1	80·7	BLUE MUD, light green-brown, coherent, fine grained, dark green when wet. Residue green.	17·00	(12·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Nummulinidæ.	(4·00 %), Otoliths of fish, Gasteropods, Lamellibranchs (larval), Pteropods, Ostracodes, Echini spines, Alcyonarian spicules.
	211	,, 28	8 0 0 N. 121 42 0 E.	2225	50·5	81·0	BLUE MUD, light yellow-brown, fine grained, homogeneous, coherent, plastic when wet. Residue brown.	14·63	(11·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), *Miliolina*, *Cassidulina subglobosa*, Lagenidæ, Rotalidæ, *Nonionina umbilicatula.*	(2·63 %), Echini spines, Coccoliths.
	212	,, 30	6 54 0 N. 122 18 0 E.	10	...	83·0	SAND, GRAVEL, and MUD.	...	...	...
Samboangan to New Guinea.	*213	Feb. 8	5 47 0 N. 124 1 0 E.	2050	38·8	83·0	BLUE MUD, with reddish surface layer, yellowish when dry, slightly coherent, fine grained, earthy, breaking up readily in water. Residue blue-grey.	1·75	A few Globigerinidæ.	A few Cephalopod beaks and Pteropod fragments.

* See anal. 63.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
64·18	(10·00 %), Sponge spicules, arenaceous Textularidæ, Astrorhizidæ, *Haplophragmium*, casts of calcareous organisms, Diatoms.	(20·00 %), m. di. 0·20 mm., angular and rounded; quartz, glauconite, plagioclase, felspar, augite, hornblende, magnetic particles.	(34·18 %), amorphous matter, fine mineral particles, and remains of siliceous organisms.	This seems to be a Green Mud in process of formation and resembles that obtained off the coast of Australia, Station 164. Abundant casts of the organisms remain after treatment with acid.	Manila to Sambongan—*continued.*
...	...	...	...	This is in the same position as the previous station, and is known as the *Euplectella* ground.	
63·94	(3·00 %), Sponge spicules, Radiolaria, arenaceous Textularidæ, casts of calcareous organisms, Diatoms.	(1·00 %), m. di. 0·08 mm., angular; glauconite, felspar, plagioclase, augite, magnetite, hornblende, olivine (?), altered volcanic rocks, a great many small yellow pellets, round and opaque in centre, probably altered glauconite or imperfect casts.	(59·94 %), much amorphous matter, fine mineral particles, and fine siliceous remains.	There were a great many oval arenaceous bodies, of different sizes, believed to be the excreta of Echinoderms.	
83·00	(3·00 %), Sponge spicules (*Euplectella* and *Geodia*), Radiolaria, *Reophax spiculifera*, arenaceous Textularidæ, Diatoms.	(5·00 %), m. di. 0·08 mm., angular; plagioclase, volcanic glass, quartz, magnetite, hornblende, hypersthene, augite, sanidine.	(75·00 %), amorphous matter, fine minerals, and siliceous remains.	The sounding was taken close to the Island of Camiguin in 185 fathoms. The bottom is a Blue Mud containing *Globigerina*, Pteropods, &c., and many small red and white mineral particles of volcanic origin. A piece of tufa about 0·5 cm. in diameter was observed in the washings. Hornblende and augite are here more abundant than in other deposits of a similar kind.	
85·37	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(2·00 %), m. di. 0·10 mm., angular; plagioclase, felspar, quartz, augite, hornblende, black mica, magnetite, volcanic glass, pumice, lapilli.	(81·37 %), light coloured clayey and amorphous matter, fine mineral particles, and siliceous remains.	The sounding was taken in the Sulu Sea in 2225 fathoms. The tube was nearly full of mud, all above the valve being of a red colour, that below slate blue; no difference but that of colour can be detected in the two samples; the blue, however, appears to have more clayey and earthy matter than the much more diffuse upper layer.	
...	...	...	...	On February 2, 1875, in the same locality, large fragments of plagioclase, often zonary, embedded in a vitreous coating, crystals of augite, magnetite, and hornblende, were observed in the mud.	
98·25	(5·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(60·00 %), m. di. 0·20 mm., angular; quartz, sanidine, plagioclase, magnetite, hornblende, mica, pumice.	(33·25 %), amorphous matter, many minute fragments of minerals, and a few fragments of siliceous organisms.	In the reddish surface layer one or two fragments of Foraminifera and a fragment of Pteropod were noticed, but the deeper blue coloured portions contain no carbonate of lime organisms, and do not show the least effervescence with acids. The Radiolaria appear also to be much more numerous in the reddish surface layer. There were many large hardened lumps of the deposit in the trawl, which contained many fragments of wood, leaves, and branches. The hornblende and felspar, often filled with vitreous inclusions, are, like many of the minerals, enveloped in a vitreous volcanic coating. Some fragments of rocks have a diameter of 0·5 mm.	Sambongan to New Guinea.

See Chart 31, and Diagrams 14 and 15.

Samboangan to New Guinea—*continued*.

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
				Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
214	1875 Feb. 10	° ′ ″ 4 33 0 N. 127 6 0 E.	500	° 41·8	° 80·5	BLUE MUD, grey, granular, coherent, earthy. Residue reddish.	34·34	(25·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Textularidæ, Lagenidæ.	(7·34 %), Otoliths of fish, Ostracodes, Echinoderm fragments, Polyzoa.
215	,, 12	4 19 0 N. 130 15 0 E.	2550	35·4	81·8	RED CLAY, red-yellow when dry, coherent, lustrous streak, homogeneous, plastic and dark red-brown when wet.	...	...	...
216	,, 16	2 46 0 N. 133 58 0 E.	1675	35·4	82·8	GLOBIGERINA OOZE, light grey with red tinge, slightly coherent, granular, plastic when wet. Residue dark red-brown.	49·03	(40·00 %), Globigerinidæ, *Pulvinulina menardii*. (1·00 %), *Miliolina venusta*, *Uvigerina asperula*, *Pulvinulina favus*.	(8·03 %), Echini spines, Coccoliths, Rhabdoliths.
216A	,, 16	2 56 0 N. 134 11 0 E.	2000	35·4	82·8	GLOBIGERINA OOZE, light red-grey, slightly coherent, fine grained, plastic and red coloured when wet. Residue dark red-brown.	34·67	(30·00 %), Globigerinidæ, *Pulvinulina menardii*, *Rotalia soldanii*.	(4·67 %), Echini spines, Coccoliths, Rhabdoliths.
217	,, 22	0 39 0 S. 138 55 0 E.	2000	35·2	83·0	BLUE MUD, blue-grey, homogeneous, coherent, fine grained, breaking up with difficulty in water, dark blue-grey when wet. Residue dark blue.	12·75	(10·75 %), Globigerinidæ, *Pulvinulina menardii*. (2·00 %), *Biloculina depressa*, *Truncatulina pygmæa*.	...
...	,, 24	Humboldt Bay, Papua.	37	...	...	BLUE MUD, blue-grey and plastic when wet, coherent, granular. Residue blue-grey.	28·91	(5·00 %), Globigerinidæ. (10·00 %), Miliolidæ, *Textularia*, Rotalidæ, Nummulinidæ.	(13·91 %), Gasteropods, Lamellibranchs (larval), Pteropods, Ostracodes, Echinoderm fragments, calcareous Algæ.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
65·66	(2·00 %), a few Sponge spicules, fragments of Radiolaria, Astrorhizidæ, Lituolidæ.	(20·00 %), m. di. 0·10 mm., angular; sanidine, plagioclase, quartz, augite, hornblende, magnetite, pumice.	(43·66 %), amorphous matter, minute fragments of minerals.	Besides a quantity of the deposit there were in the trawl many animals and numerous fragments of trachytic tufa. These fragments are generally very compact and break up with difficulty, their cohesion being nearly as perfect as that of crystalline rocks. They contain *Globigerina* and other Foraminifera, and a great number of volcanic particles, as felspar, plagioclase, augite, rarely hornblende, magnetite, fragments of volcanic glass. These concretions are true submarine tufas, and seem to be an augite-andesitic ash or to come from the disintegration of an augite-andesitic rock containing hornblende. Vitreous fragments are not frequent; probably they are altered into chloritic matter present in the concretions.
100·00	(3·00 %), many Radiolaria, siliceous spicules, Lituolidæ.	(5·00 %), m. di. 0·08 mm., angular; plagioclase, augite, volcanic glass splinters, fragments of altered volcanic rocks, magnetite.	(92·00 %), much fine amorphous matter, minute mineral particles, and remains of siliceous organisms.	There was one piece of pumice about the size of a pea in the sounding tube. In the trawl were a few fragments of pumice, about the size of a hen's egg or less. These all contain porphyritic minerals. Inside one piece was found an *Orbulina*-like body, having the shell composed of black and red particles, but containing no carbonate of lime (*Placopsilina bulla*?). The pumice fragments are slightly impregnated in some cases with manganese.
50·97	(1·00 %), Sponge spicules, Radiolaria, *Rhizammina algæformis*, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; pumice, felspar, plagioclase, augite, magnetite.	(48·97 %), much red amorphous matter, fine mineral and siliceous remains.	*Pulvinulina favus* was noticed here for the first time since leaving the Philippine Islands.
65·33	(1·00 %), Sponge spicules, Radiolaria, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, pyroxene or amphibole, magnetite, pumice, altered volcanic glass.	(63·33 %), much amorphous matter of a red-brown colour, fine mineral particles, and remains of siliceous organisms.	There are fewer Coccoliths and Rhabdoliths than in the previous sounding. There were one or two pieces of pumice stone in the sounding tube. A considerable number of pumice stones came up in the trawl, varying from the size of a marble to that of a good-sized egg. The surface of most of these was impregnated with manganese. *Stephanoscyphus simplex* with its stolons ran over these stones in great numbers. There were also present in the trawl quantities of *Rhizammina algæformis*, the tube of which is composed of Foraminifera and other bottom-living organisms cemented together. There were also many worm tubes and a large irregular Rhizopod similar in form to (but not) *Syringammina fragilissima*.
87·25	(1·00 %), Radiolaria, Sponge spicules, *Rhizammina algæformis*, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; felspar, augite, volcanic glass, sometimes altered to palagonite, quartz.	(85·25 %), much amorphous matter, fine mineral particles, and remains of siliceous organisms.	There were two or three small pieces of pumice and several worm tubes or portions of them in the sounding tube.
71·09	(2·00 %), Sponge spicules, Radiolaria, *Haplophragmium agglutinans*, *Textularia sagittula*, Diatoms.	(20·00 %), m. di. 0·07 mm., rounded; felspar, volcanic glass, quartz, magnetite, olivine, hornblende, mica, palagonite, glauconite.	(49·09 %), fine mineral particles, amorphous matter, and siliceous remains.	A few green casts of the Foraminifera remain after treatment with acid.

Sambangan to New Guinea—*continued*.

See Charts 31 and 34, and Diagrams 15 and 16.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
New Guinea to Admiralty Islands.	218	1875 Mar. 1	° ′ ″ 2 33 0 S. 144 4 0 E.	1070	° 36·4	° 84·0	**Blue Mud**, pale blue-grey with reddish tinge, homogeneous, coherent, somewhat plastic when wet. **Residue** dark blue-grey.	17·17	(10·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(4·17 %), Otoliths of fish, *Serpula*, *Ianthina*, *Dentalium*, Lamellibranchs, Pteropods, Echini spines, Corals (*Bathyactis*), Coccoliths.
New Guinea to Admiralty Islands.	...	,, 7 ,, 10	Nares Harbour.	16–25	...	...	**Coral Sands** and **Muds**, pale yellow-white, free in the case of the sand, light-brown, slightly coherent. **Residue** dark brown.	86·87	(2·00 %), Globigerinidæ. (30·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(54·87 %), *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Corals, calcareous Algæ.
New Guinea to Admiralty Islands.	*...	,, 9	Beach, Main Island, Admiralty Islands.	...	...	..	**Sand**, grey, black, white, and red particles. **Residue** dark grey.	27·30	(8·00 %), *Miliolina*, *Rotalia*, *Nonionina*.	(19·30 %), larval Gasteropods, Lamellibranch and Echinoderm fragments, Alcyonarian spicules, calcareous Algæ.
Admiralty Islands to Yokohama.	219	,, 10	1 54 0 S. 146 39 40 E.	150	...	84·0	**Coral Mud**.	...	...	...
Admiralty Islands to Yokohama.	220	,, 11	0 42 0 S. 147 0 0 E.	1100	36·2	83·8	**Globigerina Ooze**, pale yellow-white, granular, slightly coherent. **Residue** red-brown.	63·75	(50·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Biloculina depressa*, *Truncatulina lobatula*.	(11·75 %), Echini spines, Coccoliths, Rhabdoliths.
Admiralty Islands to Yokohama.	221	,, 13	0 40 0 N. 148 41 0 E.	2650	35·4	83·8	**Red Clay**, light red-brown, coherent, fine grained, presenting no macroscopic elements.	trace	*Pulvinulina favus* (fragment).	Small teeth of fish.
Admiralty Islands to Yokohama.	222	,, 16	2 15 0 N. 146 16 0 E.	2450	35·2	82·8	**Red Clay**, light brown with red tinge, coherent, fine grained, presenting no macroscopic elements. **Residue** chocolate coloured.	6·86	(5·86 %), Globigerinidæ, *Pulvinulina*. (1·00 %), *Truncatulina pygmæa*, *Nonionina umbilicatula*.	A few small teeth of fish, Echini spines.

* See Pl. XXVI. fig. 6.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
82·83	(4·00 %), Sponge spicules (including *Geodia*), Astrorhizidæ, Lituolidæ, Radiolaria, Diatoms.	(10·00 %), m. di. 0·10 mm., angular; pumice, brown glassy volcanic particles, felspar, plagioclase, augite, quartz, magnetite, altered olivine, lapilli.	(68·83 %), much fine amorphous matter, minute mineral and siliceous remains.	This deposit was red on the top, grey at the bottom, and contained some pumice fragments. There is no difference save that of colour between the upper and lower layers. In the bag of the trawl were much mud and large pieces of pumice and other stones, varying in size from that of a pea to that of a hen's egg. These are slightly impregnated in some cases with manganese and overgrown with *Serpula* and *Hyperammina vagans*. Pieces of wood, fruits, Annelid tubes, Pteropod and *Ianthina* shells were also in the trawl. *Rhizammina algæformis* is common. Many excreta of Echinoderms.	New Guinea to Admiralty Islands.
13·13	(2·00 %), Sponge spicules, Astrorhizidæ, arenaceous Textularidæ, a few imperfect casts, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; fragments of pumice, black or brown altered volcanic glass, felspar, augite, magnetite, quartz, manganese grains.	(10·13 %), amorphous matter, fine mineral particles, and remains of siliceous organisms.	Several dredgings were taken; the bottom was always found to be a Coral Sand or Coral Mud. The pelagic Foraminifera are rare. The sands are coarse and made up of fragments of Coral, calcareous Algæ, Lamellibranchs, and Gasteropods. Many of the fragments are overgrown with *Serpula*, Foraminifera, and Polyzoa. A few imperfect casts remain after treatment with acid.	
72·70	(2·70 %), Sponge spicules.	(70·00 %), m. di. 0·25 mm., angular and rounded; plagioclase, sanidine, pyroxene, hornblende, olivine more or less altered, magnetite, splinters of volcanic glass, palagonite, small rounded lapilli, quartz.	...	The sand is composed of fine particles of volcanic minerals, averaging in size 0·25 mm., mixed with calcareous organisms.	
...	...	...	...	A sounding and dredging were taken about a mile from the reef in 152 fathoms. Only traces of a greenish coloured sand were in the sounding cup.	Admiralty Islands to Yokohama.
36·25	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(2·00 %), m. di. 0·10 mm., angular; pumice, plagioclase, magnetite, brown glassy volcanic particles, hornblende, very small lapilli of andesitic rocks.	(32·25 %), fine amorphous matter, minute mineral fragments, and fine remains of siliceous organisms.	In the trawl were several rounded pieces of pumice, about ½ to 1 inch (12 to 25 mm.) in diameter, which were slightly impregnated with manganese in some cases and also overgrown with a Rhizopod (probably *Hyperammina*).	
100·00	(2·00 %), Radiolaria, Sponge spicules, *Reophax*, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; pumice, felspar, augite, palagonite, magnetite.	(97·00 %), much fine chocolate coloured amorphous matter, minute mineral particles, and siliceous remains.	On examination of the washings of a large quantity, a piece of pumice about the size of a pea was found, and one or two arenaceous Foraminifera; also a good many manganese grains.	
93·14	(2·00 %), Radiolaria, Astrorhizidæ, Diatoms.	(2·00 %), m. di. 0·10 mm., angular; magnetite, glassy volcanic fragments, manganese grains.	(89·14 %), much amorphous matter, fine mineral and siliceous remains.	The Globigerinidæ are chiefly fragmentary. In the washings was a piece of pumice, about the size of a pea, overgrown with *Hyperammina vagans*.	

See Chart 31, and Diagrams 14 and 16.

Admiralty Islands to Yokohama—*continued*.

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
				Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
223	1875 Mar. 19	° ′ ″ 5 31 0 N. 145 13 0 E.	2325	° 35·5	° 82·0	Globigerina Ooze, light grey, slightly coherent, breaking up readily in water, plastic and red coloured when wet. **Residue** red-brown.	52·47	(45·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Biloculina depressa*, Lagenidæ, *Rotalia soldanii*, *Nonionina umbilicatula*.	(5·47 %), Echini spines, Coccoliths, Rhabdoliths.
*224	,, 21	7 45 0 N. 144 20 0 E.	1850	35·4	81·2	Globigerina Ooze, with a slight rose tinge, almost white when dry, slightly coherent, friable, chalky, earthy. **Residue** chocolate coloured.	79·20	(70·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(6·20 %), Pteropods, Heteropods, Ostracodes, Brachiopods, Echinoderm fragments, Alcyonarian spicules, Coccoliths, Rhabdoliths.
†225	,, 23	11 24 0 N. 143 16 0 E.	4475	35·2	80·2	Radiolarian Ooze, upper layer red, deeper layers straw coloured, very slightly coherent, fine grained.	trace	One or two *Globigerina* observed.	A few otoliths and small teeth of fish.
‡226	,, 25	14 44 0 N. 142 13 0 E.	2300	35·5	79·0	Red Clay, deep chocolate coloured when wet, greasy to the touch, yellowish when dry, pulverulent, breaking up with difficulty in water, lustrous streak. **Residue** chocolate coloured.	6·11	(4·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(1·11 %), small teeth of fish, Echini spines.
227	,, 27	17 29 0 N. 141 21 0 E.	2475	35·2	79·2	Red Clay, chocolate coloured when wet, plastic, fine grained, presenting no macroscopic elements.	trace	*Truncatulina pygmæa* (fragments).	Small teeth of fish, larval Gasteropods, Ostracodes, Alcyonarian spicules.
228	,, 29	19 24 0 N. 141 13 0 E.	2450	35·2	80·2	Red Clay, red, coherent, fine grained, presenting no macroscopic elements, chocolate coloured when wet.	trace	...	Teeth of fish.
229	April 1	22 1 0 N. 140 27 0 E.	2500	35·2	78·5	Red Clay, red, coherent, but somewhat friable, fine grained, presenting no macroscopic elements, chocolate coloured and plastic when wet.	trace	...	Small teeth of fish.

* See anal. 45, 57. † See Pl. XV. fig. 3; Pl. XXVII. fig. 5. ‡ See anal. 13, 76.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
47·53	(3·00 %), Radiolaria, Sponge spicules, *Verneuilina pygmæa*, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; felspar, pyroxene or amphibole, magnetite, pumice, altered volcanic particles.	(43·53 %), fine amorphous matter, minute mineral particles and remains of siliceous organisms.	The Foraminifera are nearly all pelagic; both large and small specimens are present, the larger ones being much broken. A piece of pumice about the size of a pea came up in the sounding tube. About a pint (half a litre) of pumice fragments came up in the trawl, varying in size from that of a pea to that of a hen's egg, in most cases much decomposed and friable. On one or two there were attached small siliceous Sponges.
20·80	(5·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, hornblende, augite, magnetite, many small fragments of pumice.	(14·80 %), amorphous matter, many small fragments of siliceous organisms and pumice.	Only a small quantity of the ooze came up in the sounding tube, but the dredge was filled with it. On passing this through sieves many fragments of pumice were obtained, varying much in size, the largest being about 5 or 6 cm. in diameter; there were, however, many hundreds of small fragments with a diameter of 1 or 2 mm. This deposit is essentially composed of pelagic Foraminifera, the bottom-living species forming only a very small portion of the whole mass. Rhabdoliths are very rare, Coccoliths very small in size.
100·00	(80·00 %), Radiolaria, Sponge spicules, one *Haplophragmium globigeriniforme* observed, Diatoms.	(3·00 %), m. di. 0·10 mm., angular; felspar, augite, pumice, magnetite, palagonite, lapilli of andesitic rocks, bronzite spherule.	(17·00 %), a small quantity of amorphous matter, with many fine fragments of siliceous organisms and minerals.	Besides the many altered volcanic particles there are many little aggregations of the bottom difficult to break down, also little clusters of rhombohedral crystals of carbonate of lime. This is the deepest sounding from which deposit has been procured.
93·89	(3·00 %), Radiolaria, Lituolidæ, fragments of large *Coscinodiscus*.	(5·00 %), m. di. 0·08 mm., angular; magnetite free and enclosed in volcanic glass, monoclinic and triclinic felspars, augite, hornblende, many fragments of pumice, vitreous fragments transformed into palagonite.	(85·89 %), many minute fragments of pumice and other minerals, and some small fragments of siliceous organisms.	The trawl brought up a quantity of pumice. The clay at this station presents only some of the typical characters of clay, and appears to be, fundamentally, rather a fine mud than a clay, and is composed chiefly of the triturated particles of pumice. The pumice stones are all more or less decomposed and coloured by the hydroxides of iron and manganese. In some cases it is impossible to determine the nature of these fragments, believed to be pumice, even after microscopic and macroscopic examination, but in the majority the structure of pumice can be recognised in the thin slides.
100·00	(3·00 %), Sponge spicules, Radiolaria, Lituolidæ.	(3·00 %), m. di. 0·08 mm., angular; numerous particles of pumice and volcanic glass splinters (some brown), plagioclase, felspar, augite, hornblende, magnetite.	(94·00 %), fine amorphous matter, minute mineral and siliceous remains.	The deposit contains much manganese; two or three small pieces of pumice, about 0·5 cm. in diameter, were obtained. The minerals are crystals or fragments generally covered with a coating of scoriaceous glass.
100·00	(2·00 %), Sponge spicules, Radiolaria, *Haplophragmium latidorsatum*.	(8·00 %), m. di. 0·06 mm., angular; plagioclase often coated with a net-work of vesicular glass, augite, magnetite, pumice, palagonite, manganese grains.	(90·00 %), amorphous matter, fine mineral particles, and remains of siliceous organisms.	There is a considerable quantity of manganese in the form of little black grains. There are also many pellets of pumice from 1 to 5 mm. in diameter.
100·00	(3·00 %), Radiolaria, *Rhizammina algæformis*, Lituolidæ, Diatoms.	(5·00 %), m. di. 0·10 mm., angular; pumice, scoriæ, plagioclase, black or brownish volcanic glass, magnetite, pyroxene.	(92·00 %), much fine amorphous chocolate coloured matter, minute mineral and siliceous remains.	The deposit does not effervesce with acid. The microscope reveals only one or two small teeth of fish. Particles of pumice and grains of manganese are abundant. There are remains of the large cylindrical Diatom, *Ethmodiscus*.

Admiralty Islands to Yokohama—*continued*.

See Charts 31 and 35, and Diagram 16.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Yokohama—*continued*.	230	1875 April 5	26° 29′ 0″ N. 137 57 0 E.	2425	35°·5	68°·5	Red Clay, similar to the last, fine grained, coherent, chocolate coloured and plastic when wet.	...	...	...
	231	„ 9	31 8 0 N. 137 8 0 E.	2250	35·2	64·0	Blue Mud, blue-grey, fine grained, coherent, presenting no macroscopic elements, breaking up readily in water.	trace	Globigerinidæ.	...
Off Japan.	232	May 12	35 11 0 N. 139 28 0 E.	345	41·1	64·2	Green Mud, green-grey, earthy, slightly coherent, breaking up readily in water, containing shells. **Residue** dark green with brown tinge.	3·29	(1·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Textularidæ, Rotalidæ.	(1·29 %), Ostracodes, Echinoderm fragments, Coccoliths.
	233	„ 17	34 39 0 N. 135 14 0 E.	8	...	62·3	Blue Mud, light blue-grey, slightly coherent, breaking up with difficulty in water. **Residue** green.	11·32	A few *Rotalia*.	(11·32 %), Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments.
	233A	„ 19	34 38 0 N. 135 1 0 E.	50	...	62·6	Sand.	...	...	...
	233B	„ 26	34 18 0 N. 133 35 0 E.	15	...	66·3	Blue Muds, light blue-grey, coherent, breaking up with difficulty in water, plastic when wet. **Residue** dark blue-grey.	4·29	(1·00 %), Miliolidæ, Rotalidæ.	(3·29 %), *Dentalium*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments.
	233C	„ 28	34 18 0 N. 133 21 0 E.	12	59·9	66·8				
	234	June 3	32 31 0 N. 135 39 0 E.	2675	35·8	69·5	Blue Mud, light blue-grey, slightly coherent, fine grained, breaking up readily in water, dark blue-grey and somewhat plastic when wet. **Residue** dark blue-grey.	trace	*Globigerina bulloides*, *Bulimina ovata*.	...
	235	„ 4	34 7 0 N. 138 0 0 E.	565	38·1	73·0	Green Mud, light green-grey, slightly coherent, breaking up in water. **Residue** green.	[5·00]	(2·00 %), Globigerinidæ, *Pulvinulina menardii*. (1·00 %), *Bolivina textilarioides*, Lagenidæ, *Truncatulina pygmæa*.	(2·00 %) Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
100·00	(8·00 %), Radiolaria, Astrorhizidæ, *Trochammina trullissata*, Diatoms.	(10·00 %), m. di. 0·10 mm., angular; almost entirely composed of microscopic splinters of brown volcanic scoriaceous glass (volcanic ash), plagioclase, magnetite.	(82·00 %), much amorphous matter, fine mineral and siliceous remains.	A considerable quantity of the deposit was obtained in the tube. The minerals consist mainly of broken down scoriæ. In the trawl were about a dozen pieces of pumice stone, averaging an inch (25 mm.) in diameter; these fragments are impregnated with manganese and overgrown with *Hyperammina vagans*; to one was attached a small Brachiopod.	Admiralty Islands to Yokohama—*continued.*
100·00	(15·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, *Gaudryina siphonella*, Diatoms.	(10·00 %), m. di. 0·10 mm., angular; pumice fragments, scoriæ, felspar, plagioclase, hornblende, augite, magnetite, altered microscopic fragments of volcanic rocks.	(75·00 %), much fine amorphous matter, minute mineral and siliceous remains.	The upper portion of the deposit was red, the lower a blue colour. A great many Diatoms and Radiolaria are present; one fragment of pumice, 0·5 cm. in diameter, was noticed.	
96·71	(3·00 %), Sponge spicules, fragments of Radiolaria, a few casts, Diatoms.	(80·00 %), m. di. 0·20 mm., angular; felspar, plagioclase, magnetite, augite, hornblende, glauconite, quartz, fragments of volcanic glass and pumice.	(13·71 %), a small quantity of amorphous matter, minute particles of volcanic minerals and siliceous organisms.	Some of the mineral particles are coated with manganese. Some fragments of rocks measure about 0·5 cm. in diameter. Among the minerals there are a large number of lapilli of black volcanic glass more or less rounded and vesicular, measuring from 1 to 2 mm. in diameter. A few pale green casts of Foraminifera remained after treatment with acid.	Off Japan.
88·68	(10·00 %), Sponge spicules, *Haplophragmium canariensis*, Diatoms.	(50·00 %), m. di. 0·10 mm., angular and rounded; quartz, felspar, white and green mica sometimes altered, hornblende, rarely augite, zircon, chlorite.	(28·68 %), fine mineral particles, amorphous matter, and siliceous remains.	The mud proper shows only one or two points of effervescence when treated with dilute acid. Mixed with the mud are large Lamellibranch shells, twigs, &c. A great many Diatoms are present. The felspar is often kaolinised.	
...	...	...	...	The dredge brought up several rounded fragments of rocks and irregular masses of conglomerate, the latter made up of smaller rock fragments cemented together by calcareous organisms; all these were overgrown with *Serpula*, *Balanus*, Polyzoa, Corals, and Molluscs.	
95·71	(2·00 %), Radiolaria, Sponge spicules, Diatoms.	(40·00 %), m. di. 0·10 mm., rounded and angular; quartz, plagioclase, orthoclase, altered felspar, white mica, hornblende, tourmaline, zircon.	(53·71 %), fine mineral particles, some clayey matter, and remains of siliceous organisms.	These and other soundings in the Inland Sea gave a sticky Blue Mud. The washings of a large quantity of this mud consisted of a number of broken and dead Gasteropod, Lamellibranch, and *Dentalium* shells with a few Miliolidæ and Rotalidæ. There are many Diatoms present in the mud as well as on the surface. Shells of pelagic Foraminifera and Pteropods are apparently absent in these deposits.	
100·00	(3·00 %), Radiolaria, Sponge spicules, Diatoms.	(15·00 %), m. di. 0·06 mm., angular, rounded, felspar, mica, magnetite, glassy particles, coloured altered glassy particles, hornblende.	(82·00 %), fine mineral fragments, Diatom and other siliceous remains, a small quantity of fine amorphous material.	Only traces of the bottom came up on the outside of the tube, but in the water-bottle was a quantity of Blue Mud, having streaks here and there of a red tinge. The great mass of the washings consists of fine mineral particles, remains of Diatoms and Radiolaria. Only one or two *Globigerina* shells were observed and these small. Among the Radiolaria were noticed several specimens of *Challengeria tizardi*.	
[95·00]	(5·00 %), Radiolaria, Sponge spicules, casts of Foraminifera, Diatoms.	(60·00 %), m. di. 0·20 mm., angular; plagioclase, felspar, quartz, augite, magnetic particles, pumice, glauconite, fragments of volcanic rocks.	(30·00 %), fine amorphous matter, minute mineral and siliceous remains.	No mud was obtained from the sounding tube or trawl, but in the trawl were three or four pieces of pumice, and about the bases of some Actinias were traces of the bottom. Worm-tubes were present. After treatment with acid a good many light and dark green casts of Foraminifera are observed. The percentages have been approximated, there being too small a quantity for analysis.	

See Charts 35 and 36, and Diagram 17.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Off Japan—*continued.*	236	1875 June 5	° ′ ″ 34 58 0 N. 139 29 0 E.	775	° 37·6	° 66·5	Green Muds, green, slightly coherent, breaking up in water. **Residue** dark green.	trace	*Globigerina*, Lagenidæ, *Bulimina inflata.*	Echini spines, Coccoliths.
Off Japan—*continued.*	236A	„ 5	34 59 0 N. 139 31 0 E.	420	...	66·5	(as above)			
Yokohama to Sandwich Islands.	*237	„ 17	34 37 0 N. 140 32 0 E.	1875	35·3	73·0	Blue Mud, with a reddish surface layer, when dry grey-blue, slightly coherent, granular. **Residue** bluish.	4·45	(1·45 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(2·00 %), Otoliths and vertebræ of fish, Cephalopod beaks, Pteropod and Heteropod fragments, Echini spines.
Yokohama to Sandwich Islands.	238	„ 18	35 18 0 N. 144 8 0 E.	3950	35·0	70·5	Red Clay, red-grey when dry, coherent, fine grained, presenting no macroscopic elements, breaking up in water, dark brown when wet.	...	...	...
Yokohama to Sandwich Islands.	239	„ 19	35 18 0 N. 147 9 0 E.	3625	35·1	70·2	Red Clay, light red-grey when dry, coherent, fine grained, presenting no macroscopic elements, breaking up in water, somewhat plastic and red coloured when wet.	...	...	...
Yokohama to Sandwich Islands.	†240	„ 21	35 20 0 N. 153 39 0 E.	2900	34·9	64·8	Red Clay, light red-grey when dry, coherent, fine grained, breaking up in water, dark red when wet.	...	..	...
Yokohama to Sandwich Islands.	‡241	„ 23	35 41 0 N. 157 42 0 E.	2300	35·1	69·2	Red Clay, the upper layers reddish, the deeper layers greyish and more compact, when dry yellowish grey, slightly coherent. **Residue** chocolate coloured.	17·29	(10·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(4·29 %), Brachiopods, Ostracodes, Echini spines, a few Coccoliths.
Yokohama to Sandwich Islands.	242	„ 24	35 29 0 N. 161 52 0 E.	2575	35·1	68·5	Red Clay, red-brown, unctuous to the touch, slightly coherent, fine grained, lustrous streak.	trace	A few broken fragments of *Globigerina*, one or two very minute *Truncatulina pygmæa.*	A fragment of *Ianthina.*

* See Pl. XI. fig. 2. † See Pl. XXVII. fig. 3. ‡ See anal. 14, 80; Pl. I. figs. 7, 8.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
100·00	(5·00 %), Sponge spicules, Radiolaria, casts of Foraminifera, Diatoms.	(60·00 %), m. di. 0·20 mm., angular; felspar, plagioclase, pumice, augite, quartz, magnetite.	(35·00 %), amorphous matter, fine mineral and siliceous remains.	Green casts of Foraminifera are left after treatment with acid. In the trawl at the latter depth there were some very large hardened pieces of the bottom. These were perforated by worms and in some cases slightly coated with manganese. In the cup of the lead were several hardened clay nodules, and rather angular pebbles. The minerals are of volcanic origin.	Off Japan—*continued*.
95·55	(5·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Sponge spicules, Diatoms.	(30·00 %), m. di. 0·15 mm., angular; almost all volcanic minerals, monoclinic and triclinic felspars, augite, hornblende, magnetite, fragments of black vesicular glass, pumice, black mica, manganese.	(60·55 %), amorphous matter, minute fragments of minerals and siliceous organisms.	The trawl brought up many animals, much mud, several pumice stones, and many large blocks having the same mineralogical composition and clastic elements as the mud itself; these appear to be indeed simply hardened or conglomerated portions of the deposit. In these conglomerated portions there are fragments of plagioclase coated with glassy mattter, splinters of augite and hornblende, magnetite, fragments or lapilli of basaltic rocks, vesicular or massive, and opaque splinters of pumice filled with microliths. In the washings of the mud were many arenaceous Foraminifera.	Yokohama to Sandwich Islands.
100·00	(8·00 %), Sponge spicules, Radiolaria, *Reophax nodulosa*, Diatoms.	(10·00 %), m. di. 0·07 mm., angular; felspar, plagioclase, augite, magnetite, glassy volcanic splinters.	(82·00 %), much amorphous matter, fine mineral fragments.	No blue lower layer was observed in the deposit, as was the case in the bottoms taken in the Japan stream. The deposit is a Red Clay, intermixed with which are remains of siliceous organisms, broken down pumice, and volcanic mineral particles.	
100·00	(3·00 %), Radiolaria, *Reophax nodulosa*, Diatoms.	(10·00 %), m. di. 0·10 mm., angular; plagioclase, felspar, pumice, scoriæ, magnetite, palagonite, augite, manganese grains, olivine, microscopic lapilli.	(87·00 %), much amorphous red coloured matter, mineral and siliceous remains.	A considerable quantity of pumice is present; two pieces, about the size of a bean, quite black on the outside, were obtained on washing a quantity of the clay. The siliceous organisms do not seem to be so abundant as in the previous sounding. Among the washings were numerous black particles of manganese.	
100·00	(5·00 %), Radiolaria, Sponge spicules, *Rhabdammina*, Lituolidæ, Diatoms.	(5·00 %), m. di. 0·07 mm., angular; plagioclase, pumice, scoriæ, glassy volcanic particles, magnetite, augite, palagonite.	(90·00 %), much red amorphous matter, siliceous and mineral remains.	This deposit is similar to that obtained at the last station, but the siliceous organisms seem to be more abundant. In the clay were worm-tubes much impregnated with manganese, also several blackened pieces of pumice about the size of a pea. The minerals are chiefly broken down pumice.	
82·71	(15·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(10·00 %), m. di. 0·10 mm., angular; felspar, chiefly monoclinic with numerous vitreous inclusions, augite, more rarely hornblende, magnetite, numerous fragments of pumice, manganese.	(57·71 %), amorphous matter, numerous small vitreous fragments, fine mineral particles, fragments of siliceous organisms.	The trawl brought up many hundreds of pumice stones and many animals. The tow-nets attached to the beam of the trawl were filled with fine soft clay. The arenaceous Foraminifera are very abundant and macroscopic. About fifty of the fragments of pumice had a diameter of from 8 to 15 cm. The majority were about 5 cm., but fragments of all sizes were abundant, down to small microscopic particles, those of the larger size being generally less decomposed than the smaller ones. Microscopic sections of these pumice stones show vitreous basis, sanidine, plagioclase, and augite.	
100·00	(3·00 %), Radiolaria, *Haplophragmium latidorsatum*, Diatoms.	(5·00 %), m. di. 0·10 mm., angular; plagioclase, augite, pumice, some rounded grains of quartz.	(92·00 %), much fine reddish clayey matter, small particles of volcanic minerals and pumice, fragments of siliceous organisms.	There was a small quantity of the deposit in the sounding tube, and also a small quantity and two small manganese nodules in the water-bottle. The nodules had a nucleus of altered pumice, and a coating of manganese an eighth of an inch (3 mm.) in thickness.	

See Chart 36, and Diagrams 17 and 18.

Yokohama to Sandwich Islands—*continued*.

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
243	1875 June 26	° ′ ″ 35 24 0 N. 166 35 0 E.	2800	° 35·0	° 71·0	RED CLAY.	...	...	...
244	,, 28	35 22 0 N. 169 53 0 E.	2900	35·3	70·5	RED CLAY, reddish or light brown when dry, coherent, fine grained, soft to the touch.	trace	Globigerinidæ, *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ.	Small teeth of fish, fragments of Pteropods and Polyzoa.
245	,, 30	36 23 0 N. 174 31 0 E.	2775	34·9	69·0	RED CLAY, light red-grey when dry, coherent, very fine grained, breaking up readily in water, presenting no macroscopic elements, chocolate coloured and plastic when wet.	trace	One or two broken fragments of *Biloculina*.	...
*246	July 2	36 10 0 N. 178 0 0 E.	2050	35·1	73·0	GLOBIGERINA OOZE, brownish when wet, plastic, grey when dry, slightly coherent. **Residue** brownish.	56·07	(35·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(16·07 %), small teeth and otoliths of fish, Brachiopods, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Echinoderm fragments, Alcyonarian spicules, a few Coccoliths.
247	,, 3	35 49 0 N. 179 57 0 W.	2530	35·2	73·0	RED CLAY, upper layer dark red, lower layer much lighter, fine grained, presenting no macroscopic elements, coherent, breaking up in water. **Residue** red-brown.	10·06	(6·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, *Bulimina elegans*, Lagenidæ, Rotalidæ, *Nonionina umbilicatula*.	(2·06 %), Echini spines, Coccoliths.
†248	,, 5	37 41 0 N. 177 4 0 W.	2900	35·1	69·2	RED CLAY, brown-red, unctuous when wet, yellowish brown when dry, coherent, sublustrous streak.	trace	A few fragments of *Globigerina*.	Small teeth of fish, a few fragments of Pteropods.
249	,, 7	37 59 0 N. 171 48 0 W.	3000	35·2	65·2	RED CLAY.	trace	*Spiroloculina tenuis*.	...
250	,, 9	37 49 0 N. 166 47 0 W.	3050	35·0	65·0	RED CLAY, light red-grey, coherent, fine grained, dark red when wet.	trace	*Spiroloculina tenuis*.	...
251	,, 10	37 37 0 N. 163 26 0 W.	2950	35·1	65·0	RED CLAY, light red-grey, coherent, fine grained, light red-brown, unctuous, and plastic when wet.	...	...	...

* See anal. 46, 77; Pl. I. figs. 1, 2, 3, 4.

† See anal. 102; Pl. I. figs. 5, 6; Pl. II. figs. 1, 2, 2*a*, 4; Pl. IX. fig. 4.

Yokohama to Sandwich Islands—*continued.*

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
...	...	...	...	No deposit came up in the sounding tube or water-bottle. On allowing the water to settle, some fine red amorphous particles and a few black mineral grains collected, but nothing further was obtained to indicate the nature of the bottom.
100·00	(1·00 %), a few Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, sanidine, pumice, magnetite, manganese grains, cosmic spherules.	(98·00 %), amorphous matter, fragments of siliceous organisms, minute fragments of minerals.	The trawl brought up a large quantity of the clay, a number of animals, and many pumice stones mostly surrounded with concentric deposits of manganese. The pumice contains very large crystals of sanidine, plagioclase, and augite. The carbonate of lime organisms mentioned are extremely rare, being obtained from the washings of a large quantity of the deposit. The Pteropods and Globigerinidæ may have been caught by the nets on their way towards the surface.
100·00	(1·00 %), Radiolaria, *Reophax nodulosa*, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; volcanic minerals, plagioclase, augite, magnetite, pumice, manganese grains.	(98·00 %), much amorphous chocolate coloured matter, mineral and siliceous remains.	A piece of black manganese about the size of a bean, and many smaller pieces, were observed.
43·93	(5·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; sanidine, plagioclase, augite, magnetite, fragments of pumice, greenish volcanic glass, black and reddish grains of manganese.	(37·93 %), amorphous matter, minute fragments of minerals and siliceous organisms.	The trawl brought up much ooze, many pumice stones, and a large number of animals. There were several hundreds of rounded fragments of pumice, containing large crystals of sanidine, plagioclase, and augite; about thirty of the largest had an average diameter of 30 cm., and a very large number about 2 cm. in diameter. One or two Pteropod, Heteropod, and *Ianthina* shells were noticed in the washings of a large quantity.
89·94	(5·00 %), Radiolaria, Sponge spicules, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; manganese grains, felspar, glassy volcanic fragments, magnetite, palagonite, hornblende, black mica.	(83·94 %), much red or yellow-red amorphous matter, minute remains of siliceous organisms and minerals.	There was a considerable quantity of clay in the tube. The colour was lighter than in the last few soundings. The upper portion, one inch thick, was red and contained no calcareous organisms, while the lower part of the tube was filled with a light coloured mud containing the organisms indicated in the description.
100·00	(10·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(5·00 %), m. di. 0·15 mm., angular; hornblende often surrounded with glass, magnetic oxide of iron abundant and often in crystals, fragments of pumice, manganese grains.	(85·00 %), amorphous matter, fragments of minerals and siliceous organisms.	The trawl came up torn but contained much clay, many manganese nodules, pumice stones, and several animals. The carbonate of lime organisms are extremely rare and fragmentary (see remarks, St. 244). One large tooth of *Lamna*, and several smaller teeth, were obtained.
...	Radiolaria, Diatoms.	Palagonite, felspar, manganese grains.	..	No deposit came up in the tube. The instrument had been buried 18 inches into the clay, and enough of the bottom was obtained to define its nature; there was, however, insufficient for a detailed description. Radiolaria are evidently abundant.
100·00	(10·00 %), Radiolaria, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, phillipsite, mica, magnetite, hornblende, manganese grains.	(89·00 %), much yellow-red amorphous matter, siliceous and mineral remains.	The bottom was a Red Clay with a few patches of white or lighter coloured material near the bottom. There are no traces of calcareous organisms, but Radiolaria are abundant.
100·00	(10·00 %), Radiolaria, Sponge spicules, *Hormosina carpenteri*, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; volcanic glass, scoriæ, pumice, manganese grains, felspar, palagonite.	(89·00 %), much red amorphous matter, mineral and siliceous remains.	About a quart (over a litre) of the clay came up in the tube; it was of a uniform character throughout.

See Chart 36, and Diagrams 18 and 19.

Yokohama to Sandwich Islands—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1875	° ′ ″		°	°				
*252	July 12	37 52 0 N. 160 17 0 W.	2740	35·3	65·0	Red Clay, reddish or light brown, plastic, fine grained, grey-brown when dry, breaking up with difficulty in water.	trace	...	A few small teeth of fish.
†253	,, 14	38 9 0 N. 156 25 0 W.	3125	35·1	67·7	Red Clay, red-brown when wet, unctuous, yellowish brown when dry, coherent, breaking up with difficulty in water, lustrous streak.	trace	A few *Globigerina inflata*, *Miliolina*.	...
254	,, 17	35 13 0 N. 154 43 0 W.	3025	35·0	72·0	Red Clay, light red-grey when dry, fine grained, coherent, lustrous streak, breaking up with great difficulty in water, plastic, unctuous, light red-brown when wet.	...	...	...
255	,, 19	32 28 0 N. 154 33 0 W.	2850	35·0	74·0	Red Clay, light red-grey when dry, coherent, fine grained, unctuous, plastic, and light red coloured when wet.	...	...	...
‡256	,, 21	30 22 0 N. 154 56 0 W.	2950	35·2	74·0	Red Clay, light red-grey, coherent, fine grained, lustrous streak, breaking up readily in water, dark red-brown when wet.	trace	One or two fragments of *Globigerina*, *Truncatulina pygmæa*.	Small teeth of fish (shark).
257	,, 23	27 33 0 N. 154 55 0 W.	2875	34·9	76·5	Red Clay, light red colour.	...	...	...
258	,, 24	26 11 0 N. 155 12 0 W.	2775	35·2	77·0	Red Clay, brown-grey, coherent, fine grained, breaking up with difficulty in water, red-brown and plastic when wet.	trace	...	A few small teeth of fish (shark).
259	,, 26	23 3 0 N. 156 6 0 W.	2225	34·9	77·0	Red Clay, light brown with red tinge, coherent, fine grained, breaking up in water, dark brown, plastic, and unctuous when wet.	trace	...	Small teeth of fish.

* See anal. 15, 103, 104, 105, 106; Pl. III. figs. 5, 6; Pl. IV. fig. 1; Pl. IX. figs. 7, 7*a*.
† See anal. 16, 107; Pl. IX. figs. 1, 1*a*.
‡ See anal. 17, 108.

Yokohama to Sandwich Islands—*continued.*

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
100·00	(3·00 %), Radiolaria, a few Sponge spicules, Diatoms.	(1·00 %), m. di. 0·08 mm., angular; sanidine, magnetite, hornblende, manganese grains, one microscopic crystal of quartz observed, cosmic spherules.	(96·00 %), amorphous matter, very many fine mineral particles, glassy fragments, and fragments of siliceous organisms.	The deposit does not effervesce when treated with acids, and no carbonate of lime organisms are observed when examined by the microscope, with the exception of a few small teeth of fish. The trawl was much torn when it came up, but contained a quantity of manganese nodules. The nuclei of the nodules consist of pumice, volcanic glass, and *Carcharodon* teeth.
100·00	(2·00 %), Radiolaria, arenaceous Foraminifera, Sponge spicules, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, hornblende, magnetite, manganese, pumice.	(97·00 %), very many fine mineral particles, glassy fragments, fragments of siliceous organisms, some amorphous matter.	A small dredge was used with swabs, and a tow-net was attached to the dredge and another at the weights. There were some clay and manganese nodules in both the dredge and tow-nets. In the washings of a large quantity of this deposit there were observed one or two *Globigerina inflata*, and their broken remains, a few specimens of *Miliolina*, and arenaceous Foraminifera.
100·00	(1·00 %), Radiolaria, Sponge spicules, Diatoms.	(1·00 %), m. di. 0·08 mm., angular; broken down pumice, felspar, glassy volcanic particles, hornblende, palagonite, magnetite.	(98·00 %), much red coloured amorphous matter, fine pumice and minerals, siliceous remains.	A large quantity of the clay came up, and in the water-bottle there was a twin nodule of manganese about 1½ inches (38 mm.) in largest diameter. An upper and lower side of the nodule can be seen; it was covered with a reticulated Rhizopod, probably *Rhizammina algæformis.*
100·00	(1·00 %), Radiolarian fragments.	(1·00 %), m. di. 0·06 mm., angular; pumice, plagioclase, felspar, manganese grains, volcanic glass, hornblende, augite, palagonite, magnetite.	(98·00 %), much amorphous matter, fine mineral particles and a few Radiolarian remains.	The deposit obtained at this station is, in every respect, similar to the previous one. The washings consist largely of broken down pumice. Among the minerals are many manganese grains.
100·00	(1·00 %), Radiolaria, Sponge spicules, *Trochammina trullissata.*	(1·00 %), m. di. 0·08 mm., angular; felspar, volcanic glass, black mica, hornblende, magnetite, manganese grains, palagonite.	(98·00 %), much amorphous matter, fine pumice and other mineral particles and siliceous remains.	A large quantity of the deposit was obtained from the dredge. The greater part was sifted and all passed through the finest sieves, with the exception of some manganese nodules and sharks' teeth, one piece of pumice, about the size of a pigeon's egg, some smaller pieces of pumice, a few worm-tubes, and three or four Foraminifera. The sharks' teeth have a thick coating of manganese. One of the pieces of pumice was red in colour and appeared to be undergoing alteration.
...	...	...	...	The valves of the sounding tube had become jammed and consequently had not opened on reaching the bottom. The outside of the tube was marked for nearly 2 feet with clay of a red colour, and enough was scraped off with the finger for rough examination. This indicated much the same bottom as the last, the great proportion being pumice in a very fine state of division, and there were pieces of black manganese and Radiolarian remains.
100·00	(1·00 %), Sponge spicules, a few Radiolaria, Astrorhizidæ.	(1·00 %), m. di. 0·06 mm., angular; felspar, glassy volcanic particles, magnetite, augite, vesicular lapilli, hornblende, manganese grains.	(98·00 %), much amorphous matter (pumice), mineral and siliceous remains.	About a pint (over half a litre) of the clay of a uniform character came up in the sounding tube. It was of a similar nature to the last two or three soundings.
100·00	(1·00 %), a few Radiolaria, *Rhizammina algæformis, Haplophragmium latidorsatum.*	(1·00 %), m. di. 0·06 mm., angular; vesicular lapilli, plagioclase, felspar, volcanic glass, magnetite, hornblende, augite, palagonite, olivine, glauconite.	(98·00 %), much red-brown amorphous matter, disintegrated pumice, fine minerals, and remains of siliceous organisms.	A considerable quantity of the bottom was obtained in the sounding tube; it was composed chiefly of red and brown amorphous matter, disintegrated pumice, and volcanic ashes. Several pieces of pumice, about the size of a pea, were obtained when washing a quantity of the clay.

See Charts 37 and 38, and Diagram 19.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Yokohama to Sandwich Islands—*continued.*	260	1875 July 27	21° 11′ 0″ N. 157 27 0 W.	310	44°·0	76°·8	Volcanic Mud.	...	...	...
	...	„ 31	Off Honolulu, near the reefs.	20–40	...	...	Coral Sand, light yellow-grey, free, formed chiefly of fragments of calcareous Algæ and Foraminifera. Residue dark grey.	88·64	(3·00 %), Globigerinidæ. (45·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	(40·64 %), *Serpula*, fragments of Gasteropods, Lamellibranchs, and Pteropods, Ostracodes, Echinoderm fragments, Alcyonarian spicules, Polyzoa, calcareous Algæ.
	*...	Aug. 6	Beach Sand, Diamond Point.	...	...	...	Calcareous Sand, light yellow-grey, fine white and brown particles. Residue dark brown-grey.	39·76	(15·00 %), Rotalidæ, Nummulinidæ.	(24·76 %), Gasteropods, Lamellibranch and Echinoderm fragments, calcareous Algæ.
	...	„ 11	Honolulu Harbour.	4½	...	...	Volcanic Mud, dark blue, unctuous, plastic, presenting no macroscopic elements, blue-grey and coherent when dry. Residue black.	10·00	(5·00 %), Miliolidæ, *Bolivina* (several species), Rotalidæ, Nummulinidæ.	(5·00 %), Gasteropod and Lamellibranch fragments, minute portions of calcareous Algæ.
Sandwich Islands to Tahiti.	261	„ 12	20 18 0 N. 157 14 0 W.	2050	35·2	78·5	Volcanic Mud.	...	...	...
	...	„ 19	Hilo Bay, Hawaii.	6	...	...	Volcanic Mud, dark brown, fine grained, breaking up readily in water, slightly coherent. Residue dark brown.	5·00	(2·00 %), Miliolidæ, Rotalidæ.	(3·00 %), Ostracodes, Echini spines, Polyzoa, calcareous Algæ.
	†262	„ 20	19 12 0 N. 154 14 0 W.	2875	35·2	77·5	Volcanic Mud, grey when dry, gritty, breaking up on drying to an almost impalpable powder, brown-grey when wet.	...	...	...
	263	„ 21	17 33 0 N. 153 36 0 W.	2650	35·1	77·5	Volcanic Mud, red-grey, slightly coherent, gritty, presenting no macroscopic elements.	...	...	...
	‡264	„ 23	14 19 0 N. 152 37 0 W.	3000	35·2	77·5	Red Clay, light red-grey, coherent, fine grained, presenting no macroscopic elements, breaking up with difficulty in water, red-brown when wet.	trace	...	A few teeth of fish, Cephalopod beaks.

* See Pl. XXVI. fig. 5. † See Pl. XXVII. fig. 1. ‡ See anal. 109.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
...	...	...	...	No trace of any kind came up in the tube to indicate the nature of the bottom. In the trawl were a piece of black volcanic ash and a portion of branching coral (*Gorgonia*); on the iron of the beam was a trace of calcareous volcanic mud.	Yokohama to Sandwich Islands—*continued*.
11·36	(3·00 %), Sponge spicules, Lituolidæ, Diatoms.	(2·00 %), m. di. 0·10 mm., rounded; volcanic glass, felspar, magnetite, mica, hornblende, augite, palagonite, pumice.	(6·36 %), a small quantity of flocculent amorphous matter, mineral and siliceous remains.	All the minerals are of volcanic origin.	
60·24	(1·00 %), one or two Diatoms.	(58·00 %), m. di. 0·40 mm., angular and rounded; olivine, felspar, augite, hornblende, magnetite.	(1·24 %), amorphous flocculent matter and a few mineral remains, a few fragments of Diatoms.	The white and red particles making up the sand are rounded, and measure about 1 mm. in diameter. The minerals consist almost exclusively of unaltered crystals of olivine, and some vitreous particles.	
90·00	(1·00 %), Sponge spicules, one or two Diatoms.	(5·00 %), m. di. 0·08 mm., angular; magnetite, plagioclase, felspar, hornblende, augite, brown volcanic glass, pumice, palagonite.	(84·00 %), a considerable quantity of blue coloured amorphous matter and minute mineral particles.	The mud here described came up on the anchor. It is of a dark blue colour and contains several varieties of small Foraminifera and many small calcareous particles mixed up with debris of volcanic rocks and ashes, and coal from ships. The blue mud extends only as far as the reef, for just outside there is a pure Coral Sand. On treatment with acid a large quantity of sulphuretted hydrogen is liberated.	
...	...	...	...	The tube came up quite empty, but on the outside, one foot above the valves, there was a slight trace of a reddish mud, containing many black and white mineral particles and many remains of siliceous organisms, including Diatoms. One piece of *Globigerina* was the only evidence of carbonate of lime.	Sandwich Islands to Tahiti.
95·00	(3·00 %), Sponge spicules and Diatoms.	(20·00 %), m. di. 0·10 mm., angular; magnetite, plagioclase, augite, olivine, glassy volcanic particles, palagonite.	(72·00 %), a considerable quantity of minute mineral fragments, some amorphous matter, and a few remains of siliceous organisms.	The mud is chiefly composed of volcanic debris.	
100·00	(2·00 %), Radiolaria, Sponge spicules, *Haplophragmium latidorsatum*, Diatoms.	(70·00 %), m. di. 0·12 mm., angular; olivine, brown splinters of volcanic glass, plagioclase, augite, magnetite.	(28·00 %), many fine mineral particles, a small quantity of amorphous matter.	Only a small quantity of the deposit came up in the tube. This consisted chiefly of volcanic debris; some green crystalline particles had a coating of dull black.	
100·00	(3·00 %), Radiolaria, Sponge spicules, *Haplophragmium latidorsatum*, *Trochammina trullissata*, Diatoms.	(50·00 %), m. di. 0·08 mm., angular; brown volcanic glass, plagioclase, magnetite, augite, hornblende, olivine, phillipsite.	(47·00 %), fine minerals, some amorphous matter, and some siliceous remains.	The deposit consists mainly of volcanic debris, much finer than at the previous station. There is also less olivine here than in the previous deposit.	
100·00	(1·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, palagonite, magnetite, hornblende, augite, black mica, phillipsite.	(98·00 %), much fine amorphous matter, remains of minerals and siliceous organisms.	The valves of the sounding tube had not opened, and consequently it contained no deposit. The tube was coated on the outside for about two feet with Red Clay; this was scraped off and subjected to examination, but gave no indication of carbonate of lime. Palagonite was abundant. In the bag of the trawl were seven or eight small manganese nodules, and some small hardened pieces of the bottom, but no clay proper. Some pieces of the bottom had a slight coating of manganese, while others were perforated by worms, the tracks of which were, in some cases, coated with manganese. The manganese nodules were not of the usual rounded character but were very irregular. In addition to these there were small sharks' teeth and Cephalopod beaks.	

See Chart 38, and Diagram 19.

Sandwich Islands to Tahiti—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1875	° ′ ″		°	°				
*265	Aug. 25	12 42 0 N. 152 1 0 W.	2900	35·0	79·2	RADIOLARIAN OOZE, red-brown or chocolate coloured, soft to the touch, homogeneous, reddish when dry, breaking up with difficulty in water, coherent, pulverising to impalpable powder, lustrous streak.	trace	Fragments of *Globigerina* and *Pulvinulina.*	...
†266	,, 26	11 7 0 N. 152 3 0 W.	2750	35·1	80·0	RADIOLARIAN OOZE, light grey, coherent, gritty, breaking up with difficulty in water, red-brown when wet.	trace	...	Small teeth of fish.
267	,, 28	9 28 0 N. 150 49 0 W.	2700	35·0	80·0	RADIOLARIAN OOZE, light yellow-grey, fine, coherent, presenting no macroscopic elements, yellow-red when wet.	trace	Fragments of *Pullenia obliquiloculata.*	...
‡268	,, 30	7 35 0 N. 149 49 0 W.	2900	34·8	81·0	RADIOLARIAN OOZE, red-brown when wet, fine grained, red-grey when dry, breaking up on the lightest touch to an almost impalpable powder.	trace	...	One or two small teeth of fish.
269	Sept. 2	5 54 0 N. 147 2 0 W.	2550	35·2	81·2	RADIOLARIAN OOZE, brown when wet, fine grained, coherent, light yellow-grey when dry, presenting no macroscopic elements. **Residue** red-brown.	20·00	(17·00 %), Globigerinidæ, *Pulvinulina tumida.* (1·00 %), *Pullenia quinqueloba,* Rotalidæ, *Nonionina umbilicatula.*	(2·00 %), small teeth of fish, Ostracode valves, Echini spines.
270	,, 4	2 34 0 N. 149 9 0 W.	2925	34·6	79·5	GLOBIGERINA OOZE, white with light yellow tinge, slightly coherent, chalky. **Residue** pale fawn.	71·47	(65·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Lagenidæ, Rotalidæ.	(5·47 %), small teeth of fish, Echini spines, Coccoliths.
§271	,, 6	0 33 0 S. 151 34 0 W.	2425	35·0	78·7	GLOBIGERINA OOZE, white, slightly coherent, chalky. **Residue** pale fawn.	81·27	(70·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·27 %), small teeth of fish, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths.
272	,, 8	3 48 0 S. 152 56 0 W.	2600	35·1	79·0	RADIOLARIAN OOZE, brown-grey, slightly coherent when dry, dark red-brown when wet. **Residue** dark red-brown.	10·19	(8·00 %), Globigerinidæ, *Pulvinulina tumida.*	(2·19 %), teeth of fish, Echini spines, Coccoliths.
273	,, 9	5 11 0 S. 152 56 0 W.	2350	34·5	80·7	RADIOLARIAN OOZE, brown-grey when dry, slightly coherent, fine grained, presenting no macroscopic elements, dark brown when wet. **Residue** dark red-brown.	2·00	(1·00 %), Globigerinidæ, *Pulvinulina tumida.*	(1·00 %), teeth of fish, Coccoliths.

* See anal. 28. † See anal. 30. ‡ See Pl. XV. fig. 4 § See Pl. XV. figs. 2*a*, 2*b*.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
100·00	(50·00 %), Radiolaria, very few arenaceous Foraminifera, Sponge spicules, casts of organisms, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, augite, hornblende, magnetite, small prismatic zeolitic crystals, manganese grains, magnetic spherules.	(49·00 %), amorphous matter, minute fragments of pumice and other minerals, fragments of siliceous organisms.	The dredge and the two tow-nets attached to it came up filled with the dark coloured ooze, from which were obtained a few small pieces of pumice and one manganese nodule. One or two fragments of *Globigerina* and *Pulvinulina* were the only calcareous organisms observed. There are very many remains of *Ethmodiscus*.
100·00	(55·00 %), Radiolaria, Sponge spicules, *Haplophragmium latidorsatum*, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; felspar, very few volcanic particles.	(44·00 %), much amorphous matter, Radiolarian and other siliceous remains, some fine mineral particles.	The most of the ooze was of a red-brown colour, but there were some very light spots. Remains of *Ethmodiscus* are abundant.
100·00	(50·00%), Radiolaria, Sponge spicules, *Trochammina galeata*, Diatoms.	(1·00 %), m. di. 0·13 mm., angular; felspar, manganese grains, magnetite, volcanic particles.	(49·00 %), much fine amorphous matter, Radiolarian and other siliceous remains, some mineral particles.	Only a small quantity came up in the sounding tube, much lighter in colour than in the last few soundings. Much of the ooze was rolled in little pellets. Many manganese grains were observed, one (broken) larger than a good sized marble.
100·00	(65·00 %), Radiolaria, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, palagonite, manganese grains, black mica, glassy volcanic particles.	(34·00 %), Radiolarian remains, amorphous matter, and a few mineral particles.	About a pint (over half a litre) of ooze of a red-brown colour came up in the tube; near the top were some straw-coloured patches. The difference between the layer seems to be due to the manganese. One spherical granulated manganese grain, about the size of a pea, was noticed.
80·00	(50·00 %), Radiolaria, Sponge spicules, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·10 mm., angular; manganese grains, glassy particles, felspar, analcim, palagonite, magnetite.	(29·00 %), Radiolarian remains, amorphous matter, and some fine mineral fragments.	In the upper part of the tube were some yellow coloured patches indicating a surface layer about an inch in thickness. The colour appears to be due to the smaller number of manganese grains in the upper layer. The Foraminifera are much corroded.
28·53	(5·00 %), Radiolaria, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; a few glassy volcanic particles, felspar, one or two manganese grains.	(22·53 %), fine amorphous matter and remains of siliceous organisms.	There were about six inches (15 cm.) of ooze in the tube, the lower part pure white and gradually becoming brown on the upper surface. The white lower layer is a nearly pure Globigerina Ooze, while the upper brown layer seems to be composed of equal parts of siliceous and calcareous organisms. Coccoliths are abundant.
18·73	(10·00 %), Radiolaria, Sponge spicules (*Hyalonema*), Astrorhizidæ, Lituolidæ, Textularidæ, Diatoms.	...	(8·73 %), amorphous matter and siliceous remains.	In the washings from the trawl were some large deep-sea Keratosa, and a fragment of pumice about the size of a pigeon's egg.
89·81	(60·00 %), Radiolaria, Astrorhizidæ, Diatoms.	(1·00 %), m. di. 0·15 mm., angular; magnetite, palagonite, mica, glassy volcanic particles, felspar, phillipsite.	(28·81 %), Radiolarian remains, amorphous matter, and some minute mineral fragments.	Compare this with the deposit obtained on August 30th. It is dark red-brown in colour, showing light coloured patches at the upper surface. In the trawl there were a rounded piece of pumice, slightly impregnated with manganese, and two or three irregular manganese nodules which, on breaking, presented nuclei of pumice.
98·00	(30·00 %), Radiolaria, Diatoms.	(1·00 %), m. di. 0·15 mm., angular; phillipsite, rounded manganese grains, volcanic particles.	(67·00 %), much amorphous matter, Radiolarian remains, and fine mineral fragments.	The *Globigerinæ* are large, but much broken. There are present a great number of manganese grains, some of them of considerable size.

See Charts 38 and 39, and Diagram 19.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Sandwich Islands to Tahiti—*continued.*	*274	1875 Sept. 11	7° 25′ 0″ S. 152 15 0 W.	2750	35°·1	80°·2	RADIOLARIAN OOZE, red-brown or chocolate coloured, fine grained, unctuous, yellow-red when dry, slightly coherent, earthy, clayey, characters not well pronounced. **Residue** red.	3·89	(2·00 %), fragments of *Globigerina* and *Pulvinulina.*	(1·89 %), a few small teeth of fish, Gasteropods.
	†275	„ 14	11 20 0 S. 150 30 0 W.	2610	35·0	80·0	RED CLAY, when wet dark red or deep chocolate coloured, gritty, deep brown when dry, slightly coherent, earthy.	trace	...	Small teeth of fish.
	‡276	„ 16	13 28 0 S. 149 30 0 W.	2350	35·1	80·0	RED CLAY, brown when dry, slightly coherent, pulverising easily into a granular powder, earthy, sublustrous streak. **Residue** dark brown or chocolate coloured.	28·28	(25·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(2·28 %), teeth of fish, Cephalopod beaks, Gasteropods, Ostracodes, Echini spines.
	277	„ 17	15 51 0 S. 149 41 0 W.	2325	35·1	79·0	RED CLAY, light red-grey, coherent, fine grained, chocolate coloured and plastic when wet. **Residue** chocolate coloured.	9·43	(7·00 %), Globigerinidæ, *Pulvinulina tumida.* (1·00 %), *Biloculina depressa, Lagena,* Rotalidæ, *Nonionina umbilicatula.*	(1·43 %), teeth of fish, Echini spines.
	278	„ 18	17 12 0 S. 149 43 0 W.	1525	36·5	79·5	VOLCANIC MUD, grey when dry, slightly coherent, gritty, grey-blue when wet. **Residue** black.	20·47	(10·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Textularidæ, Lagenidæ, Rotalidæ.	(7·47 %), *Serpula,* Gasteropods (larval), Lamellibranch and Pteropod fragments, Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
Off Tahiti.	...	„ 28	Papiete Harbour.	20	...	...	CORAL SAND, grey, made up of white and black particles fine grained. **Residue** black.	83·34	(5·00 %), Miliolidæ, Textularidæ, Rotalidæ, Nummulinidæ.	8·34 %), *Serpula,* Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, Alcyonarian spicules, Coral fragments, calcareous Algæ.
	279	Oct. 2	17 30 26 S. 149 33 45 W.	420	...	79·0	VOLCANIC MUD, blue-grey when dry, slightly coherent, dark blue when wet. **Residue** black.	22·30	(7·00 %), Globigerinidæ. (7·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·30 %), Otoliths of fish, *Serpula,* Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Polyzoa, Coral fragments, Alcyonarian spicules, Coccoliths.
	279A	„ 2	17 29 53 S. 149 34 0 W.	590	...	79·0	VOLCANIC MUD, blue-grey, slightly coherent, breaking up readily in water, dark blue and plastic when wet. **Residue** blue.	25·28	(5·00 %), Globigerinidæ. (10·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(10·28 %), Otoliths of fish, *Serpula,* Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm and Coral fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.

* See anal. 29, 110, 111, 112; Pl. IV. fig. 2; Pl. VI. figs. 8, 11, 11*a*, 16, 16*a*; Pl. VIII. figs. 4, 5, 12, 13; Pl. IX. figs. 2, 5, 6, 10; Pl. XXIII. fig. 12.
† See anal. 18, 89, 90, 91.
‡ See anal. 19, 20, 21, 83, 92, 93, 94, 113, 114, 115 116, 136; Pl. IV. figs. 6, 7, 8; Pl. V. fig. 12; Pl. VI. figs. 1, 1*a*, 19; Pl. VII. figs. 6, 7; Pl. IX. fig. 8; Pl. XVI. fig. 1; Pl. XVIII. figs. 2, 3, 4; Pl. XIX. figs. 1, 2, 4; Pl. XXI. fig. 1; Pl. XXII. figs. 1, 2, 3, 4; Pl. XXIII. figs. 2, 3, 5, 6, 7, 9.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
96·11	(50·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Sponge spicules, Diatoms.	(5·00 %), m. di. 0·08 mm., angular; felspar, augite, magnetite, magnetic spherules, manganese grains, many small prismatic crystals of phillipsite, pumice.	(41·11 %), very many small crystals of phillipsite, fragments of pumice and siliceous organisms, relatively little amorphous matter.	The trawl and attached tow-nets contained a few animals, much ooze, a quantity of manganese nodules, some earbones of Cetaceans, sharks' teeth, and pumice fragments. The nucleus of one nodule is composed of amorphous clayey matter, bordered with zeolitic crystals. A glassy volcanic pebble, the outer rim transformed into palagonite, was also obtained.	Sandwich Islands to Tahiti—*continued.*
100·00	(1·00 %), a few fragments of Radiolaria and arenaceous Foraminifera.	(10·00 %), m. di. 0·20 mm., angular and rounded; almost exclusively made up of crystals of phillipsite, augite, felspar, magnetite, manganese.	(89·00 %), composed essentially of small crystals of phillipsite, small manganese grains, and amorphous matter.	Not a single fragment of pelagic Foraminifera can be observed; there are, however, a few arenaceous Foraminifera, and a good many small teeth of fish, but only a few Radiolaria. The crystals of phillipsite are frequently grouped so as to form small yellowish or dark globules made up of a more or less considerable number of microliths. One small fragment of quartz was observed.	
71·72	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Sponge spicules.	(5·00 %), m. di. 0·15 mm., angular; phillipsite spherules, felspar, plagioclase, augite, hornblende, magnetite, glassy volcanic fragments, manganese, magnetic spherules.	(65·72 %), very many small crystals of phillipsite, fragments of other minerals, manganese and amorphous matter.	The trawl brought up about half a ton (508 kilogrammes) of manganese nodules,* some small pieces of pumice, some angular basaltic pebbles, many sharks' teeth (one very large); some of these are thickly and others slightly coated with manganese. The most numerous minerals are crystals or globules of phillipsite, which sometimes have a diameter of 0·20 mm. The percentage of carbonate of lime is the mean of two analyses.	
90·57	(1·00 %), Radiolaria, Sponge spicules, *Rhizammina algæformis*, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; magnetite, volcanic glass, palagonite, felspar.	(88·57 %), much amorphous matter, mineral and siliceous remains.	The deposit in the lower part of the tube was of a chocolate colour, and contained only traces of carbonate of lime (small teeth) and no Radiolaria or Diatoms. The mud in the upper part was of a light grey colour, the transition between the two being gradual. In the upper layer the organisms mentioned were observed.	
79·53	(3·00 %), Radiolaria, Sponge spicules, *Hyperammina ramosa*, Lituolidæ, arenaceous Textularidæ.	(20·00 %), m. di. 0·10 mm. angular; altered volcanic glass, augite, plagioclase, felspar, a great number of black volcanic particles some of them magnetic.	(56·53 %), many fine mineral particles, amorphous matter, and fine remains of siliceous organisms.	The minerals are all volcanic.	
16·66	(2·00 %), Sponge spicules, Lituolidæ, arenaceous Textularidæ, a few Diatoms.	(12·00 %), m. di. 0·20 mm., rounded; quartz, felspar, augite, hornblende, glassy volcanic fragments, magnetite, manganese grains, titanite.	(2·66 %), amorphous matter, and a few remains of minerals and siliceous organisms.	The bulk of the deposit is made up of fragments of corals. These and the other particles measure 0·5 mm. in diameter.	Off Tahiti.
77·70	(2·00 %), Sponge spicules, Lituolidæ, arenaceous Textularidæ, Diatoms.	(15·00 %), m. di. 0·10 mm., angular; plagioclase, felspar, augite, olivine, magnetite, volcanic rock fragments, palagonite.	(60·70 %), many mineral fragments, amorphous matter, and siliceous remains.	This sounding is 705 fathoms from the edge of the reef.	
74·72	(2·00 %), Sponge spicules, Lituolidæ, arenaceous Textularidæ, Diatoms.	(15·00 %), m. di. 0·10 mm., angular; volcanic glass, olivine, plagioclase, felspar, magnetite, augite, hornblende.	(57·72 %), many minute mineral particles, amorphous matter, and fine siliceous remains.	Not much of the deposit was brought up. The upper layer was slightly red, but otherwise the bottom is similar to that taken in 420 fathoms.	

* The nuclei of the nodules consist of fragments of basaltic rocks or lapilli, vitreous and generally vesicular, the vesicles coated with green delessite and chabasite, and prismatic zeolites; dolerite; augite-andesite; palagonite; clayey matter; sharks' teeth and bones of Cetaceans. Sometimes palagonite is seen transforming into clayey matter. In all cases these nuclei are very much altered. The nodules were mostly from 1 to 2 cm. in diameter.

See Charts 38 and 39, and Diagram 19.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
		1875	° ′ ″		°	°				
Off Tahiti—*continued.*	279B	Oct. 2	17 29 38 S. 149 34 7 W.	620	...	79·0	VOLCANIC MUD, green-grey, plastic when wet, grey when dry, slightly coherent, breaking up readily in water. **Residue green.**	22·66	(5·00 %), Globigerinidæ. (9·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·66 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Coral fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
	279C	,, 2	17 29 11 S. 149 34 32 W.	680	...	79·0	VOLCANIC MUD, blue-grey, slightly coherent, plastic and green coloured when wet. **Residue green.**	19·47	(7·00 %), Globigerinidæ. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(7·47 %), Otoliths of fish, *Serpula*, Gasteropods, Lamellibranchs, Pteropods, Heteropods, Ostracodes, Echinoderm and Coral fragments, Polyzoa, Alcyonarian spicules, calcareous Algæ, Coccoliths, Rhabdoliths.
Tahiti to Valparaiso.	280	,, 4	18 40 0 S. 149 52 0 W.	1940	35·3	77·2	GLOBIGERINA OOZE, grey with red tinge, slightly coherent, breaking up in water, yellow-brown when wet. **Residue** black.	53·36	(45·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), *Biloculina depressa*, Lagenidæ, *Truncatulina*, *Nonionina umbilicatula*.	(6·36 %), teeth of fish, Gasteropods, Lamellibranch fragments, Echini spines, Coccoliths, Rhabdoliths.
	*281	,, 6	22 21 0 S. 150 17 0 W.	2385	34·9	74·5	RED CLAY, red when dry, gritty, slightly coherent, breaking up in water to fine powder, red-brown when wet.	trace	a few Miliolidæ.	..
	†282	,, 7	23 46 0 S. 149 59 0 W.	2450	35·1	73·2	RED CLAY, red when dry, gritty, slightly coherent, breaking up in water to fine powder, red-brown when wet.	trace	...	A few small teeth of fish.

* See anal. 22, 26, 117, 118, 119; Pl. IV. figs. 3, 4, 5; Pl. V. figs. 1, 1*a*, 2, 3, 3*a*, 4, 5, 5*a*, 13; Pl. VI. figs. 9, 9*a*, 10, 10*a*, 13, 13*a* 15, 15*a*, 17; Pl. XXI. fig. 2.
† See Pl. XXVI. fig. 2.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
77·34	(2·00 %) Sponge spicules, Astrorhizidæ, Lituolidæ, arenaceous Textularidæ, Diatoms.	(15·00 %), m. di. 0·10 mm., angular; volcanic glass, plagioclase, felspar, magnetite, hornblende, augite, mica.	(60·34 %), many fine mineral fragments, amorphous matter, and remains of siliceous organisms.	A considerable quantity of the mud was obtained, similar in every respect to the last. The upper layer was distinctly red.	Off Tahiti—*continued.*
80·53	(2·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ, arenaceous Textularidæ, Diatoms.	(40·00 %), m. di. 0·08 mm., angular; altered volcanic glass, plagioclase, felspar, magnetite, augite, black volcanic particles some of them magnetic.	(38·53 %), many fine mineral particles, amorphous matter, and minute remains of siliceous organisms.	The deposit is similar to the three preceding ones, the minerals being finer and more angular. There was a red coloured surface layer in this as in the last.	Off Tahiti—*continued.*
46·64	(2·00 %), Radiolaria, Sponge spicules, *Rhizammina*, Lituolidæ, casts of calcareous organisms, Diatoms.	(25·00 %), m. di. 0·10 mm., angular; plagioclase, augite, hornblende, mica, olivine, magnetite, fragments of volcanic rocks, manganese grains.	(19·64 %), amorphous matter, fine mineral and siliceous remains.	Two soundings were taken. After treatment with acid there remain very perfect casts of the organisms in a red coloured material which also covers the shells. All the mineral particles are covered with a thin coating of manganese and iron. In the washings from the tow-net there were some fragments of volcanic rock in a high state of decomposition. There were also in the tow-net two or three manganese nodules, one about two inches (5 cm.) long and very irregular. These nodules seem to be formed of portions of the bottom and are perforated in all directions by worm-tubes. In the sounding tube was a piece of wood perforated by worms. One of the nodules had a nucleus composed of clay and of volcanic ashes; among this volcanic débris were fragments of green hornblende, reddish augite, plagioclase, and magnetite. These minerals are imbedded in a mass which appears in some places to be zeolitic.	Tahiti to Valparaiso.
100·00	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ.	(50·00 %), m. di. 0·12 mm., angular and rounded; magnetite, palagonite, hornblende, augite, felspar, phillipsite, black mica.	(48·00 %), amorphous red coloured matter, many fine mineral particles, and remains of siliceous organisms.	No deposit was obtained in or on the sounding tube. In the bag of the trawl, however, there were about two gallons (9 litres) of Red Clay. In the washings there was a great number of dark red and brown spherical and irregular bodies, which are coated with a substance of a zeolitic nature. In the trawl was an immense number of manganese nodules and sharks' teeth. Some of the manganese nodules, measure 18 × 12 × 3 inches (45 × 30 × 7·5 cm.). These, along with most of the smaller ones, have only a slight coating of manganese, the interior being filled with a volcanic tufa. Among the nodules are several fragments of pumice passing into clayey matter. The nodules were overgrown with *Hyperammina vagans* and other Rhizopods. There appears to be evidence that volcanic disturbances have taken place at the bottom near this locality.	Tahiti to Valparaiso.
100·00	(2·00 %), Sponge spicules, Radiolaria, *Rhizammina algæformis*, Lituolidæ, Diatoms.	(50·00 %), m. di. 0·15 mm., rounded; palagonite, plagioclase very abundant, augite microliths, magnetic particles, great number of small rounded red transparent grains some of them palagonite, or altered olivine, or felspar coated with iron and manganese.	(48·00 %), much fine red or chocolate coloured matter, many fine mineral fragments, and remains of siliceous organisms.	Only a small quantity of the deposit, similar in every respect to that obtained at the previous station, came up in the tube. The greater part of the washings was composed of the red and yellow rounded bodies noticed on the 6th. There were many fragments of manganese, and several small pieces of pumice.	Tahiti to Valparaiso.

See Chart 38, and Diagram 19.

Tahiti to Valparaiso—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1875	° ′ ″		°	°				
283	Oct. 9	26 9 0 S. 145 17 0 W.	2075	35·4	68·5	GLOBIGERINA OOZE, grey, slightly coherent, chalky, brown when wet. Residue dark brown.	46·61	(40·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, *Cassidulina subglobosa*, Lagenidæ, Rotalidæ.	(3·61 %), small teeth of fish, Echini spines, Coccoliths, Rhabdoliths.
284	" 11	28 22 0 S. 141 22 0 W.	1985	35·1	68·0	GLOBIGERINA OOZE, white with yellow tinge, slightly coherent, chalky, yellow when wet. Residue red-brown.	65·81	(50·00 %), Globigerinidæ, *Pulvinulina*. (1·00 %), Miliolidæ, Lagenidæ, Textularidæ, Rotalidæ, *Nonionina umbilicatula*.	(14·81 %), Otoliths of fish, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
*285	" 14	32 36 0 S. 137 43 0 W.	2375	35·0	65·0	RED CLAY, dark red-brown when dry, coherent, plastic and dark brown when wet. Residue dark brown.	26·25	(20·00 %), Globigerinidæ. (1·00 %), *Cassidulina subglobosa*, *Lagena lævis* (?), Rotalidæ.	(5·25 %), sharks' teeth, larval Lamellibranchs, Polyzoa, Coccoliths, Rhabdoliths.
†286	" 16	33 29 0 S. 133 22 0 W.	2335	34·8	63·0	RED CLAY, reddish yellow, slightly coherent, plastic and red-brown when wet. Residue dark red-brown.	25·13	(15·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, *Nonionina umbilicatula*.	(7·13 %), fragments of teeth of fish, Ostracodes, Coccoliths, Rhabdoliths.
287	" 19	36 32 0 S. 132 52 0 W.	2400	34·7	57·8	RED CLAY, chocolate brown colour, unctuous, plastic, coherent, lustrous streak. Residue chocolate brown.	[1·00]	Globigerinidæ, *Pulvinulina*, *Uvigerina*.	Small teeth of fish.

* See anal. 23, 81, 82, 120, 121, 122, 123, 124, 125, 137, 138, 139, 140, 143, 149; Pl. II. figs. 5, 7; Pl. V. figs. 6, 7, 7*a*, 10, 11; Pl. VI. figs. 2, 2*a*, 3, 3*a*, 4, 4*a*, 5, 5*a*, 6, 6*a*, 7, 7*a*, 12, 12*a*, 18, 20, 21, 23; Pl. VII. fig. 1; Pl. XVI. fig. 3; Pl. XVII. fig. 1; Pl. XVIII. fig. 1; Pl. XXIII. figs. 1, 4, 8; Pl. XXVIII. fig. 3; Pl. XXIX. figs. 1, 2, 3, 4.

† See anal. 27, 75, 78, 126, 127, 128, 141, 142, 144, 145, 146, 148, 150, 151, 152, 153; Pl. II. fig. 6; Pl. V. figs. 8, 9; Pl. VI. figs. 14, 14*a*, 22; Pl. VII. figs. 2, 3, 4, 5; Pl. VIII. figs. 1, 2, 3, 6, 7, 8, 9, 9*a*, 14, 14*a*; Pl. X. figs. 1, 1*a*, 1*b*, 2, 2*a*, 3, 4, 4*a*, 5.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
53·39	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ, Diatoms.	(10·00 %), m. di. 0·10 mm., angular; plagioclase, augite, phillipsite, magnetite, manganese grains, glassy volcanic particles.	(42·39 %), much amorphous matter, fine mineral fragments, and remains of siliceous organisms.	Nearly a foot (30 cm.) of the deposit came up in the tube; the upper surface was a light yellow Globigerina Ooze. In addition to the observed organisms, there were a good many manganese grains, and yellow and red crystals. Passing down the tube the ooze became gradually darker, till at the bottom there was a dark chocolate coloured clay, containing manganese in rounded pellets, and many yellow crystals (phillipsite); some of these are in the form of balls. Twinned crystals of phillipsite were observed.
34·19	(10·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, arenaceous Textularidæ, Diatoms.	(1·00 %), m. di. 0·08 mm., angular; volcanic glass, felspar, palagonite, hornblende, phillipsite, black mica, magnetite.	(23·19 %), fine amorphous matter, minute mineral and siliceous remains.	Many of the Foraminifera are coated on the outside with a deposit of a crystalline nature; all stages of this deposition can be seen in the deposit. *Pulvinulina menardii* is absent. Coccoliths and Rhabdoliths are very abundant.
73·75	(1·00 %), a few Radiolaria, one or two Sponge spicules, *Rhizammina algæformis* (fragments), Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; glassy volcanic particles, felspar, olivine, augite, palagonite, phillipsite, hornblende, magnetite, cosmic spherules.	(71·75 %), much fine amorphous matter, a few minute fragments of minerals and siliceous remains.	Only a small quantity came up in the sounding tube. Crystals of phillipsite are present, as on the 9th. Manganese grains are abundant. The trawl brought up some clay and a barrelful of manganese nodules. Among these were numerous sharks' teeth, and eight or nine earbones of Cetaceans. The bony material of the teeth has been completely removed. Some of the nuclei of the nodules are altered basaltic fragments, others volcanic glass, others augite-andesite or hornblende-andesite. All the glassy fragments are cemented to the manganese coating by zeolites crystallised *in situ*. There are some angular pebbles, generally basalt or augite-andesite, and rounded ones of granite or fragments of clastic rocks composed of quartz, decomposed felspar, and mica (arkose).
74·87	(1·00 %), a few Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, arenaceous Textularidæ.	(1·00 %), m. di. 0·06 mm., angular; manganese grains, magnetite, palagonite, felspar, olivine, augite, a few glassy volcanic particles, magnetic spherules.	(72·87 %), much fine amorphous matter, minute mineral and siliceous remains.	Two layers were to be observed in the contents of the sounding tube. The upper two inches were very dark red, the lower four or five inches light yellow, smooth, and firm. In the top layer only a few Foraminifera and Radiolaria were present, a sample scarcely effervescing with acid. The lower layer, however, effervesced considerably, and the microscope revealed a few Foraminifera and immense numbers of very fine Coccoliths. There is much less manganese in the lower than in the upper layers. The trawl brought up large numbers of manganese nodules, sharks' teeth, earbones of Cetaceans, one or two pieces of pumice, and a granite nodule 3 × 2 × ½ inches (7·5 × 5 × 1·2 cm.). There were also some clayey concretions of the bottom, perforated by worm-tubes, lined with manganese.
[99·00]	...	(2·00 %), m. di. 0·10 mm., angular; fibro-radiating globules and loose crystals of phillipsite, sanidine, plagioclase, augite, magnetite, magnetic spherules, small concretions of manganese, and fragments of volcanic glass and rocks.	(97·00 %), a large quantity of clayey matter, coloured by manganese, very small crystals of phillipsite, and minute mineral particles.	About a quart of this deposit came up, containing an immense quantity of manganese, several of the nodules measuring from 0·5 to 1 cm. in diameter. In one or two instances these nodules are joined together. The Foraminifera are fragmentary except *Uvigerina asperula*, which is the most commonly occurring. The crystals of phillipsite are very abundant in this deposit. Among the mineral particles are a number of small volcanic fragments, which appear opaque under the microscope. Associated with these there are small volcanic particles altered to brownish palagonite.

Tahiti to Valparaiso—*continued*.

See Chart 38, and Diagrams 19 and 20.

Tahiti to Valparaiso—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1875	° ′ ″		°	°				
288	Oct. 21	40 3 0 S. 132 58 0 W.	2600	34·8	54·5	Red Clay, brown-grey, very coherent, presenting no macroscopic characters, dark red-brown and plastic when wet.	trace	*Globigerina* (fragments).	A few small teeth of fish.
*289	" 23	39 41 0 S. 131 23 0 W.	2550	34·8	54·5	Red Clay, pale brown-grey, coherent, fine grained, dark red-brown and plastic when wet.	...	...	...
290	" 25	39 16 0 S. 124 7 0 W.	2300	34·9	52·5	Red Clay, light brown-grey, coherent, fine grained.	...	...	..
291	" 27	39 13 0 S. 118 49 0 W.	2250	34·6	53·0	Red Clay, light brown-grey, coherent, fine grained.	...	...	..
292	" 29	38 43 0 S. 112 31 0 W.	1600	35·2	53·2	Globigerina Ooze, light brown-grey, slightly coherent. Residue red-brown, very fine.	83·75	(75·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Rotalidæ.	(6·75 %), fragments of Lamellibranchs, Ostracode valves, Echini spines, Coccoliths, Coccospheres.
†293	Nov. 1	39 4 0 S. 105 5 0 W.	2025	34·4	53·7	Globigerina Ooze, brown, coherent, dark red-brown or chocolate coloured and plastic when wet. Residue dark brown.	44·68	(35·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, *Nonionina umbilicatula*.	(6·68 %), Ostracode valves, Echini spines, Coccoliths, Rhabdoliths.
‡294	" 3	39 22 0 S. 98 46 0 W.	2270	34·6	57·5	Red Clay, chocolate coloured when dry, coherent, homogeneous, rich chocolate colour and plastic when wet.	trace	Globigerinidæ (fragments), *Uvigerina asperula*, Rotalidæ.	A few small teeth of fish.

* See anal. 129, 147; Pl. III. fig. 7; Pl. IX. fig. 3. † See anal. 47, 130; Pl. XVII. fig. 2; Pl. XIX. fig. 3. ‡ See Pl. XXVII. fig. 4.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
100·00	(1·00 %), Radiolaria, Sponge spicules, *Thurammina papillata.*	(1·00 %), m. di. 0·10 mm., angular; manganese grains, phillipsite, felspar, augite, glassy volcanic particles.	(98·00 %), much dark brown fine amorphous matter, a few fragments of siliceous organisms, and manganese grains.	The clay was not so dark coloured as at the last station. In one place there were one or two spots of a yellow colour. A few small manganese nodules overgrown with *Hyperammina vagans* were observed. The tube had been buried about 18 inches (45 cm.) in the deposit.
100·00	(1·00 %), a few Radiolaria.	(1·00 %), m. di. 0·20 mm., angular; magnetite, augite, olivine, felspar.	(98·00 %), much fine dark brown amorphous matter, manganese grains, and minute mineral particles.	No bottom was in the tube or on the outside. The trawl brought up a great quantity of manganese nodules, but no deposit; on the iron work were some patches of clay. On examining this it was found to contain very many yellow crystals of phillipsite, a few pelagic Foraminifera and their broken parts, and a few Coccoliths and Rhabdoliths. A great many manganese grains were noticed. Among the nodules in the trawl were a few earbones of Cetaceans and fragments of bones. One pebble was a fragment of diabase containing altered plagioclase, augite, replaced by a chloritic mineral, quartz, epidote, black mica, titanic iron and leucoxene.
...	...	...	...	No deposit came up in the tube. About a gramme of the clay was found adhering to the bottom of the water-bottle, insufficient for detailed examination. Under the microscope it showed the yellow crystals of phillipsite, manganese grains, some Coccoliths, a good many fragments of pelagic Foraminifera, and a *Uvigerina.*
...	...	.	...	Inside the tube there were two or three small pellets of Red Clay. On breaking these down and examining them with the microscope, *Globigerina* and *Pulvinulina* remains were found. These are small compared with those further north. One or two *Textularia*, a good many Coccoliths, portions of Rhabdoliths, a good many manganese grains, and a few yellow crystals of phillipsite were also observed. In the bag of the trawl there was only one manganese nodule, the size of a marble, to which was attached an egg capsule.
16·25	(1·00 %), Sponge spicules, a few Radiolaria and arenaceous Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; crystals and irregular fragments of plagioclase, sanidine, augite, rhombic pyroxene, magnetite, altered glassy and other volcanic particles, grains of manganese.	(14·25 %), a small quantity of amorphous matter coloured by manganese, minute mineral particles, and small fragments of siliceous organisms.	Coccoliths are comparatively abundant. In this deposit are found crystals of plagioclase, loose or coated with volcanic glass, in the form of rhombic tables, also crystals of augite and rhombic pyroxene, and fragments of palagonite. The trawl line carried away in heaving in.
55·32	(1·00 %), a few Sponge spicules, Astrorhizidæ, arenaceous Textularidæ.	(3·00 %), m. di. 0·08 mm., angular; sanidine, plagioclase, augite, altered olivine, splinters of volcanic glass, manganese grains, magnetite.	(51·32 %), fine dark red-brown amorphous matter, fine mineral particles.	The most abundant of the pelagic Foraminifera is a thick-shelled *Globigerina bulloides.* The trawl brought up about a dozen manganese nodules, two sharks' teeth, and a small grey pebble of augite-andesite. The largest of the nodules is about the size of a pigeon's egg. Several have nuclei of palagonite, others appear to be made up entirely of manganese. The teeth and pebble are slightly coated with manganese.
100·00	...	(3·00 %), m. di. 0·10 mm., angular; manganese grains, felspar, plagioclase, augite, phillipsite, crystals, quartz, magnetite, glassy volcanic particles.	(97·00 %), much fine amorphous matter of a dark chocolate colour, and some fine mineral fragments.	The lower part of this deposit did not effervesce with acid; only one or two fragments of pelagic Foraminifera and a few broken pieces of sharks' teeth were observed. In the upper portion there were a few whole and a good many broken pieces of pelagic Foraminifera, one or two small Coccoliths, and fragments of Rhabdoliths. The great mass of the washings was composed of small pellets or particles of manganese (one small nodule the size of a pea was noticed), along with crystals of phillipsite and fragments of palagonite.

Tahiti to Valparaiso—*continued.*

See Chart 38, and Diagrams 20 and 21.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Tahiti to Valparaiso—*continued.*	295	1875 Nov. 5	° ′ ″ 38 7 0 S. 94 4 0 W.	1500	° 35·3	° 58·5	GLOBIGERINA OOZE.	...	*Biloculina depressa*, Textularidæ, *Uvigerina*, Globigerinidæ, Rotalidæ.	Cephalopod beaks, Pteropods, Ostracode valves, Echini spines.
	*296	„ 9	38 6 0 S. 88 2 0 W.	1825	35·3	59·8	GLOBIGERINA OOZE, light brown-grey when dry, somewhat coherent. **Residue** dark red-brown.	64·34	(55·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(7·34 %), Otoliths and teeth of fish, *Serpula*, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	†297	„ 11	37 29 0 S. 83 7 0 W.	1775	35·5	57·0	GLOBIGERINA OOZE, yellow-grey, slightly coherent. **Residue** rich brown.	71·15	(60·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, *Nonionina umbilicatula*.	(6·15 %), Echini spines, Coccoliths, Rhabdoliths.
	298	„ 17	34 7 0 S. 73 56 0 W.	2225	35·6	59·0	BLUE MUD, light blue-grey when dry, coherent, presenting no macroscopic elements, fine grained, plastic when wet. **Residue** blue-grey.	5·65	(4·00 %), Miliolidæ, *Bolivina textilarioides*, Lagenidæ, Globigerinidæ, *Pulvinulina canariensis*, *Nonionina umbilicatula*.	(1·65 %), Ostracodes, Echini spines, Coccoliths.
	...	Dec. 11	Off Valparaiso.	41	...	...	BLUE MUD, blue-grey when dry, coherent, presenting no macroscopic elements, fine grained, breaking up in water, blue and plastic when wet.	trace	*Miliolina seminulum*, Textularidæ, *Globigerina bulloides*, Rotalidæ, *Nonionina*.	Echinoderm fragments, a few Coccoliths.

* See anal. 48.

† See anal. 49, 131; Pl. III. figs. 8, 9; Pl. IX. fig. 9.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
...	Radiolaria, Astrorhizidæ, Lituolidæ, arenaceous Textularidæ.	Particles of volcanic glass some of them black, and minute rock fragments.	...	The water in the sounding tube on being allowed to settle deposited some brown coloured sediment, composed of *Globigerina*, *Pulvinulina*, Echini spines, Ostracode valves; a good many small manganese particles, and many small red mineral fragments were also observed, as also a few *Uvigerina*. Altogether, this indicates a red coloured Globigerina Ooze. In the tow-net at the weights there were an angular pebble about one inch (25 mm.) long, and a great many small rock fragments, measuring from 1 to 5 mm. in diameter, some of them augite-andesite.
35·66	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, arenaceous Textularidæ.	(3·00 %), m. di. 0·10 mm., angular; plagioclase, augite, altered olivine, many white glassy volcanic splinters, palagonite, phillipsite in single crystals and fibro-radiating aggregations, magnetite, manganese grains.	(31·66 %), much fine amorphous matter, a few mineral fragments, and remains of siliceous organisms.	Two layers were noticeable in the tube, a straw coloured upper and a dark brown lower. The upper layer contained the organisms noted, while in the lower layer the organisms were few and manganese abundant. A small nodule (the size of a pea) was observed. In the washings of the ooze from the trawl there were a few volcanic pebbles, some of them transformed into palagonite.
28·85	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·08 mm., angular; plagioclase, magnetite, a few isolated yellow crystals of phillipsite, augite, glassy volcanic particles.	(26·85 %), a quantity of dark red-brown, very fine grained, amorphous matter, some mineral fragments.	There was no trace of deposit in the tube, except a few shells of *Globigerina* at the valves. The trawl brought up a large quantity of manganese nodules (3 to 4 quarts = 3·4 to 4·5 litres) varying from the size of a pea to that of a hen's egg. One of the tow-nets at the trawl was full of a yellow coloured ooze in which were many rounded manganese nodules. The nuclei of some of the larger of these nodules are composed of a yellow or dark green material easily cut with a knife, showing the last stage of decomposition of palagonite. There were some lumps of the ooze in the tow-net, showing the beginning of the nodule formation.
94·35	(4·00 %), Radiolaria, *Reophax*, casts of Foraminifera, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; manganese grains, pumice, augite, quartz, mica, hornblende palagonite, glauconite.	(89·35 %), much blue-grey amorphous matter, some mineral and siliceous remains.	A section of about a foot (30 cm.) of mud of a blue colour was in the tube; on the surface there was a layer of a reddish colour which gave no trace of carbonate of lime on treatment with acid. The tow-nets at the trawl had each a little mud of a red or brown colour which did not effervesce with acid; evidently from the surface layers of the deposit. In a tow-net there was a manganese nodule, flat and round, about one inch (25 mm.) across and one and a quarter inches (31 mm.) thick, with a neucleus of pumice, also portions of a Cephalopod beak, and two pieces of twigs. Many excreta of Echinoderms are present. Imperfect casts of Foraminifera remain after treatment with dilute acid.
100·00	(1·00 %), Lituolidæ, arenaceous Textularidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, plagioclase, hornblende, white or yellowish mica, olivine, magnetite, quartz (rare).	(98·00 %) much greenish amorphous matter, fine minerals, and a few siliceous remains.	No effervescence is noticed when the mud is treated with dilute acid, but a strong smell of sulphuretted hydrogen is evolved. The mica and olivine are both altered and yellowish or nearly opaque. The particles are very small for a shore deposit.

See Charts 40 and 41, and Diagram 21.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Valparaiso to Gulf of Peñas.	*299	1875 Dec. 14	° ′ ″ 33 31 0 S. 74 43 0 W.	2160	° 35·2	° 62·0	BLUE MUD, pale blue-grey, coherent, fine grained, plastic, red-brown, and compact when wet. **Residue** red-brown.	15·40	(10·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Lagenidæ, Rotalidæ, *Nonionina umbilicatula*.	(2·40 %), Ostracodes, Echinoderm fragments, Coccoliths.
	†300	" 17	33 42 0 S. 78 18 0 W.	1375	35·5	62·5	GLOBIGERINA OOZE, yellow-white, slightly coherent, yellow-brown and somewhat plastic when wet. **Residue** red-brown.	54·09	(45·00 %), Globigerinidæ, *Pulvinulina*. (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, *Pullenia quinqueloba*, Rotalidæ, *Nonionina umbilicatula*.	(4·09 %), Pteropod fragments, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.
	‡302	" 28	42 43 0 S 82 11 0 W.	1450	35·6	55·0	GLOBIGERINA OOZE, pale yellow-brown, slightly coherent, yellow-red and gritty when wet. **Residue** red-brown.	82·31	(70·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, *Pullenia*, Rotalidæ, *Nonionina umbilicatula*.	(9·31 %), teeth of fish, Lamellibranchs, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
	§303	" 30	45 31 0 S. 78 9 0 W.	1325	36·0	54·8	BLUE MUD, light blue-grey, slightly coherent, breaking up in water, blue-grey and plastic when wet. **Residue** grey.	25·79	(20·00 %), Globigerinidæ, *Pulvinulina micheliniana*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, *Pullenia*, Rotalidæ.	(3·79 %), Ostracodes, Echini spines, Polyzoa, Coccoliths, Rhabdoliths.
Gulf of Peñas to Sandy Point through Magellan Strait.	304	" 31	46 53 15 S. 75 12 0 W.	45	..	57·2	QUARTZ SAND, green-grey, fine grained, dark grey when wet. **Residue** dark grey, almost black.	2·72	Textularidæ, Lagenidæ, Globigerinidæ, Rotalidæ, Nummulinidæ.	Lamellibranch fragments, Ostracodes, Echini spines.

* See anal. 132, 133, 134; Pl. III. fig. 4.
† See anal. 50; Pl. XXVI. fig. 1.
‡ See anal. 51, 95, 135; Pl. XVI. fig. 4; Pl. XVII. fig. 4.
§ See Pl. XXVI. fig. 4.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
84·60	5·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; glassy volcanic particles, felspar, plagioclase, hornblende, augite, magnetite, quartz, small particles of andesitic rocks.	(78·60 %), much amorphous matter, fine mineral and siliceous remains.	A section of about four inches (10 cm.) came up in the sounding tube; the uppermost inch was of a red colour containing no calcareous organisms, the lower portion being a blue-grey compact mud containing the organisms noted, two or three pieces of pumice, and several manganese grains. One of the tow-nets at the trawl was half full of a red-brown mud, and some of this was in the bag of the trawl and adhering to the nodules, &c. In the trawl there was over a quart (over a litre) of nodules and fragments of pumice. Some of these nodules are manganese throughout; others are formed of pumice surrounded by a deposit of manganese, while one had a nucleus of altered basalt. In addition there were a hard angular piece of granite, small hardened concretions of the bottom, and a fragment of a Cephalopod beak. On one of the nodules was attached a large *Scalpellum darwinii*. In the washings from the trawl were observed great numbers of *Rhizammina algæformis*.	Valparaiso to Gulf of Peñas.
45·91	(1·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, arenaceous Textularidæ.	(2·00 %), m. di. 0·08 mm., angular; felspar, plagioclase, magnetite, augite, small volcanic lapilli, palagonite, manganese grains.	(42·91 %), amorphous brown coloured matter, fine mineral and siliceous remains.	Only a small quantity of ooze came up in the tube. A considerable quantity came up in the trawl, amongst which were several small basaltic pebbles having a slight coating of manganese, and three or four pieces of a hardened tufa of a red colour, flat, and coated with manganese to the thickness of ¼ or ½ an inch (6 or 12 mm.). The ooze contains also a good many black particles and pebbles about the size of peas.	
17·69	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Textularidæ, casts of Foraminifera, Sponge spicules, Diatoms.	(1·00 %), m. di. 0·07 mm., angular; felspar, quartz, augite, pumice, palagonite, manganese grains, glauconite, zircon.	(15·69 %), red-brown amorphous matter, mineral and siliceous remains.	A considerable quantity of ooze was obtained in the sounding tube. In it were small pieces of manganese, pumice, and other mineral particles. In the trawl was about a peck (9 litres) of the ooze, in which were a number of manganese nodules, with nuclei of fragments of basalt with a vitreous base passing into palagonite, overgrown with worm tubes and *Hyperammina vagans*, some volcanic pebbles, and a piece of granite with a slight coating of manganese. There was also a fragment of a siliceous rock resembling flint, composed of calcedony and grains of crystalline silica. Red and yellow casts of the Foraminifera remain after treatment with acid. Some particles of quartz are large and rounded.	
74·21	(1·00 %), Radiolaria, Sponge spicules, *Reophax difflugiformis*, Textularidæ.	(10·00 %), m. di. 0·10 mm., angular; brown vesicular volcanic glass, felspar, plagioclase, augite, hornblende, magnetite, many particles of pumice, quartz, glauconite.	(63·21 %), grey coloured amorphous matter, fine mineral particles, and a few remains of siliceous organisms.	The tube brought up a considerable quantity of stiff light blue-grey mud containing the organisms noted. The surface of the section was of a yellowish colour and much softer than the deeper layers. The Foraminifera are fewer and pumice particles more abundant in the lower layers.	
97·28	...	(96·28 %), m. di. 0·17 mm., rounded; quartz, yellow-green mica flakes with apatite inclusions, felspar, fragments of ancient crystalline rocks and schists, hornblende, green chloritic substance covering the quartz and the other mineral particles.	(1·00 %), a few fine mineral particles.	...	Gulf of Peñas to Sandy Point through Magellan Strait.

See Chart 41.

Gulf of Peñas to Sandy Point through Magellan Strait—*continued.*

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
	1876	° ′ ″		°	°				
305	Jan. 1	47 47 0 S. 74 47 0 W.	165	...	55·5	BLUE MUDS, blue-grey when dry, coherent, slate coloured and plastic when wet. **Residue** blue-grey.	4·16	(3·00 %), Miliolidæ, Textularidæ, Lagenidæ, *Globigerina bulloides*, Rotalidæ, Nummulinidæ.	(1·16 %), *Dentalium*, Gasteropod and Lamellibranch fragments, Ostracodes, Echinoderm fragments, Polyzoa.
305A	,, 1	47 48 30 S. 74 47 0 W.	125	...	56·0				
305B	,, 1	47 48 0 S. 74 46 0 W.	160	...	55·7				
306	,, 2	48 17 0 S. 74 33 0 W.	565	...	57·0	BLUE MUDS, blue-grey, coherent, fine grained, dark blue-grey and plastic when wet.	trace	Miliolidæ, Textularidæ, *Truncatulina lobatula*, *Nonionina umbilicatula*.	*Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm and Coral fragments.
306A	,, 2	48 27 0 S. 74 30 0 W.	345	46·0	57·5				
307	,, 4	49 24 30 S. 74 23 30 W.	140	...	53·0	BLUE MUD, light blue-grey, coherent, breaking up readily in water.	trace	*Truncatulina tenera*, *Nonionina scapula*.	Gasteropod and Lamellibranch fragments, Echini spines.
308	,, 5	50 8 30 S. 74 41 0 W.	175	...	51·7	BLUE MUD, yellow-grey, slightly coherent, breaking up in water, green-brown when wet. **Residue** green-brown.	28·84	(6·00 %), Globigerinidæ. (9·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, *Nonionina umbilicatula*.	(13·84 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments.
309	,, 8	50 56 0 S. 74 15 0 W.	40	47·0	50·5	BLUE MUDS, light blue-grey, coherent, dark blue-grey and plastic when wet, unctuous.	trace	*Truncatulina lobatula*.	Gasteropods.
309A	,, 8	50 56 0 S. 74 14 0 W.	140	...	50·5				
310	,, 10	51 27 30 S. 74 3 0 W.	400	46·5	50·5	BLUE MUD, light blue-grey, coherent, fine grained, dark blue-grey and plastic when wet.	trace	*Miliolina seminulum*, *Truncatulina lobatula*, *Nonionina umbilicatula*.	Lamellibranch fragments, Ostracodes.
311	,, 11	52 45 30 S. 73 46 0 W.	245	46·0	50·0	BLUE MUD, yellow-grey with green tinge, coherent, breaking up in water, green-brown when wet. **Residue** yellow-green.	34·07	(8·00 %), *Globigerina bulloides*. (10·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, *Nonionina umbilicatula*.	(16·07 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments.

	Residue.			Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
95·84	(3·00 %), Sponge spicules, Astrorhizidæ, Lituolidæ, Textularidæ, Diatoms.	(65·00 %), m. di. 0·20 mm., rounded and angular; mica, quartz, plagioclase, hornblende, rhombic pyroxene, glauconite, small fragments of crystalline rocks.	(27·84 %), amorphous matter, many fine mineral particles, and some siliceous remains.	These three deposits are similar to each other, but vary as to amorphous matter, number of shell fragments, and mineral particles. Many of the Foraminifera shells are filled with glauconite, which remains as casts on treatment with acid. At the second station many of the mineral fragments measure from 0·5 to 2 mm.
100·00	(2·00 %), Sponge spicules, Astrorhizidæ, Textularidæ, Diatoms.	(1·00 %), m. di. 0·10 mm., rounded and angular; orthoclase, plagioclase, quartz, hornblende, tourmaline, splinters of schisto-crystalline and volcanic rocks, glauconite.	(97·00 %), much fine clayey matter, some mineral and siliceous remains.	Two soundings were taken on this date. The deposits are similar, the former containing perhaps larger traces of carbonate of lime, while the latter disintegrates more readily in water. The organisms noted were obtained from the washings of the trawl.
100·00	(1·00 %), Sponge spicules, a few Diatoms.	(75·00 %), m. di. 0·15 mm., rounded and angular; quartz, felspar, plagioclase, green hornblende, chlorite, zircon, epidote, particles of crystalline rocks.	(24·00 %), fine clayey matter of a blue-grey colour, fine mineral fragments, a few remains of Sponge spicules and Diatoms.	There was very little effervescence with acid indicating only traces of carbonate of lime. The minerals are small, the largest being only about 0·5 mm. in diameter.
71·16	(2·00 %), Sponge spicules, Textularidæ, glauconitic casts, a few Diatoms	(35·00 %), m. di. 0·15 mm., angular and rounded; quartz, felspar, plagioclase, augite, hornblende, black and white mica, zircon, glauconite, fragments of crystalline rocks.	(34·16 %), clayey matter, mineral particles, a few siliceous remains.	A few glauconitic casts remain after treatment with acid. Some pebbles and rock fragments, measuring from 1 mm. to 4 cm. in diameter, were embedded in the deposit.
100·00	(1·00 %), *Clavulina communis.*	(30·00 %), m. di. 0·20 mm., angular and rounded; quartz, plagioclase, felspar, brown hornblende, augite, pumice, magnetite, lapilli.	(69·00 %), fine clayey matter, minute mineral fragments.	Some rock fragments, measuring over 1 cm. in diameter, were noticed. The felspar contains brown glassy inclusions. The mineral particles seem to be the product resulting from the disintegration of a coarse-grained modern volcanic rock or a coarse volcanic ash, but if this be the case glassy particles are very rare.
100·00	(1·00 %), Sponge spicules, *Ammodiscus incertus*, a few Diatoms.	(3·00 %), m. di. 0·10 mm., rounded; quartz, olivine, felspar, zircon, mica, hornblende.	(96·00 %), much blue-grey clayey matter, and some fine mineral particles.	The mud is of a much finer character than that obtained at the previous stations.
65·93	(1·00 %), Sponge spicules, Textularidæ, casts, Diatoms.	(2·00 %), m. di. 0·10 mm., angular and rounded; quartz, felspar, plagioclase, hornblende, augite, zircon, glauconite, glaucophane, epidote, altered glauconite.	(62·93 %), amorphous matter, fine mineral fragments, and some siliceous remains.	Imperfect casts of Foraminifera remain after treating the deposit with acid.

Gulf of Peñas to Sandy Point through Magellan Strait—*continued.*

See Charts 41 and 42, and Diagram 22.

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
		° ′ ″		°	°				
Sandy Point to Falkland Islands.									
313	1876 Jan. 20	52 20 0 S. 67 39 0 W.	55	47·8	48·2	COARSE SAND, grey. Residue dark brown with green tint.	1·13	A few *Globigerina inflata*.	Echinoderm fragments, Polyzoa.
314	„ 21	51 35 0 S. 65 39 0 W.	70	46·0	48·0	COARSE SAND.	...	...	...
...	Feb. 6	Stanley Harbour, Falkland Islands.	6	...	...	BLUE MUD, green-grey, smelling strongly of sulphuretted hydrogen, plastic, finely granular, drying into slightly coherent masses. Residue dark brown.	39·12	(10·00 %), Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(29·12 %), Gasteropods, Lamellibranchs, Ostracodes, Echini spines.
Falkland Islands to Rio de la Plata.									
317	„ 8	48 37 0 S. 55 17 0 W.	1035	35·7	46·7	SANDY GRAVEL, mottled red, black, brown, and white. Residue brown-grey.	14·61	(8·00 %), Globigerinidæ, *Pulvinulina*. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(4·61 %), Otoliths of fish, sharks' teeth, Gasteropods, Lamellibranchs, Cirripeds, Echinoderm fragments, Polyzoa.
318	„ 11	42 32 0 S. 56 29 0 W.	2040	33·7	57·5	GLOBIGERINA OOZE, light grey, granular, slightly coherent, earthy. Residue dark grey.	32·69	(25·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(4·69 %), Ostracodes, Echini spines, a few Coccoliths.
319	„ 12	41 54 0 S. 54 48 0 W.	2425	32·7	59·5	BLUE MUD, blue-grey, finely granular, plastic, drying into small grey pulverulent masses, sublustrous streak. Residue green-grey.	6·41	(3·00 %), Textularidæ.	(3·41 %), small teeth of fish.
320	„ 14	37 17 0 S. 53 52 0 W.	600	37·2	67·5	BLUE MUD, green-grey, fine grained. Residue green.	11·89	(5·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(3·89 %), *Serpula*, Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
98·87	(2·00 %), fragments of Sponge spicules and Diatoms.	(90·00 %), m. di. 0·60 mm., rounded; quartz, felspar, mica, hornblende, augite, glauconite, pumice, particles of crystalline and schistose rocks, epidote, garnet.	(6·87 %), a small quantity of amorphous matter, flocculent organic matter, and many minute mineral particles.	The dredge brought up some sand, sandy concretions, and many animals, also some pieces of carbonised wood. The particles of crystalline and schistose rocks are often black, and more or less rounded. Many of the mineral and rock particles are covered with chloritic matter as well as with limonite.	Sandy Point to Falkland Islands.
...	...	...	...	This deposit is the same in all respects as that described for Station 313, except perhaps that there is a little more glauconite.	
60·88	(3·00 %), Sponge spicules, Diatoms.	(1·00 %), m. di. 0·08 mm., rounded; quartz, felspar, hornblende.	(56·88 %,) amorphous matter and fine particles of minerals and siliceous organisms.	With the exception of the Foraminifera and Ostracodes, the organisms are fragmentary; some are macroscopic.	
85·39	(2·00 %), Sponge spicules, Lituolidæ.	(70·00 %), m. di. 0·15 mm., rounded and angular; fragments of clastic rocks, black mica, quartz, felspar, augite, magnetite, glauconite, hornblende.	(13·39 %), a small quantity of amorphous matter, with many minute fragments of minerals and siliceous organisms.	There was nothing in the sounding tube. The trawl line parted between the weights and the trawl while being hauled in. The gravel and animals obtained came up in the tow-net attached to the weights. Among the pebbles were glauconitic and phosphatic concretions.	Falkland Islands to Rio de la Plata.
67·31	(2·00 %), Radiolaria, *Astrorhiza*, imperfect casts, Diatoms.	(50·00 %), m. di. 0·10 mm., angular and rounded; quartz, pumice, felspar, hornblende, augite, mica, magnetite, glauconite.	(15·31 %), amorphous matter, with many fine mineral particles and fragments of siliceous organisms.	The sounding tube had sunk over a foot (30 cm.) into the bottom, but brought up only a small quantity of the mud. This was of a blue colour with here and there some lighter coloured patches. There was no evidence to show that the trawl had ever touched the bottom.	
93·59	(3·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, frustules of Diatoms.	(40·00 %), m. di. 0·12 mm., rounded; quartz, monoclinic and triclinic felspars, hornblende, pumice, glauconite.	(50·59 %), amorphous matter, fine mineral particles, and fragments of siliceous organisms.	The sounding tube had sunk nearly 14 inches (35 cm.) into the deposit and brought up about a litre of the mud. This was of a blue-grey colour throughout, with the exception of the thin watery surface layer, which had a brown colour. Some of the particles of felspar are kaolinised while others show no alteration.	
88·11	(2·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, a few Diatoms.	(70·00 %), m. di. 0·15 mm., rounded; quartz, felspar, plagioclase, hornblende, augite, magnetite, pumice, glauconite.	(16·11 %), amorphous matter and many minute mineral particles.	The sounding tube brought up only a small concretion about 15 cm. in diameter. In the trawl there were five or six similar concretions and a little of the Blue Mud described. The concretions are phosphatic and contain glauconite. Many of the Foraminifera are macroscopic. Some of the mineral particles attain a diameter of 1 mm. Many of the minerals, principally the felspar, are covered by or impregnated with a green chloritic matter apparently intimately united to the mineral which it envelops. Felspar is chiefly represented by plagioclase. Some quartz grains contain inclusions of liquid carbonic acid.	

See Chart 16, and Diagrams 6 and 22.

Route	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Temperature of the Sea-water (Fahr.). Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Carbonate of Calcium. Foraminifera.	Carbonate of Calcium. Other Organisms.
Falkland Islands to Rio de la Plata—*continued.*	...	1876 Feb. 15	Off Monte Video.	4	...	...	...	...	...	...
	321	,, 25	35° 2′ 0″ S. 55 15 0 W.	13	...	73°·5	Blue Mud, grey-brown, plastic, greasy, homogeneous, but containing some large fragments of Molluscs and terrestrial plants, sublustrous streak. **Residue** brown.	1·13	A few Miliolidæ.	Fragments of Gasteropods and Lamellibranchs, a few Ostracodes and Echini spines.
Rio de la Plata to Tristan da Cunha.	322	,, 26	35 20 0 S. 53 42 0 W.	21	...	71·5	Sand and Shells.	...	...	...
	*323	,, 28	35 39 0 S. 50 47 0 W.	1900	33·1	73·5	Blue Mud, grey, arenaceous, slightly plastic, finely granular, sublustrous streak. **Residue** blue-grey.	3·04	(2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Globigerinidæ, Rotalidæ.	(1·04 %), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa.
	324	,, 29	36 9 0 S. 48 22 0 W.	2800	32·6	71·5	Blue Mud, grey, arenaceous, plastic, greasy, and very finely granular to the touch. **Residue** brown.	4·04	(2·00 %), *Globigerina Pulvinulina.*	(2·04 %), small teeth of fish.
	325	Mar. 2	36 44 0 S. 46 16 0 W.	2650	32·7	70·8	Blue Mud, grey, slightly plastic, arenaceous, finely granular, earthy, pulverulent, sublustrous streak.	...	...	...

* See anal. 64, 65.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
...	...	...	...	'The mud from the anchor in the harbour was the same as that described for Station 321, only somewhat darker in colour.	Falkland Islands to Rio de la Plata—*continued.*
98·87	(1·00 %), Lituolidæ, frustules of Diatoms.	(3·00 %), m. di. 0·08 mm., angular and rounded; quartz, pumice, felspar, plagioclase, hornblende, augite, magnetite, particles of volcanic rocks, a few glauconitic grains.	(94·87 %), amorphous matter and small mineral particles.	The dredge brought up a large quantity of blue tenacious mud.	
...	...	...	...	The trawl brought up many dead shells of *Pecten*, &c., covered with Annelid tubes, and some sand formed of grains, about 1 mm. in diameter, of quartz, felspar, mica, hornblende, augite, and pumice. The trawl also brought up some sandy aggregations of a more or less oval shape and grey colour. These contained all the above minerals, quartz particles about 0·5 mm. in diameter predominating. The mineral particles are agglutinated by a ferruginous clay.	Rio de la Plata to Tristan da Cunha.
96·96	(5·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(20·00 %), m. di. 0·08 mm., angular and rounded; quartz, felspar, plagioclase, mica, hornblende, augite, magnetite, glauconite.	(71·96 %), amorphous matter, with many minute mineral particles.	The sounding tube brought up over a quart (over a litre) of the mud. This was of a blue colour, except a thin watery surface layer of a red or brown colour. The calcareous organisms were chiefly confined to the surface layers. The trawl and attached tow-nets contained a little of the deposit, the same as the upper layers in the sounding tube, and in the trawl there were several large lumps of the stiff Blue Mud of the lower layers. Some of the Foraminifera are macroscopic. Some of the quartz grains have a diameter of 1 mm., and are covered with limonite. Some of the felspar particles have vitreous inclusions.	
95·96	(5·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(20·00 %), m. di. 0·08 mm., angular and rounded; quartz, pumice, plagioclase, hornblende, mica, magnetite, glauconite.	(70·96 %), amorphous matter, with many minute mineral particles.	The sounding tube brought up over a litre of the mud of the same grey-brown colour throughout. A second sounding was taken and gave the same kind of deposit at a depth of 2840 fathoms. Some of the quartz particles reach a diameter of 1 mm., and are covered with limonite. The trawl line parted after the trawl had been some time on the bottom.	
100·00	(5·00 %), Radiolaria, *Astrorhiza*, Lituolidæ, Diatoms.	(20·00 %), m. di. 0·08 mm., angular and rounded; quartz sometimes coated with limonite, pumice, brown glassy volcanic particles, mica, sanidine, hornblende, augite, magnetite.	(75·00 %), amorphous matter and many fine mineral particles.	The sounding tube had sunk fifteen inches (37·5 cm.) into the bottom and brought up nearly two litres of the mud, of which the lower layer was reddish rather than grey. There was also about half a litre of mud in the trawl and attached tow-nets. No effervescence was observed when the deposit was treated with acid. The magnetite is not always isolated, but is often found inclosed in particles of volcanic rocks, or as inclusions in hornblende and augite.	

See Chart 16, and Diagram 6.

Rio de la Plata to Tristan da Cunha—continued.

Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.		Designation and Physical Characters.	Carbonate of Calcium.		
				Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
	1876	° ′ ″		°	°				
326	Mar. 3	37 3 0 S. 44 17 0 W.	2775	32·7	67·8	**Blue Mud**, grey-brown, arenaceous, plastic, finely granular, drying into slightly coherent earthy masses. **Residue** grey-brown.	3·11	...	(3·11 %), small teeth of fish.
327	,, 4	36 48 0 S. 42 45 0 W.	2900	32·8	70·2	**Red Clay**, grey-brown, finely granular, slightly coherent, earthy.	...	...	...
328	,, 6	37 38 0 S. 39 36 0 W.	2900	32·9	68·0	**Red Clay**, grey-brown, plastic, unctuous, coherent when dry, finely granular, sublustrous streak.	...	...	...
329	,, 7	37 31 0 S. 36 7 0 W.	2675	32·3	64·5	**Red Clay**, grey-brown, plastic, unctuous, homogeneous, drying into fine-grained coherent masses, sublustrous streak.	0·70	Fragments of pelagic Foraminifera.	...
330	,, 8	37 45 0 S. 33 0 0 W.	2440	32·7	64·2	**Red Clay**, grey-brown, homogeneous, coherent, lustrous streak. **Residue** brown.	10·36	(6·00 %), fragments of Globigerinidæ, *Pulvinulina*.	(4·36 %), Ostracodes, one or two fragments of Echini spines, Coccoliths.
331	,, 9	37 47 0 S. 30 20 0 W.	1715	35·4	64·5	**Globigerina Ooze**, white with a slight rose tint, granular, pulverulent. **Residue** brown.	78·38	(60·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(15·38 %), Ostracodes, Echini spines, Polyzoa, Coccoliths, Coccospheres, Rhabdoliths.
*332	,, 10	37 29 0 S. 27 31 0 W.	2200	34·0	64·0	**Globigerina Ooze**, grey with a rose tinge, homogeneous, slightly coherent. **Residue** brown.	65·67	(55·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(7·67 %), fragments of Pteropods, Echini spines, Coccoliths, Coccospheres, Rhabdoliths.
333	,, 13	35 36 0 S. 21 12 0 W.	2025	35·3	67·0	**Globigerina Ooze**, white, slightly coherent. **Residue** red.	88·97	(75·00 %), Globigerinidæ, *Pulvinulina*. (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(10·97 %), fragments of Pteropods, Ostracodes, Echini spines, Polyzoa, Coccoliths, Coccospheres, Rhabdoliths.

* See anal. 52.

Residue.				Additional Observations.
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	
96·89	(5·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, frustules of Diatoms.	(20·00 %), m. di. 0·08 mm., angular and rounded; quartz, pumice, white mica, hornblende, felspar, magnetite.	(71·89 %), amorphous matter, with many fine mineral particles and fragments of siliceous organisms.	The sounding tube had sunk 15 inches (37·5 cm.) into the bottom and brought up a quart and a half of the deposit. It had a red, rather than a grey, tinge, and not nearly so dark in colour as the soundings nearer the coast.
100·00	(5·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ, Diatoms.	(5·00 %), m. di. 0·06 mm., angular and rounded; quartz, pumice, mica, hornblende, augite, magnetite, magnetic spherules.	(90·00 %), amorphous matter, with a large quantity of fine mineral particles and fragments of siliceous organisms.	Over a quart (over a litre) of the deposit was obtained in the sounding tube. The upper layers had a dark slate colour, while the lower had a tinge of red and were more compact. No effervescence was noticed when treated with acids, and the remains of calcareous organisms appear to be quite absent.
100·00	(5·00 %), Radiolaria, Sponge spicules, one or two arenaceous Foraminifera, frustules of Diatoms.	(3·00 %), m. di. 0·10 mm., angular and rounded; quartz, magnetite, pumice, basaltic scoriæ, felspar, augite.	(92·00 %), amorphous matter, with a large quantity of minute mineral particles and fragments of siliceous organisms.	The sounding tube brought up over a quart (over a litre) of the clay, of which the upper layers were slightly darker than the lower. The particles of basaltic scoriæ attain in some cases a diameter of 1 mm.
99·30	(5·00 %), Radiolaria, Sponge spicules, one or two arenaceous Foraminifera, frustules of Diatoms.	(1·00 %), m. di. 0·07 mm., angular; quartz, plagioclase, volcanic scoriæ, magnetite, mica.	(93·30 %), amorphous matter with many minute mineral particles and fragments of siliceous organisms.	The sounding tube brought up over a quart (over a litre) of the clay. The whole had a slightly red tinge, the upper layers being rather darker than the lower. A second sounding gave a depth of 2750 fathoms, and the deposit brought up was quite the same as that described.
89·64	(1·00 %), Radiolaria, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, quartz, mica, magnetite, glassy volcanic particles, manganese.	(87·64 %), a large quantity of amorphous matter with minute mineral particles.	The sounding tube had sunk about 15 inches (37·5 cm.) into the bottom, and brought up about two quarts (over two litres) of the clay, of which the lower layers had a blue rather than a red tinge. These lower layers contained very little, if any, carbonate of lime. One worm tube had a deposit of manganese in the inside.
21·62	(2·00 %), Sponge spicules, Radiolaria, Astrorhizidæ, Lituolidæ, imperfect casts of Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; quartz, felspar, olivine, hornblende, black mica, volcanic scoriæ.	(18·62 %), amorphous matter, with many minute mineral particles, and fragments of siliceous organisms.	The tube had sunk a foot (30 cm.) into the bottom and brought up about a quart (over a litre) of the ooze. The lower layers were more compact than the upper. The trawl came up fouled. In one of the tow-nets at the trawl there were a great many dead empty shells of Foraminifera which evidently came from the bottom. Some of the quartz particles are about 1 mm. in diameter, and sometimes rounded.
34·33	(3·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; quartz, felspar, hornblende, augite, magnetite, pumice.	(30·33 %), amorphous matter, minute mineral particles, fragments of siliceous organisms.	Although the sounding tube had penetrated the bottom to a depth of 15 inches (37·5 cm.), yet only a small quantity of the deposit was brought up. One of the tow-nets at the trawl was full of ooze of the same nature as that brought up by the sounding tube. In the dredge there was a piece of red volcanic scoria, and on passing a large quantity of the deposit through fine sieves four or five fragments of rocks were obtained with a diameter of about 5 mm., one formed principally of red orthoclase, the others lapilli, probably basaltic.
11·03	(1·00 %), a few Radiolaria, Astrorhizidæ, Lituolidæ, imperfect casts of Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; monoclinic and triclinic felspars, hornblende, augite, glassy volcanic particles, scoriaceous and magnetic particles.	(9·03 %), amorphous matter, fine mineral particles, minute fragments of siliceous organisms.	Judging from the marks found on the outside, the sounding tube had sunk nearly a foot (30 cm.) into the deposit; in the inside of the tube there was, however, only a small quantity of the ooze. There was a little ooze in the tow-nets at the weights and trawl and in the bag of the trawl. About six quarts (nearly 7 litres) altogether of the ooze were obtained. This was the same as that procured by the sounding tube.

Rio de la Plata to Tristan da Cunha—*continued.*

See Chart 16, and Diagrams 6 and 7.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.).		Designation and Physical Characters.	Carbonate of Calcium.		
					Bottom	Surface		Per cent.	Foraminifera.	Other Organisms.
Rio de la Plata to Tristan da Cunha—*continued.*	334	1876 Mar. 14	° ′ ″ 35 45 0 S. 18 31 0 W.	1915	° 35·8	° 68·5	Globigerina Ooze, light brown upper layer, white homogeneous lower layer. **Residue** red-brown and cream coloured respectively.	85·21	(75·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), *Biloculina*, Textularidæ, Lagenidæ, Rotalidæ.	(7·21 %), Pteropods, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
Tristan da Cunha to Ascension Island.	335	,, 16	32 24 0 S. 13 5 0 W.	1425	37·0	73·5	Pteropod Ooze, white with rose tinge, granular, pulverulent, presenting many sharp particles when pressed between the fingers. **Residue** yellow-brown.	93·77	(75·00 %), Globigerinidæ, *Pulvinulina.* (3·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(15·77 %), Otoliths of fish, *Dentalium*, Gasteropods, Lamellibranchs, Pteropods, Ostracodes, *Scalpellum* (plates), Echini spines, Coccoliths, Coccospheres, Rhabdoliths.
	336	,, 18	27 54 0 S. 13 13 0 W.	1890	36·5	76·0	Globigerina Ooze, white with rose tinge, fine grained, slightly coherent. **Residue** dark red-brown.	79·02	(70·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Textularidæ, Lagenidæ, Rotalidæ.	(7·02 %), small teeth of fish, Coccoliths, Rhabdoliths.
	337	,, 19	24 38 0 S. 13 36 0 W.	1240	37·2	77·0	Pteropod Ooze, white with black spots and shining scales, granular. **Residue** grey-brown.	98·47	(50·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), *Miliolina*, Textularidæ, Rotalidæ.	(46·47 %), Otoliths of fish, Gasteropods, Pteropods, Heteropods, Ostracodes, Echini spines, Coccoliths.

Residue. Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.	Additional Observations.	
14·79	(1·00 %), a few Radiolaria, imperfect casts of Foraminifera, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; sanidine, plagioclase, hornblende, mica, magnetite, glassy volcanic particles.	(12·79 %), amorphous matter, many fine mineral particles, a few fragments of siliceous organisms.	The sounding tube had sunk about a foot (30 cm.) into the bottom and brought up a litre of the deposit. Of this there were two layers separated by a thin dark line, an upper layer of a light brown colour and about 8 inches (20 cm.) in thickness, composed essentially of the shells of pelagic Foraminifera, and a lower, milk white and over an inch (25 mm.) in thickness, chiefly made up of amorphous calcareous matter and Coccoliths. On analysis the upper layer gave 84·65 per cent. of carbonate of lime, the lower 85·77 per cent. The annexed analysis is the mean of these two results. The passage between the two layers appeared to be quite abrupt, so far as could be judged from a careful examination of the contents of the sounding tube. The tow-nets at the weights and at the trawl contained a little of the ooze, which was the same as the upper layer above described. A fragment of the hardened deposit about 1 cm. in diameter was taken from the washings from the trawl.	Rio de la Plata to Tristan da Cunha—*continued*.
6·23	(1·00 %), Sponge spicules, Radiolaria, Lituolidæ, imperfect casts of Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; felspar, hornblende, grains and crystals of magnetite, glassy volcanic fragments, pumice, manganese grains.	(4·23 %), amorphous matter, many fine mineral particles, some fragments of siliceous spicules.	The sounding tube had not apparently sunk far into the bottom as there were no traces of mud or ooze on the outside, and in the inside only about half a pint (0·3 litre) of the ooze. In the dredge and attached tow-nets there were about 10 litres of the ooze and three pieces of pumice, measuring fully an inch (25 mm.) in diameter, and more or less rounded. They are white and scoriaceous, although the pores are generally small and contain only a few porphyritic minerals, felspar and augite. These porphyritic minerals in many instances project above the rounded smooth surface of the pumice. Some of the shells of the arenaceous Foraminifera are formed of agglomerations of microliths of hornblende, little fragments of felspar and magnetite, and of vitreous particles. Many of the shells of the pelagic Molluscs are black and brown from a coating of manganese, and are macroscopic. A Pteropod Ooze, it must be remembered, only indicates a relative abundance and not a predominance of these shells in the deposit.	Tristan da Cunha to Ascension Island.
20·98	(1·00 %), Radiolaria, Lituolidæ.	(1·00 %), m. di. 0·10 mm., angular; fragments of brown glassy volcanic rock with the conchoidal fracture of obsidian, sanidine, magnetite, vesicular felspathic lapilli, small particles of manganese.	(18·98 %), flocculent amorphous matter, with minute fragments of minerals, manganese, and Radiolaria.	The sounding tube brought up only a small quantity of the deposit. The splinters of volcanic rock are sometimes 0·5 mm. in diameter, and make up almost the whole of the mineral particles in the deposit. Note the absence of Pteropod and Heteropod shells in this deposit.	
1·53	A few large Radiolaria, fragments of Sponge spicules, Astrorhizidæ, Lituolidæ.	M. di. 0·06 mm., angular; a few particles of felspar and magnetite.	Traces of flocculent matter.	The sounding tube brought up about half a pint (0·3 litre) of the deposit, which contains very little amorphous calcareous or clayey matter, and is chiefly composed of the shells of pelagic Molluscs and Foraminifera. Many of the shells are fully 1 cm. in length, some of them black or brown with a thin coating of manganese, some transparent. The tow-nets had not been at the bottom, and the dredge seemed just to have touched. This is the shallowest depth far removed from land of any kind met with during the cruise.	

See Charts 16 and 48, and Diagram 7.

Region	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Surface	Designation and Physical Characters.	Carbonate of Calcium. Per cent.	Foraminifera.	Other Organisms.
Tristan da Cunha to Ascension Island—*continued.*	*338	1876 Mar. 21	21° 15′ 0″ S. 14 2 0 W.	1990	36°·3	76°·5	GLOBIGERINA OOZE, white, with slight rose tinge, granular, homogeneous, resembling chalk when dry. **Residue** reddish-brown.	92·54	(80·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(11·54), Otoliths of fish, Gasteropods, Lamellibranchs, Pteropods, Heteropods, *Lepas* valves, Ostracodes, Echinoderm fragments, Polyzoa, Coccoliths, Rhabdoliths.
	339	„ 23	17 26 0 S. 13 52 0 W.	1415	37·2	76·0	PTEROPOD OOZE, white, with a faint red tinge, granular, pulverulent. **Residue** red.	95·61	(70·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(23·61), Otoliths of fish, Gasteropods, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Coccoliths, Coccospheres, Rhabdoliths.
	340	„ 24	14 33 0 S. 13 42 0 W.	1500	37·6	77·2	PTEROPOD OOZE.	...	*Globigerina, Pulvinulina.*	Pteropods, Coccoliths, Rhabdoliths.
	341	„ 25	12 16 0 S. 13 44 0 W.	1475	38·2	79·0	PTEROPOD OOZE.	...	*Globigerina, Pulvinulina.*	Pteropods, Coccoliths, Rhabdoliths.
	342	„ 26	9 43 0 S. 13 51 0 W.	1445	37·5	80·0	PTEROPOD OOZE.	...	Miliolidæ, Textularidæ, Lagenidæ, *Globigerina*, Rotalidæ.	Otoliths of fish, Pteropods, Heteropods, Ostracodes, Echinoderm fragments, Coccoliths, Rhabdoliths.
Off Ascension.	343	„ 27	8 3 0 S. 14 27 0 W.	425	40·3	80·8	GLOBIGERINA OOZE, white. **Residue** brown-black.	96·80	(75·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), *Miliolina*, Textularidæ, Lagenidæ, Rotalidæ.	(16·80 %), Lamellibranchs (larval), fragments of Pteropods, Heteropods, Ostracodes, Echinoderm fragments.
	...	„ 30	From Long Beach.	...	...	...	CORAL SAND, white, with some black and pink particles. **Residue** grey.	98·04	A few fragments of *Polytrema rubra.*	(98·04 %), fragments of Gasteropods, Lamellibranchs, Echinoderms, Polyzoa, Millepores, and calcareous Algæ.
	...	April 2	From the Anchorage.	7	...	...	CORAL SAND, light yellow, with bosses of living calcareous Algæ. **Residue** heavy black and fine cream coloured matter.	96·56	(5·00 %), *Miliolina, Amphistegina.*	(91·56 %), Gasteropods, Lamellibranchs, Ostracodes, Echinoderm fragments, Polyzoa, Millepores, calcareous Algæ.

* See anal. 53, 59*a*, 58, 59; Pl. XI. fig. 4; Pl. XII. fig. 1; Pl. XXIII. figs. 10, 11, 13.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
7·46	(1·00 %), Sponge spicules, Radiolaria, imperfect casts of Foraminifera, Astrorhizidæ, Lituolidæ, a few Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, hornblende, magnetite, magnetic spherules, pumice, a few manganese grains, bronzite spherules.	(5·46 %), amorphous matter, with small mineral particles and fragments of scoriæ and siliceous organisms.	This is one of the purest Globigerina Oozes obtained by the Challenger and is almost wholly composed of the dead shells of surface organisms. The general appearance of the deposit is represented in Pl. XII. fig. 1. On comparison with fig. 3 it will be noticed that the majority of the shells are, in this deposit, much smaller and thinner than in the deposit nearer the equator. The younger specimens are much more numerous and the species which predominate are different. These remarks hold good also for the specimens taken on the surface. A few pumice fragments were found in the washings of a large quantity of deposit.	Tristan da Cunha to Ascension Island—*continued*.
4·39	(1·00 %), Radiolaria, Sponge spicules, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; fragments and crystals of sanidine and plagioclase often inclosed in vitreous matter, augite, magnetite, greenish chloritic particles, manganese grains.	(2·39 %), amorphous matter, fine mineral particles, and a few minute fragments of siliceous spicules.	The tube had sunk nearly 10 inches (25 cm.) into the bottom and brought up over one litre of the deposit. Many of the Pteropod and Heteropod shells are quite black and others have a brown colour from a coating of manganese. The shells of the pelagic Molluscs were more abundant in the surface than in the deeper layers of the deposit, only a few being observed in the ooze at the lower end of the tube. Many of the Foraminifera are brown coloured from a deposit of oxide of iron on their surface. Note that the shells of Pteropods and Heteropods are abundant in this deposit, but are rare at the preceding station, which is 575 fathoms deeper.	
...	...	Manganese grains.	...	The sounding tube came up with some traces on the outside which indicated that it had sunk about a foot (30 cm.) into the bottom. The deposit is similar to that at Station 339.	
...	...	Manganese grains.	...	The sounding tube came up empty, with the exception of a few Pteropod shells, Foraminifera, and small particles of peroxide of manganese. On the outside of the tube there were several black streaks, which on examination were found to be due to peroxide of manganese.	
...	A few Radiolaria, Lituolidæ.	..	A trace of amorphous matter.	The hydra sounding tube was used, and brought up only a small quantity of the deposit which was chiefly composed of Pteropods, Heteropods, and pelagic Foraminifera. Many of the Pteropods are covered with a thin coating of peroxide of manganese. Many of the shells are macroscopic. There was an insufficient quantity for analysis.	
3·20	(1·00 %), one or two Radiolaria, fragments of Sponge spicules, *Haplophragmium*.	(1·00 %), m. di. 0·20 mm., angular; much plagioclase and sanidine, hornblende, magnetite, augite, very rarely quartz and olivine.	(1·20 %), a small quantity of flocculent matter and minute fragments of minerals.	The sounding tube brought up two pieces of Coral coated with manganese. There was a little ooze on one of the swabs, from which the analysis and description is taken; probably the percentage of carbonate of lime is too high. The dredge was empty.	Off Ascension.
1·96	...	(1·00 %), m. di. 1·00 mm., rounded and angular; a few fragments of volcanic rocks and vesicular lapilli.	(0·96 %), a small quantity of flocculent matter and a few fragments of minerals.	This sand is chiefly composed of calcareous Algæ, fragments of Gasteropod and Lamellibranch shells, with a few fragments of Millepores, Echinoderms, very rarely Polyzoa, and Foraminifera. The fragments are all rounded and polished by the action of the waves, and have a mean diameter of about 1·3 mm.	
3·44	...	(1·00 %), m. di. 0·50 mm., angular and rounded; felspar, magnetite, augite, olivine, scoriaceous particles and other fragments of volcanic rocks.	(2·44 %), flocculent organic matter and minute fragments of minerals.	The sand of Long Beach would appear to have its origin from the broken fragments of calcareous Algæ carried by the waves from this locality and similar depths around the island.	

See Charts 6, 12, and 43, and Diagram 7.

	Number of Station.	Date.	Position.	Depth in Fathoms.	Temperature of the Sea-water (Fahr.). Bottom	Temperature of the Sea-water (Fahr.). Surface	Designation and Physical Character.	Carbonate of Calcium. Per cent.	Carbonate of Calcium. Foraminifera.	Carbonate of Calcium. Other Organisms.
		1876	° ′ ″		°	°				
Off Ascension—*continued.*	344	April 3	7 54 20 S. 14 28 20 W.	420	...	82·0	Calcareous Volcanic Sand, mottled brown, black, and white. **Residue** mottled black, yellow, and brown.	71·65	(50·00 %), Globigerinidæ, *Pulvinulina.* (5·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(16·65 %), Otoliths of fish, fragments of Gasteropods and Lamellibranchs, Pteropods, Ostracodes, Echinoderm fragments, Polyzoa, Corals.
Ascension Island to St. Vincent.	345	,, 4	5 45 0 S. 14 25 0 W.	2010	36·8	82·8	Globigerina Ooze, white with slight rose tinge, granular, pulverulent, chalky. **Residue** red.	93·90	(80·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Rotalidæ.	(11·90 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
	346	,, 6	2 42 0 S. 14 41 0 W.	2350	34·0	82·7	Globigerina Ooze, light grey, granular, slightly coherent, chalky. **Residue** brownish.	85·42	(75·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ.	(8·42 %), fragments of Echini spines, Coccoliths, Rhabdoliths.
	347	,, 7	0 15 0 S. 14 25 0 W.	2250	36·2	82·0	Globigerina Ooze, grey, granular, slightly coherent. **Residue** red-brown.	84·48	(75·00 %), Globigerinidæ, *Pulvinulina.* (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(7·48 %), Ostracodes, Echini spines, Coccoliths, Rhabdoliths.
	*348	,, 9	3 10 0 N. 14 51 0 W.	2450	...	84·0	Globigerina Ooze, brown-grey, homogeneous, granular, pulverulent. **Residue** black.	83·13	(73·00 %), Globigerinidæ. (2·00 %), Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ.	(8·13 %), Lamellibranchs, Ostracodes, Echinoderm fragments, a few Coccoliths and Rhabdoliths.
St. Vincent towards Azores.	353	May 3	26 21 0 N. 33 37 0 W.	2965	37·6	70·7	Red Clay, unctuous, homogeneous, caking into light brown coherent lumps, plastic when wet. **Residue** brick red.	11·12	(7·00 %), *Globigerina*, *Pulvinulina.* (1·00 %), *Miliolina*, *Lagena*, Rotalidæ.	(3·12 %), Otoliths and small teeth of fish, Echini spines, a few Coccoliths.
	354	,, 6	32 41 0 N. 36 6 0 W.	1675	37·8	70·0	Globigerina Ooze, light grey with rose tinge, granular, pulverulent. **Residue** rose coloured.	90·58	(80·00 %), Globigerinidæ, *Pulvinulina.* (1·00 %), Miliolidæ, Lagenidæ, Rotalidæ.	(9·58 %), Otoliths and teeth of fish, Cirriped plates, fragments of Lamellibranch shells, Ostracodes, Echini spines, Coccoliths, Rhabdoliths.

* See Pl. XII. fig. 3.

Residue.				Additional Observations.	
Per cent.	Siliceous Organisms.	Minerals.	Fine Washings.		
28·35	(1·00 %), two or three Radiolaria and a few thin brown imperfect casts.	(25·00 %), m. di. 0·60 mm., angular; volcanic materials, lapilli, plagioclase, hornblende, augite, olivine, magnetite, palagonite, many glassy volcanic fragments and coloured altered particles.	(2·35 %), flocculent amorphous matter, a few minute fragments of minerals and siliceous organisms.	The sounding tube brought up a few pieces of dead shells and Corals. In the dredge and tow-net attached there was a little of the sand described. Many of the fragments of rock, shells, and Corals, were quite black from a coating of manganese. Some of the small rock fragments are black vesicular basalt, transforming into palagonite.	Off Ascension—*continued.*
6·10	(1·00 %), Radiolaria, imperfect casts of Foraminifera.	(1·00 %), m. di. 0·06 mm., angular; felspar, magnetite.	(4·10 %), flocculent amorphous matter, minute mineral particles.	The sounding tube brought up about half a quart (over half a litre) of the ooze of a uniform colour throughout. The pelagic Foraminifera, which make up the greater part of this deposit, are relatively of very large size compared with those from higher latitudes.	Ascension Island to St. Vincent.
14·58	(2·00 %), Radiolaria, Sponge spicules, Astrorhizidæ, Lituolidæ.	(1·00 %), m. di. 0·07 mm., angular; monoclinic and triclinic felspars, hornblende, magnetite, magnetic spherules, fragments of volcanic rocks with microliths of plagioclase, glassy volcanic particles.	(11·58 %), amorphous matter, small mineral particles, and minute fragments of siliceous organisms.	The sounding tube had sunk about a foot (30 cm.) into the deposit, but with the exception of a few streaks on the outside, it brought up no specimen of the ooze; in the dredge and attached tow-nets there were about five litres. The percentage of carbonate of lime is the mean of three determinations from different parts of the collected deposit.	
15·52	(2·00 %), Radiolaria, imperfect casts of Foraminifera, Lituolidæ.	(1·00 %), m. di. 0·06 mm., angular; sanidine, magnetite, magnetic spherules, hornblende, manganese.	(12·52 %), amorphous matter and minute mineral particles.	About one litre of the ooze came up in the sounding tube. Some of the Foraminifera in this deposit have their surfaces dotted with grains of manganese. A few shells are coated with manganese, and the Foraminifera are filled with a red substance which remains as an internal cast after treatment with dilute acid.	
16·87	(1·00 %), Radiolaria, Astrorhizidæ, Lituolidæ, Diatoms.	(1·00 %), m. di. 0·06 mm., angular; felspar, hornblende, magnetite.	(14·87 %), amorphous matter, with many very minute fragments of minerals and siliceous organisms.	A sounding was taken at this spot in 1873 (see Station 102), but only a small quantity of the deposit was then obtained. In the present instance a dredge and tow-net attached were used and brought up altogether over 11 litres of the ooze. Many of the Foraminifera are covered and filled with a black or dark brown substance. This dark substance, to which the colour of the deposit is due, is probably carbonaceous, and probably comes from the rivers of the western coast of Africa.	
88·88	(1·00 %), a few Radiolaria and Sponge spicules.	(1·00 %), m. di. 0·10 mm., angular; monoclinic and triclinic felspars, rounded grains of quartz, hornblende, black mica, magnetite and magnetic particles, volcanic glass, manganese grains.	(86·88 %), flocculent clayey matter, with many minute fragments of minerals and Radiolaria.	The colour of the deposit is due to the hydrate of iron. The sounding tube had sunk 14 inches (35 cm.) into the bottom and brought up over a litre of the clay. The deeper portions were darker coloured and contained less carbonate of calcium than the surface layers. The manganese grains and fishes' teeth were more abundant in the lower layer. The shells of the Foraminifera seem to be undergoing decomposition, and many of the shells split into concentric layers. Some of the mineral particles have probably been carried by the Harmattan winds from Africa. This deposit resembles those taken in the same region in 1873.	St. Vincent towards Azores.
9·42	(1·00 %), Radiolaria and Sponge spicules.	(1·00 %), m. di. 0·10 mm., angular; sanidine, plagioclase, rounded fragments of quartz, magnetite, augite, manganese grains.	(7·42 %), flocculent amorphous matter, with many minute mineral particles and some fragments of Radiolaria.	The sounding tube brought up about half a litre of the deposit. The residue of this deposit resembles in most of its characters the clays in this region of the ocean sound at greater depths. The augite is feebly dicroscopic. The Foraminifera are not so large as those nearer the equator.	

b. Remarks on the Variation of the Deposits with Change of Conditions along the different Lines of Soundings and Dredgings.

With the view of enabling the reader to obtain a general idea of the more important variations which take place in the nature and composition of marine deposits with a change in the conditions, special reference will now be made to the different lines of soundings and dredgings of the Challenger Expedition across the various oceanic basins, and along the coasts of continents and oceanic islands. In doing this we shall in a special manner point out the variations which appear to be due directly to differences in depth and of distance from coast influences. A somewhat graphic representation of these lines of soundings is presented in the Diagrams at the end of the Volume, where the percentage of carbonate of lime in the deposits is placed beneath the name at each station, and where the temperature conditions and submarine reliefs are also shown.

1. *Atlantic Ocean.*

England to Gibraltar.—A number of preliminary soundings and dredgings were made along the coasts of Spain and Portugal, at the outset of the Expedition, with the view of testing the various kinds of apparatus. (See Charts 2 and 3).

The deposit at 560 fathoms, off the mouth of the Tagus, was a Green Mud or Sand, consisting of Foraminifera, Coccoliths, fragments of Echinoderms, Molluscs, and Polyzoa, angular fragments of quartz, felspar, mica, magnetite, and many glauconitic particles. The calcareous organisms made up about 32 per cent. of the deposit, and, after treatment with dilute hydrochloric acid, many dark and pale green, perfectly formed, glauconitic casts were observed. The percentage of carbonate of lime in the deeper deposits remained about the same, but the glauconitic particles were not nearly so abundant. The mineral constituents of this deposit are chiefly derived from the disintegration of continental land, and are similar in all respects to those found later on to prevail along the borders of the great continents. Passing outwards from the shore, the deposit altered to a Blue Mud, which, as the shore was again approached, became a Green Mud in about 1000 fathoms, and Green Sands in lesser depths. In the Green Muds the glauconitic casts were found to be abundant, while they were almost if not entirely absent in the Blue Muds.

Gibraltar to Madeira.—Between Gibraltar and Madeira six soundings and three hauls of the trawl were obtained, in depths varying from 1090 to 2000 fathoms (see Charts 2 and 3). The deposit at each of the stations at which a sample was obtained was a Globigerina Ooze. The percentage of carbonate of lime ranged from 53 to 75, and consisted almost entirely of pelagic Foraminifera, Coccoliths, and Rhabdoliths. The residue, insoluble in dilute acid, consisted of a few Radiolaria, minute particles of quartz, felspar, augite, glassy volcanic fragments, and clayey matter.

Off Madeira.—The deposits about the Dezertas and Madeira (see Chart 4) were Volcanic Muds, with from 30 to 40 per cent. of carbonate of lime, consisting chiefly of pelagic Foraminifera, except in one instance in 670 fathoms, where there was a Calcareous Sand with 96 per cent. of carbonate of lime made up of fragments of shells, Corals, Polyzoa, &c. The mineral particles in the deposits were angular fragments of felspar, magnetite, lapilli, basaltic scoriæ, and volcanic glass.

Madeira to Tenerife.—One sounding in 1975 fathoms was taken between Madeira and Tenerife (see Charts 2 and 5); only a small quantity of material was obtained sufficient to indicate that the deposit was a Globigerina Ooze.

Around the Canary Islands.—A number of soundings were taken around and among the Canary Islands (see Chart 5). Like those off Madeira, the deposits were chiefly Volcanic Muds, the percentage of carbonate of lime varying from 10 to 45. The mineral particles were angular fragments of vesicular basalt, augite, sanidine, magnetite, olivine, and volcanic glass.

Tenerife to Sombrero.—The character of the deposits in the section from Tenerife to Sombrero (see Chart 6) presented marked differences. All the deposits in depths less than 2600 fathoms contained over 50 per cent. of carbonate of lime, and for these the names Globigerina and Pteropod Oozes have been adopted. Pteropod Ooze is confined to two deposits from depths of 1525 and 1420 fathoms, the former on the eastern, the latter on the western side of the section, in which very many Pteropod and Heteropod shells occurred; in 1420 fathoms the proportion of carbonate of lime was the greatest, being 80·69 per cent. In 1525 fathoms fragments of a large dead Alcyonarian Coral coated with manganese peroxide, and attached to large manganese nodules, were obtained in the dredge. Only a few fragments of Pteropods were found in the Globigerina Ooze ranging between 1890 and 2025 fathoms, the carbonate of lime in the Globigerina Ooze being made up chiefly of the dead shells of pelagic Foraminifera. The Pteropod Ooze, however, contained all the pelagic Foraminifera, together with Pteropod and Heteropod shells. In depths greater than 2600 fathoms, the quantity of carbonate of lime decreased as the depth increased, and below 3000 fathoms there were only a few traces in the deposit.

Siliceous organisms, such as spicules of Sponges, Radiolaria, and Diatoms, were not abundant; generally they did not appear to make up more than 1 or 2 per cent. of the whole deposit, with the exception of the two deposits at 1525 and 1420 fathoms, above referred to, where the proportion probably rises to from 6 to 20 per cent., owing to the large number of Sponge spicules.

The mineral particles, which were mostly of volcanic origin, seldom exceeded 0·10 mm. in diameter, and consisted of felspars, hornblende, augite, magnetite, glassy fragments, and palagonite. In the deposits from the eastern portion of the section there were numerous small rounded particles of quartz covered with limonite. These would appear to be mostly wind-borne particles, carried by the Harmattan and other winds from the coast of Africa. The Red Clay found in the greater depths was almost entirely composed of amorphous and clayey matter and fine mineral particles not exceeding 0·05 mm. in diameter. In the dredging on the 7th March in 2435 fathoms, there were several round compact manganese nodules, several millimetres in diameter, and three or four sharks' teeth coated with peroxide of manganese.

With reference to the distribution of the deposits in this section the Red Clays occupy two areas of the ocean bottom, one to the east and one to the westwards, separated by an elevated area known as the Dolphin Rise, covered with Globigerina Ooze. A general idea of this section, with the relation of the percentage of carbonate of lime to depth and the distribution of the deposits, can be formed from Diagram 1.

Off Sombrero Island.—Three soundings were taken off Sombrero Island, in 450 to 590 fathoms (see Chart 7). These were designated Pteropod Oozes, for, although containing a large percentage of pelagic and other Foraminifera, there was also present a relatively large number of Pteropod and Heteropod shells. The average percentage of carbonate of lime was 84·27. The mineral particles were similar in quality and quantity to those in the deposit in 1420 fathoms in the preceding section.

St. Thomas to Bermuda.—In the section from St. Thomas to Bermuda (see Charts 6 and 7), the deposits at the depths of 625 and 390 fathoms on the plateau to the north of the Virgin Islands were Pteropod Oozes, with 69 and 74 per cent. of carbonate of lime, containing a few small mineral particles and some amorphous matter. These deposits resemble in most respects the deposits in similar depths off Sombrero, and, although named Pteropod Oozes, differ considerably from deposits bearing the same name obtained at greater depths far removed from dry land. The deposits from depths greater than 2700 fathoms contained from 4 to 18 per cent. of carbonate of lime, which consisted of broken shells of pelagic Foraminifera; these were mostly confined to the surface layers. A few inches beneath the surface the deposit showed only a very slight sign of effervescence when treated with dilute acid. There is a gradual decrease in the depth from 2960 fathoms, north of St. Thomas, onwards to Bermuda, and the corresponding increase in the percentage of carbonate of lime is strikingly exemplified. At 2960 fathoms there was 3 per cent. of carbonate of lime, at 2859 fathoms there was 18 per cent., at 2700 fathoms there was 22 per cent., at 2600 fathoms 29 per cent., at 2475 fathoms 54 per cent, at 2250 fathoms 70 per cent., at 1820 fathoms 82 per cent., and at 950 fathoms 89 per cent., while the deposits immediately surrounding the island of Bermuda in some instances contained as much as 93 per cent. of carbonate of lime, the percentage being greater the nearer the reef and the less the depth. The mineral particles in all the deposits in this section were exceedingly minute, rarely exceeding 0·07 mm. in diameter, and consisted of fragments of pumice, felspars, magnetite, and augite. The relation of depth and percentage of carbonate of lime is seen at a glance by referring to Diagram 2.

Off Bermuda.—During the two visits to Bermuda a number of soundings and dredgings were made around the islands and inside the reefs (see Chart 8). At a depth of 200 fathoms, about 2 miles from the reefs, the deposit was composed of large fragments of Coral, Foraminifera, Echinoderms, Polyzoa, Molluscs, Algæ, and concretionary lumps, some of which were 2 or 3 centimetres in diameter. At 380 fathoms, 3 miles from the reefs, the fragments were smaller, and, in addition to the above, there were many Pteropod and Heteropod shells. At 950 fathoms, 4 miles from the reefs, the particles were still smaller, and there was a considerable admixture of pelagic Foraminifera. At 1950 fathoms, 5 miles from the reefs, the deposit was a nearly pure Globigerina Ooze, made up chiefly of pelagic Foraminifera, with only a small proportion of species living on the bottom and fragments from the reefs. All these deposits contained from 81 to 93 per cent. of carbonate of lime. The residue, after treatment with dilute acid, consisted of a few siliceous spicules, of felspar, augite, magnetite, and glassy fragments. None of the mineral particles exceeded 0·07 mm. in diameter. At 2650 fathoms, 30 miles from the reef, the deposit was a Globigerina Ooze, containing over 60 per cent. of carbonate of lime, and Red Clay at still greater depths. The appearance of the deposits off the Bermudas, in depths of 200, 380, 950, and 1950 fathoms, is represented in the four figures of Plate XIII., and these show a gradual change in the size and nature of the calcareous organic remains with increasing depth and distance from the islands, although the percentage of carbonate of lime remains nearly the same at all depths.

Inside the reefs, in depths of 4 to 10 fathoms, there were Coral Muds and Sands, consisting for the most part of triturated fragments of calcareous Algæ, Corals, Polyzoa, mixed with which were Foraminifera, *Serpula*, Gasteropods, and Lamellibranchs. These gave on analysis from 86 to 95 per cent. of carbonate of lime. A few Sponge spicules, imperfect casts of Foraminifera, and Diatoms were also present; the mineral particles were few but relatively large, fragments of quartz and volcanic glass being the most abundant.

Bermuda to Halifax.—The deposits between Bermuda and the coasts of North America (see Chart 9) showed, irrespective of depth, a regular decrease in the quantity of carbonate of lime as the American shores were approached. While over 50 per cent. of carbonate of lime occurred at 2600 fathoms, about 100 miles from Bermuda, in 1240 and 1250 fathoms, near the American shores, only 15 and 16 per cent. were found. The large pelagic Foraminifera made up the principal part of the carbonate of lime in the deposits around Bermuda, but they disappeared almost completely from the bottom when within the influence of the Labrador current. Rhabdoliths likewise disappeared from the bottom along with the larger tropical pelagic Foraminifera, while Coccospheres were found in the deposits under the Labrador current. The remains of siliceous organisms were uniformly though sparingly represented, with, however, specific differences in the cold and warm regions.

The mineral particles increased in size and number as the American continent was approached, where they consisted of fragments of quartz, monoclinic and triclinic felspars, hornblende, augite, magnetite, mica, and glauconite. An ideal section, with depths and percentages of carbonate of lime, is given in Diagram 2. On the 7th May a large block of syenite weighing 490 lbs. (222 kilogrammes), which had become jammed between the arms of the dredge, was brought up from 1340 fathoms. In this and the other dredgings within the influence of the Labrador current, over 100 miles from the shore, many stones were dredged, most of them being rounded pebbles or large grains with rounded angles; nearly two-thirds of the smaller fragments were milky quartz, whilst the larger fragments were quartzite, compact limestone, dolomite, mica-schist, and serpentine rocks, some of them with glacial striations. These deposits along the American coast were Blue Muds with a reddish surface layer, in which quartz and fragments of ancient rocks were abundant, making up from 40 to 70 per cent. of the deposits in 1240, 1350, and 1340 fathoms, while these minerals were not detected in the deposits around Bermuda.

Halifax to Bermuda.—The deposits from Halifax southwards to Bermuda (see Chart 9) were Blue Muds containing from 16 to 32 per cent. of carbonate of lime. The larger pelagic Foraminifera and Rhabdoliths became more abundant as Bermuda was approached, while the siliceous organisms became fewer. The mineral particles were of the same nature as those in the deposits in the previous section, being larger and more abundant in the more northern stations which are under the influence of the Labrador current.

Bermuda to the Azores.—With the exception of the deposit from Station 67, 2700 fathoms, which contained 54 per cent. of carbonate of lime, all the deposits in the section between Bermuda and the Azores (see Chart 6) from depths greater than 2400 fathoms contained less, and all from depths less than 2400 fathoms contained more, than 50 per cent. of carbonate of lime. In the greatest depths, 2850 and 2875 fathoms, there were only 8 and 10 per cent. The highest percentage of carbonate of lime was 83·31 in 1675 fathoms. In the greater depths the carbonate of lime consisted chiefly of fragments of pelagic Foraminifera and Coccoliths; in depths less than 1600 fathoms, the shells of pelagic Molluscs and fragments of Echinoderms were more or less abundant, and along with pelagic and other Foraminifera made up the principal part of the carbonate of lime in the deposits. Radiolaria and Sponge spicules never made up more than 1 or 2 per cent. of the deposit.

In the deep water immediately to the south of the banks of Newfoundland, there were fragments of quartz, monoclinic and triclinic felspars, and fragments of mica-schist and other ancient continental rocks. These were believed to be ice-borne fragments, although apparently south of the southern limit of the ice region in the North Atlantic as shown on the charts. On approaching the Azores these fragments disappeared more or less completely from the bottom, and the mineral particles then consisted almost entirely of volcanic minerals and pumice. Except the pumice, the mineral particles seldom exceeded 0·10 mm. in diameter, and generally they were much smaller. A few fragments of tufa coated with peroxide of manganese were dredged (see Diagram 3).

Off the Azores.—The afternoon of the 2nd July was spent in dredging in 50, 90, and 450 fathoms, in the straits between Pico and Fayal (see Chart 10). The deposit was a Volcanic Mud, containing pumice, fragments of volcanic rocks, plagioclase, sanidine, augite, magnetite, hornblende, black mica, and pelagic and other Foraminifera, Pteropods and other Molluscs, Coccoliths, Polyzoa, *Serpula*-tubes, and a few Radiolaria and siliceous Sponge spicules. In some instances the pumice stones were completely coated with *Serpula*, *Polytrema*, and calcareous Algæ.

The deposit at 900 fathoms between Pico and San Miguel was a Pteropod Ooze with 52·22 per cent. of carbonate of lime. The mineral particles were smaller than at the other stations in this section, but were of the same nature. At 1000 fathoms, between San Miguel and Santa Maria, the deposit was chiefly made up of pumice and volcanic minerals, with 8 per cent. of carbonate of lime.

Azores to Madeira.—Globigerina Ooze was found throughout this section between the Azores and Madeira (see Chart 6), containing from 55 to 80 per cent. of carbonate of lime. Pteropod shells were present in the shallower deposits, but absent in depths greater than 2000 fathoms, although one fragment was observed in the deposit from 2675 fathoms. The relatively high percentage of carbonate of lime at 2660 and 2675 fathoms, viz., 66 and 62 per cent., is worthy of note, compared with deposits from similar depths south of the banks of Newfoundland. The carbonate of lime here consisted almost wholly of the shells of pelagic Foraminifera in a very fragmentary condition. The fragments of siliceous organisms did not exceed 1 per cent. in any of the deposits.

The deposits in this section were remarkable for the large quantity of pumice which they contained; one or two fragments of quartz were observed but no particles of continental rocks could be detected (see Diagram 3).

Madeira to Cape Verde Islands.—The deposit to the west of the island of Palma (see Chart 6) in 1125 fathoms was a brown Volcanic Mud, containing about 6 per cent. of carbonate of lime. The size of the mineral particles rarely exceeded 0·15 mm. When the mud was passed through sieves the washings which remained were almost wholly made up of dead shells of Pteropods and Heteropods. In the dredge there were a few living animals and several large fragments of a dead Gorgonoid Coral, coated with manganese peroxide, similar to that obtained in 1525 fathoms about 200 miles further south on the Tenerife-Sombrero section. The next sounding was in 2300 fathoms, a little to the west of the position where the depth of 1525 fathoms was obtained in February. Here the deposit was a Globigerina Ooze, containing 57 per cent. of carbonate of lime. Later on the same day, 21st July, a sounding and dredging were obtained in 1675 fathoms, in nearly the same locality as on the 18th of February; the dredge again brought up more of the black Coral fragments coated with manganese. In 2300 and 2400 fathoms farther south a Globigerina Ooze with 64 and 58 per cent. of carbonate of lime was obtained; there were no Pteropod or Heteropod shells in these deposits. The mineral particles were chiefly volcanic, with a mean diameter of 0·07 mm., but here also small rounded grains of quartz were found, which, with similar particles observed in the sounding from 2675 fathoms to the north-west of Madeira, appear to be wind-borne fragments, carried from Africa by the Harmattan winds. Soundings in 2075 and 1795 fathoms gave a Globigerina Ooze with 60 and 57 per cent. of carbonate of lime. About 1 per cent. of these deposits was made up of Radiolaria and fragments of other siliceous organisms, the remainder being composed of volcanic minerals, a few grains of quartz, and clayey matter.

The mineral particles throughout this section were of volcanic origin, decreasing in size and quantity after leaving Madeira, and increasing in both respects as St. Vincent was approached.

Off Cape Verde Islands.—The deposits in the vicinity of the Cape Verde Islands (see Chart 11) from 200 down to a depth of 1150 fathoms were Volcanic Muds, with a varying proportion of carbonate of lime, from 8 to 56 per cent., in which Pteropod and Heteropod shells were abundant. In the harbour of St. Vincent the deposit in depths of 7 to 50 fathoms was a Calcareous Sand, with 87 to 94 per cent. of carbonate of lime, chiefly made up of Foraminifera shells and calcareous Algæ. In some places the shells of *Amphistegina lessonii* made up fully two-thirds of the whole deposit; *Polystomella*, *Discorbina*, and *Orbiculina* were also abundant. The mineral particles in these deposits decreased in size and abundance with distance from the land.

Cape Verdes to St. Paul's Rocks.—The line of this section runs south-east from St. Vincent towards Cape Palmas on the Guinea coast; thereafter it bends round and runs nearly due west to St. Paul's Rocks (see Chart 12).

The deposits at the two depths, 2575 and 2500 fathoms, near the African coast, contained respectively 30 and 6 per cent. of carbonate of lime, the small percentage in the latter being due to the abundance of continental débris, but at all the other stations the deposit was a Globigerina Ooze with over 50 per cent.; at 1850 fathoms in Mid-Atlantic the amount reached 90 per cent. In all the deposits the carbonate of lime consisted chiefly of pelagic Foraminifera and Coccoliths, with a few fragments of Echinoderms and other organisms; Rhabdoliths also were present in considerable quantity except at Stations 101 and 102. An analysis of the mud from the dredge at Station 102 (2450 fathoms) gave 83 per cent. of carbonate of lime, while the specimen from the sounding tube gave only 66·27 per cent. A careful examination of a large quantity of this deposit showed that nearly the whole of the carbonate of lime present came from the dead shells of surface organisms. It is estimated that of the 83 per cent. of carbonate of lime, 75 per cent. comes from pelagic Foraminifera, 6 per cent. from Coccoliths, and 2 per cent. from other calcareous Foraminifera, fragments of Echinids, and Ostracodes. *Pulvinulina menardii* and *Pulvinulina tumida* were the predominant forms, but *Globigerina sacculifera*, *Globigerina dubia*, and *Globigerina conglobata*, and *Sphæroidina dehiscens* were also very abundant. It is worthy of notice that the majority of the shells were very large, and the more delicate surface forms, as *Hastigerina* and *Candeina*, appeared to be quite absent. The smaller fragments were almost wholly made up of broken pieces of larger shells. The small specimens and primordial chambers, so common in shallower deep-sea soundings, were nearly absent. In the same way Rhabdoliths were not complete, if present at all, and the Coccoliths were very minute. The typical *Globigerina bulloides* did not appear to be present. The Foraminifera here were, as has been stated, thick-shelled and of large size, and it was precisely in this region that the largest specimens of pelagic Foraminifera were obtained on the surface by means of the tow-net. Many of the shells were broken and appeared to be in a crumbling condition.

The mineral particles in the soundings along the African coast sometimes reached 0·7 mm. in diameter, but in Mid-Atlantic they seldom exceeded 0·06 mm. Quartz and glauconite were present only in the deposits near the African continent. In the other deposits the mineral particles consisted of fragments of felspars (sanidine), magnetite, hornblende, and volcanic rocks. Radiolaria, Diatoms, Sponge spicules, and arenaceous Foraminifera never made up more than 2 per cent.

The deposits in this section were of a grey or reddish colour, except in a few of the soundings near the African coast, where they were of a dark slate colour, owing, apparently, to the presence of fine mud or river detritus.

Off St. Paul's Rocks.—The soundings close to St. Paul's Rocks (see Chart 13) showed either a hard and rocky bottom, or a Globigerina Ooze containing numerous fragments of the rocks of the island, and olivine, enstatite, serpentine, magnetic grains, and actinolite. The deposits from 1900 and 2275 fathoms, at a considerable distance on either side of St. Paul's Rocks, were Globigerina Oozes with 84 and 72 per cent. of carbonate of lime respectively, chiefly made up of remains of pelagic Foraminifera, while Pteropods, though present in considerable numbers in the Globigerina Oozes in lesser depths in the immediate vicinity of the islands, appeared to be entirely absent. In those depths also the mineral particles, which make up from 15 to 30 per cent. of the whole deposit near the islands, were few and small, not exceeding 1 per cent. and 0·07 mm. in diameter. The mineral particles from 1900 fathoms were similar in character to those found nearer the islands, and had evidently mostly come from St. Paul's Rocks.

St. Paul's Rocks to Fernando Noronha.—Between St. Paul's Rocks and Fernando Noronha (see Chart 12) there is a deep depression, the greatest depth recorded being 2475 fathoms. At this depth there was 36 per cent. of carbonate of lime in the deposit, while at the depths of 2275 and 2200 fathoms there were respectively 72 and 81 per cent. This is a good instance illustrating the diminution of carbonate of lime in the deposit with increasing depth, as here the surface conditions were the same, and the character of the mineral particles alike in all the soundings. The mineral particles consisted of felspars, hornblende, augite, magnetite, and vitreous particles. Radiolaria, Diatoms, and fragments of other siliceous organisms did not make up more than 1 per cent. of the deposits.

Off Fernando Noronha.—At Fernando Noronha (see Chart 14) dredgings were taken close to shore, in depths varying from 7 to 25 fathoms. The bottom was covered with a calcareous sand or gravel, of a mottled red and white colour, the fragments varying from 2 to 3 cm. in diameter, and consisting chiefly of calcareous Algæ, with fragments of Echinoderms, Molluscs, Polyzoa, Corals, *Polytrema*, *Amphistegina*, and other Foraminifera. There were also numerous volcanic pebbles.

Fernando Noronha to Pernambuco and Bahia.—Between Fernando Noronha and the American coast there is a deep depression, in which a depth of 2275 fathoms was obtained, and comparatively deep water extends to within 30 miles of the American shore. With one exception, the deposits in the section from Fernando Noronha to Pernambuco (see Charts 12 and 15) were Globigerina Oozes, with from 37 to 80 per cent. of carbonate of lime. The exception was a Red Mud from 500 fathoms, the first of the kind obtained since leaving England.

The deposits along the coast of Brazil differed in colour from those which the Challenger found along other continental shores. Here they were red, due, apparently to the large quantities of ochreous matter carried into the sea by the Brazilian rivers. Usually the colour of deposits along continental shores is blue, with a surface layer of a red or brownish colour. The carbonate of lime in the soundings off this coast varied from 60 to 6 per cent. according to depth, distance from the coast, and whether or not opposite the embouchures of rivers. The mineral particles consisted of fragments of quartz, plagioclase, felspars, sometimes kaolinized, epidote, mica, augite, hornblende, fragments of rocks and vitreous particles, the size varying from 0·05 to 1 or 2 mm. in diameter. Radiolaria and Diatoms were nearly, if not quite, absent from these deposits, and when present they, along with siliceous Sponge spicules, did not appear to make up over 1 per cent. of the whole deposit. The apparently complete absence of glauconite along this coast was also remarkable.

If this and the two preceding sections be examined, by reference to Diagram 4, it will be observed that two elevations, crowned by St. Paul's Rocks and Fernando Noronha respectively, divide the Atlantic at this part into three basins or depressions.

Off Bahia.—During the stay at Bahia the pinnace was engaged several days dredging in the bay. In some places the deposit was a white quartz sand containing fragments of felspar, mica, magnetite, hornblende, and other minerals, and also fragments of Echinoderms, Polyzoa, *Serpula*, and other organisms. In other places it was a dark blue mud, containing, along with fine amorphous matter, all the above-mentioned minerals and organisms.

Bahia to Tristan da Cunha.—Between the coast of America and Tristan da Cunha (see Chart 16 and Diagram 6) the greatest depth obtained was 2350 fathoms. There were many indications of an extensive plateau surrounding the Tristan group, with depths varying from 1425 to 2000 fathoms.

The deposits in depths less than 2100 fathoms on the Tristan plateau, except when close to the islands, contained from 85 to 95 per cent. of carbonate of lime, which was almost wholly composed of the shells of pelagic organisms. The three soundings in depths greater than 2100 fathoms towards the American coast contained from 35 to 55 per cent. of carbonate of lime. The deposit was a Globigerina Ooze throughout the section. The carbonate of lime came from pelagic Foraminifera, but it was observed that as the ship proceeded southward the Foraminifera in the deposits became dwarfed, and some tropical species disappeared. There were quartz fragments in the deposits near the American shores, but these disappeared or were exceedingly rare in the deposits towards the centre of the South Atlantic. The mineral particles were very few and very small, never exceeding 1 per cent. and a mean diameter of 0·10 mm.

Around the Tristan da Cunha Islands.—Many hauls of the dredge and trawl were taken around and between the islands of the Tristan da Cunha group (see Chart 17) in depths of 60 to 1100 fathoms. There was generally a coarse shelly bottom, composed of fragments of Polyzoa, Lamellibranch and Gasteropod shells, Brachiopods, Echinoderms, Pteropods, *Serpula*, and a few pelagic and other Foraminifera. In 360 fathoms close to Tristan the deposit was a Volcanic Sand composed essentially of mineral particles, with about 7 per cent. of carbonate of lime. The minerals were exclusively of volcanic origin, and had a mean diameter of 0·5 mm. Mineral particles of the same nature but smaller were present in the shelly bottoms around Nightingale Island.

Tristan da Cunha to Cape of Good Hope.—Between the Tristan plateau and the Cape of Good Hope there is a wide and deep depression (see Chart 16 and Diagram 6), where depths of 2550 and 2650 fathoms were obtained. The deposits at these depths contained 35 and 26 per cent. of carbonate of lime, consisting of pelagic Foraminifera and their broken parts. The mineral particles consisted of rounded and angular fragments of quartz, orthoclase, hornblende, tourmaline, and augite. These mineral fragments, a few of which were fully 1 mm. in diameter, indicate that these soundings are within the area which is occasionally affected with Antarctic ice. The two soundings in 2325 and 1250 fathoms, near the coast of Africa, contained 47 and 50 per cent. of carbonate of lime. The mineral particles seldom exceeded 0·15 mm. in diameter, and consisted of quartz, glauconite, felspar, augite, and magnetite. About 1 per cent. of these deposits was made up of Radiolaria, Diatoms, and Sponge spicules; glauconitic casts were observed after treatment with dilute acid, but these were not in sufficient abundance to warrant the deposits being called Green Muds, although very pure glauconitic muds and sands were dredged in the shallow water of the Agulhas Bank, to be referred to in describing the section from Cape of Good Hope to Prince Edward Island.

Sandy Point to Falkland Islands.—On the return voyage the Challenger entered the Atlantic by the Strait of Magellan. The deposit at 55 fathoms, as well as in two other soundings, 70 and 110 fathoms (see Chart 42), was a coarse sand, the grains about one millimetre in diameter, consisting of quartz, jasper, felspars, mica, hornblende, augite, glauconite, pumice, and particles of crystalline and schistose rocks.

Falkland Islands to Rio de la Plata.—The deposit in 1035 fathoms in this section was a sandy gravel (see Chart 42). The trawl line carried away and the trawl was lost, but the tow-net attached to the line at the weights contained some of the gravel. The larger particles were from 1 to 2 cm. in diameter, brown coloured, flattened, ellipsoidal, derived from ancient continental formations, such as schist, gneiss, arkose, and sandstone, together with milky and hyaline quartz, felspar, augite, magnetite, microcline, hornblende, and glauconite. The glauconite was globular, ovoid, elongated, or vaguely triangular, with rounded angles; many of the particles were not so homogeneous as true glauconite, and appeared as aggregates of minerals cemented by a green matter. Sometimes they showed a schistoid structure, and often it was difficult to say whether the fragments were glauconite or pieces of rocks strongly impregnated with a chloritic substance. Mixed up with the above-mentioned sandy particles were calcareous Foraminifera, fragments of Molluscs, Brachiopods, Echinoderms, and Polyzoans. In 2040 fathoms the deposit was a Globigerina Ooze containing 33 per cent. of carbonate of lime. At 2425 fathoms there was a Blue Mud containing about 40 per cent. of mineral particles with a mean diameter of 0·12 mm., and 6 per cent. of carbonate of lime derived from bottom-living Foraminifera and small teeth of fish, the remainder of the deposit being composed of the remains of siliceous organisms, fine mineral particles, and clayey matter.

In 600 fathoms the deposit was a Blue Mud, green-grey in colour, containing 12 per cent. of carbonate of lime. In the sounding tube and in the trawl there were several small concretions, from 1 to 3 cm. in diameter, nodular, more or less elliptical, and varying in colour from grey-green to yellow-green. They were agglutinations of the clastic materials forming the deposit, cemented together by a clayey matter united with a chloritic mineral, but were not very coherent. Cut into thin sections, they were seen to be formed of angular fragments of quartz (1·0 to 0·5 mm. in diameter), of felspars, some of which were triclinic, of hornblende, of glauconite, and of garnet. The amorphous matter cementing this sand was finely granular, and impregnated with a green or yellowish chloritic substance, with vague outlines and non-birefrangent, the same as that observed upon the isolated grains of the mud. With these sandy agglutinations were associated rounded elliptical fragments with a diameter of from 1 to 2 cm.; they were green, fine grained, could be scratched with steel, and at first sight appeared to have the grain and structure of glauconite. Examined with the microscope, they presented a greenish fundamental mass, with scattered colourless and irregular particles (0·05 mm. in diameter), and black and brown points which appeared to be organic. With polarised light the colourless particles with vague contours were seen to be crystalline, and were probably felspar or quartz. Other fragments with a coarser grain were seen, under the microscope, to be composed of felspar and quartz perfectly discernible, cemented and surrounded by chlorite.

Off Monte Video.—In leaving the Rio de la Plata two hauls of the trawl were obtained in 13 and 21 fathoms (see Chart 16). The deposit in the former depth was a blue tenaceous mud containing large fragments of Molluscs and plants, and many sandy particles; in the latter, sand and shells.

Rio de la Plata to Ascension.—In 1900 fathoms, off the mouth of the Rio de la Plata (see Chart 16), the deposit was a Blue Mud, containing about 3 per cent. of carbonate of lime, which consisted chiefly of a few shells of pelagic Foraminifera. The six following soundings showed depths ranging between 2650 and 2900 fathoms. Four of these contained not more than a trace of carbonate of lime, and no remains of calcareous organisms were observed; the other two had 3 and 4 per cent. The remains of siliceous organisms made up about 5 per cent. of the deposits. The mineral particles had a mean diameter of 0·1 mm. or less, and consisted of fragments of quartz, plagioclase, augite, grains of magnetite, mica, and a very large number of fragments of pumice and volcanic scoriæ. The fragments making up these deposits appear to have been mostly derived from the Rio de la Plata, the influence of which on the deposits could be distinctly traced several hundred miles seawards.

When the depth diminished as the Tristan plateau was reached, the character of the deposits likewise changed. A sounding in 2440 fathoms gave 10 per cent. of carbonate of lime. All the other soundings, on the plateau surrounding Tristan da Cunha and extending north to the Island of Ascension, ranged from 2200 to 1240 fathoms. The percentage of carbonate of lime varied from 66 to 98 per cent., the proportion being greater in the lesser depths. In depths less than 1500 fathoms the deposits appeared to be largely made up of the dead shells of pelagic Molluscs, such as Pteropods, Heteropods, and pelagic Gasteropods, and they have in consequence been called Pteropod Oozes. In depths of 2000 fathoms and deeper these shells were almost completely removed from the deposits, which then consisted chiefly of pelagic Foraminifera.

Off Ascension.—A sounding in 420 fathoms, about 5 miles distant from Ascension Island (see Chart 43), was a Globigerina Ooze with 97 per cent. of carbonate of lime, made up of pelagic Foraminifera and pelagic Molluscs. Another similar deposit, nearer to the island, contained a much higher percentage of volcanic minerals, the proportion of carbonate of lime being 71 per cent. These deposits might be equally well classed as Pteropod Ooze.

Ascension to Cape Verdes.—On this trip three dredgings, four soundings, and eight serial temperatures were obtained (see Chart 12 and Diagram 7). The depths ranged from 2010 fathoms to 2450 fathoms, and the deposit in each case was a Globigerina Ooze, containing 94 per cent. of carbonate of lime in the former depth and 83 per cent. in the latter depth. Only one or two small fragments of Pteropod shells were observed in these deposits, in which the carbonate of lime consisted chiefly of the shells of pelagic Foraminifera, Coccoliths, and Rhabdoliths. The remains of siliceous organisms did not make up more than 2 per cent. of the whole deposit. The mineral particles were exceedingly minute, and consisted of fragments of felspars, hornblende, augite, and magnetite.

Cape Verdes to England.—On the 3rd May 1876, in lat. 26° 21′ N., long. 33° 37′ W., a sounding was obtained in 2965 fathoms (see Chart 6), the bottom being Red Clay containing in the surface layers 12. per cent. of carbonate of lime, which consisted of a few shells of the larger pelagic Foraminifera and their broken fragments. The mineral particles did not exceed 0·1 mm. in diameter, and consisted of a few grains of felspar, quartz, hornblende, magnetite, volcanic glass, and manganese peroxide. The principal part of the deposit consisted of flocculent clayey matter, with exceedingly minute fragments of minerals, Radiolarians, and Sponge spicules.

On the 6th May, in lat. 32° 41′ N., long. 36° 6′ W., another sounding was obtained in 1675 fathoms, the deposit being a Globigerina Ooze containing 91 per cent. of carbonate of lime, which consisted of pelagic Foraminifera, Coccoliths, Rhabdoliths, and a few fragments of Pteropods and Echinoderms. The residue, after the removal of the carbonate of lime by dilute acid, resembled in most respects the Red Clay found at greater depths in the same region of the Atlantic.

2. *Southern and Antarctic Oceans.*

Cape of Good Hope to Prince Edward and Marion Islands.—On the 17th December 1873, the Challenger left Simon's Bay for the southern cruise. A sounding and dredging were taken in 98 fathoms (see Chart 18 and Diagram 8). The deposit consisted of a green glauconitic sand, containing 50 per cent. of carbonate of lime, which was derived chiefly from shells of Foraminifera, fragments of Molluscs, Polyzoa, *Serpula*, and Echinoderms.

On the 18th the ship sounded and dredged in 150 fathoms. The deposit was nearly the same as on the preceding day, the carbonate of lime being a little higher, viz., 68 per cent. Glauconite is exceptionally abundant in these deposits on the Agulhas Bank; the grains are about one millimetre in diameter, and are isolated or agglomerated into phosphatic nodules several centimetres in diameter. Besides these grains, the Foraminifera are often filled with a pale green glauconitic substance, which only rarely shows all the typical characters of glauconite. This green material remained as an internal cast of the shells when the deposit was treated with dilute acid. In these deposits there was much green-coloured amorphous matter, some of it not unlike vegetable tissue, which, when heated on platinum, charred like an organic substance, became black, then red. In these Green Sands the mineral particles formed a large percentage, being 40 and 20 respectively, and the remains of siliceous organisms including the green-coloured casts were estimated at about 6 per cent. (see Pl. XXIV. fig. 1 for glauconitic particles).

On the 19th a sounding and dredging were obtained in 1900 fathoms (see Chart 18). The deposit was a Globigerina Ooze, containing 90 per cent. of carbonate of lime, which consisted almost entirely of pelagic Foraminifera. In the dredge were several irregular brown-coloured phosphatic nodules from 1 to 4 cm. in diameter, containing 49 per cent. of tricalcic phosphate.

On the 24th, a sounding and temperatures were obtained in 1570 fathoms. The deposit was a Globigerina Ooze containing 92 per cent. of carbonate of lime, and a few Diatoms, Radiolaria, and mineral particles chiefly of volcanic origin. The pelagic Foraminifera in this sounding belonged to the small and thick-shelled varieties peculiar to colder waters, although they were not of the typical Arctic or Antarctic varieties. Probably many of the finer particles were washed out of the sounding tube.

Off Marion Island.—The dredgings between Marion and Prince Edward Islands (see Chart 19), showed that the bottom, in depths less than 100 fathoms, was overgrown with great masses of Polyzoa, the dredges and swabs being filled and covered with them. Mr Busk records thirty species of Polyzoa from this locality, fifteen of which are new. In 140 and 310 fathoms there was a Volcanic Sand containing 15 to 20 per cent. of carbonate of lime shells, many Diatoms, and many volcanic minerals and lapilli of vitreous basaltic rocks.

Marion Island to Crozet Islands.—The deposit at 1375 fathoms (see Chart 18) was a Globigerina Ooze, containing 86 per cent. of carbonate of lime, the residue being almost wholly remains of Diatoms and Radiolarians. At 1600 fathoms there was 35 per cent. of carbonate of lime, 35 per cent. of minerals and amorphous and clayey matter, and 30 per cent. of Diatom and Radiolarian remains, and this deposit was in consequence called a Diatom Ooze. There were a few rounded quartz particles in each of the deposits, but the great majority of the mineral particles were of volcanic origin. The carbonate of lime in these deposits consisted chiefly of *Globigerina* shells and Coccoliths. *Orbulina* shells were not observed in the deposits, nor at the surface, and Rhabdoliths were not observed in the deposits since leaving the Cape, so that these stations are probably beyond the southern limit of these organisms.

Off Crozet Islands.—The deposit at 600 fathoms (see Chart 20) was a Diatom Ooze with 36 per cent. of carbonate of lime, chiefly made up of shells of pelagic Foraminifera, the residue consisting principally of Diatoms and other siliceous organisms with many fragments of volcanic minerals. At 210 and 550 fathoms the bottom was hard ground, gravel and shells.

Off Kerguelen Island.—During the month of January 1874, the Challenger took many soundings and dredgings in the bays and several miles off the east coast of Kerguelen (see Chart 21), in depths varying from 20 to 130 fathoms.

In all cases the deposit was a green Volcanic Mud[1] with a strong smell of sulphuretted hydrogen, and composed principally of mineral particles and the siliceous skeletons of organisms. Generally these muds did not effervesce with acids; sometimes, however, a few spots of effervescence were observed. The carbonate of lime never appeared to make up more than 1 or 2 per cent. of the deposit, and consisted of a few fragments of Echinids, Mollusc shells, Polyzoa, and Foraminifera. These last were *Miliolina*, *Uvigerina*, and *Discorbina*; only one or two pelagic Foraminifera were noticed in these muds. The mineral particles made up from 20 to 60 per cent. of the deposit, and consisted of fragments of felspar, plagioclase, augite, magnetite, hornblende, olivine, sometimes decomposed with red tint, lapilli, pumice, and brown volcanic glass. The size of these particles was from 0·5 mm. to 0·1 mm. in diameter, the larger sized particles being found in those soundings nearest the coasts. The frustules of Diatoms made up in every case a large part of the deposit, and along with the siliceous spicules of Sponges, probably as much as 50 per cent. in some of the samples. The soundings farthest removed from the coast contained generally much the larger proportion of siliceous remains. These muds contained but little clayey matter, and when dried were grey-green, slightly coherent, and earthy in aspect.

Off Heard Island.—On the 2nd February, after leaving Kerguelen Island, a successful sounding and dredging were obtained (see Chart 18) at Station 150 in 150 fathoms, on a hard bottom. The bottom was covered with a coarse gravel; the dredge brought up a large number of stones, fragments of rocks of irregular form, varying from 1 to 7 centimetres in diameter, with the angles more or less rounded, but much less so than those of ordinary rolled pebbles. They were blue-black, and the majority had a compact structure and were fine grained, while others were porous with a rough surface, all belonging to the felspathic basalts (dolerite). Among these volcanic fragments were noticed two or three pieces of granite and one of sandstone. The majority of these stones were overgrown by Foraminifera, Sponges, Actiniaria, Brachiopods, Ascidians, *Serpula*, and Polyzoa. It was roughly estimated that 20 per cent. of the deposit was made up of the remains of calcareous organisms, and that 15 per cent. came from Sponge spicules and other siliceous remains, and that 60 per cent. consisted of the mineral particles, and 5 of amorphous clayey matter.

The deposit in the sounding and dredging in 75 fathoms off Heard Island (see Chart 22) was a greenish black Volcanic Sand, composed essentially of black volcanic sand and remains of organisms. There was only 2·58 per cent. of carbonate of lime, consisting of shells of *Miliolina*, *Discorbina*, *Uvigerina*, and one or two *Globigerina*, along with fragments of Polyzoa, Molluscs, Echinoderms, &c. The mineral particles made up 80 per cent., and

[1] Green Mud should have been green Volcanic Mud in the Tables (see p. 78).

had a mean diameter of about 0·3 mm.; they formed a black sand consisting chiefly of fragments of brown and red glass—sometimes decomposed, sometimes massive and enclosing microliths of olivine, and sometimes porous—with fragments of felspar, plagioclase, augite, and magnetite. There was also 5 per cent. of Diatoms, Sponge spicules, and Radiolaria.

Heard Island to Melbourne.—In the cruise between Heard Island and Australia (see Charts 23 and 24, and Diagrams 9 and 10) four kinds of deposits were met with, viz., Blue Mud, Diatom Ooze, Globigerina Ooze, and Red Clay.

The first of these was found in depths of 1675, 1800, and 1300 fathoms at the most southern latitude reached by the Challenger, between lat. 64° and 66° S. (see Chart 23), and therefore a short distance north of the great Ice-barrier and the Antarctic Continent. These Blue Muds contained less than 12 per cent. of carbonate of lime, which consisted chiefly of the dead shells of *Globigerina dutertrei*, and less than 20 per cent. of the remains of siliceous organisms, chiefly Diatoms. The mineral particles consisted of quartz, felspars, hornblende, garnet, glauconite, mica, tourmaline, and fragments of granitic, amphibolic, and other rocks. From the depth of 1675 fathoms the dredge brought up many kinds of rocks and pebbles, some of them showing distinct marks of glaciation, and many of them having a coating of peroxide of manganese on that part which had projected above the mud when lying at the bottom. The rocks belonged to the following lithological types:—granites, quartziferous diorites, schistoid diorites, amphibolites, mica-schists, grained quartzites, and partially decomposed earthy shales.

To the northward of the stations at which Blue Mud was found, between lat. 64° and 53° S. (see Charts 23 and 24), in depths of 1260, 1975, and 1950 fathoms, the deposit was a Diatom Ooze, usually of a yellowish straw colour, which when dried had the aspect of flour, the particles being extremely fine, and the whole taking the impress of the fingers when pressed, gritty particles being now and then recognisable. One of the samples contained as much as 22 per cent. of carbonate of lime, consisting chiefly of the dead shells of *Globigerina bulloides*, *Globigerina inflata*, and *Globigerina dutertrei*. The mineral particles were similar to those in the Blue Muds just mentioned, and appeared to make up from 3 to 15 per cent. of the deposit, the remainder of the deposit (from 62 to 88 per cent.) consisting of the frustules of Diatoms and the skeletons of Radiolaria. The dredgings in these deposits yielded, in addition to all the varieties of rocks mentioned in the Blue Muds further south, several fragments of pumice stone, basaltic volcanic rock, palagonite, and one or two fragments of a compact limestone and sandstone.

Between lat. 53° and 47° S. two soundings were obtained in 1800 and 2150 fathoms (see Chart 24). The deposit in each case was a whitish Globigerina Ooze, containing respectively 85 and 88 per cent. of carbonate of lime, which consisted chiefly of Coccoliths, Coccospheres, and pelagic Foraminifera belonging to the species: *Globigerina bulloides*, *Globigerina inflata*, *Globigerina dubia*, *Pulvinulina micheliniana*, and

Orbulina universa, together with other Foraminifera and fragments of Echinoderms. The mineral particles appeared to make up 1 per cent. of the deposit, and consisted of hornblende, magnetite, felspar, vitreous fragments, and a few quartz grains. There was from 2 to 10 per cent. of Diatoms and Radiolaria in these Globigerina Oozes.

The remaining variety of deposit (Red Clay) was obtained in lat. 42° S. at a depth of 2600 fathoms (see Chart 24). It contained 18 per cent. of carbonate of lime, consisting of entire shells and fragments of *Globigerina bulloides*, *Globigerina inflata*, and *Globigerina rubra*, *Pulvinulina micheliniana*, *Orbulina universa*, a few other Foraminifera, Coccoliths, Polyzoa, and fragments of Echinoderms. The mineral particles only formed 1 per cent. of the deposit, and consisted of felspars, hornblende, augite, magnetite, pumice, fragments of volcanic glass, and grains of peroxide of manganese, with a mean diameter of about 0·08 mm., while a few rounded fragments of quartz reached a diameter of 0·5 mm. The remainder of the deposit consisted essentially of amorphous and clayey matter with very minute fragments of minerals and pumice. There was a larger percentage of carbonate of lime in the upper layers of the deposit than in the deeper ones. The trawl brought up 10 or 12 litres of manganese nodules, pumice stones, rolled pebbles of gneiss, fragments of palagonite, earbones of Cetaceans, and sharks' teeth.

From the foregoing description it appears that the deposits forming at the most southerly points reached by the Challenger are composed chiefly of continental debris carried into the ocean by the floating ice of these regions, and that this material makes up less and less of the deposit as the distance from the Antarctic Continent increases until it almost disappears about lat. 46° or 47° S., although at other longitudes in the Atlantic and Pacific continental debris from the Antarctic Continent appears to be carried fully ten degrees farther to the north. The deposits along the Antarctic Ice-barrier, which have been called Blue Muds, resemble in many respects the deposits formed at similar depths off the Atlantic coast of British North America. The nature of the rock fragments dredged in these latitudes conclusively proves the existence of continental land certainly of considerable extent within the Antarctic Circle. One of the fragments of gneiss dredged from a depth of 1950 fathoms measured 50 by 40 centimetres, and weighed more than 20 kilogrammes. In the region occupied by the Diatom Ooze, northward of the Blue Muds, the predominant feature of the deposit is due to the innumerable frustules of Diatoms and skeletons of Radiolaria which have fallen from the surface and subsurface waters of the ocean. Farther north again the pelagic Foraminifera predominate in the deposit, except at the depth of 2600 fathoms, where the greater part of them has been removed by the solvent powers of the sea-water, as is usual at the great depths of the ocean.

South of lat. 50° S., Diatoms were frequently met with in the surface nets in enormous abundance. The most abundant were various species of *Chætoceros*, but there were also many other genera. The tow-nets were on some occasions so filled with these that large quantities could be dried by heating over a stove, when a whitish felt-like mass was obtained. Mixed up with these Diatoms there were many species of Radiolaria. Coccospheres and Rhabdospheres, which were found so abundantly in the surface water of the warmer parts of the Atlantic and Southern Oceans, were not met with south of lat. 50° S., either on the surface or in the deposits at the bottom. The same remark applies to *Orbulina universa*, *Pulvinulina*, and several species of *Globigerina*. South of lat. 50° S., the only pelagic Foraminifera found on the surface were *Globigerina bulloides*, *Globigerina dutertrei*, and *Globigerina inflata*, and these were the only pelagic species found in the deposit at the bottom (see Diagrams 9 and 10).

3. *Pacific Ocean.*

Melbourne to Sydney.—The deposits from the shallow water between Melbourne and Moncœur Island (see Chart 25) were shelly sands with 82 per cent. of carbonate of lime, coming chiefly from fragments of Polyzoa; these fragments were usually over 5 mm. in diameter. Mineral particles formed about 5 per cent., and consisted for the most part of quartz, mica, and felspars. Green casts of the shells were left after treatment with dilute acids.

Soundings were taken in 2200 and 150 fathoms to the north of Cape Howe, the shallower depth being several miles nearer shore. In the former case the deposit was a Globigerina Ooze with 62 per cent. of carbonate of lime largely coming from the remains of pelagic Foraminifera. The trawling in 150 fathoms showed that the bottom was covered with Polyzoa, shells, and gravel.

Off Sydney.—The deposits in depths of from 120 to 1200 fathoms off the Australian coast (see Chart 26) were Green Sands and Muds, containing a considerable quantity of glauconite, and resembling in many respects the deposits at similar depths off the south coast of Africa. The deposits from 120 and 290 fathoms were Green Sands, those from greater depths Green Muds. The carbonate of lime ranged from 46 to 50 per cent., and consisted of the shells of *Globigerina*, *Orbulina*, *Pulvinulina*, *Pullenia*, *Miliolina*, *Textularia*, *Discorbina*, *Cristellaria*, and other Foraminifera; Coccospheres and Rhabdoliths; fragments of Pteropods and other pelagic Molluscs; Ostracode valves, fragments of Echinoderms, Polyzoa, and other calcareous organisms. The mineral particles in these deposits were about 0·12 mm. in diameter, and consisted of rounded fragments of quartz, felspars, hornblende, magnetite, mica, volcanic glass, in addition to glauconite. There were a few Radiolaria and Sponge spicules. Many of the Foraminifera shells were filled with green glauconitic matter which remained as internal casts after treatment with dilute acids. A quantity of the glauconitic grains and casts were carefully collected after removing the calcareous organisms by dilute acid, and an analysis of these is given in the description of glauconitic deposits (see Pl. XXIV. fig. 2 for glauconitic casts).

Sydney to New Zealand.—The two soundings in 2600 fathoms contained respectively 7 and 19 per cent. of carbonate of lime. In 1975 fathoms there was 77 per cent., in 1100 fathoms 84 per cent., and in 275 fathoms 88 per cent. (see Chart 27). The carbonate of lime in all these consisted essentially of the shells of pelagic Foraminifera, with Coccoliths, Coccospheres, and Rhabdoliths. In the deeper deposits there is, it will be noticed, less and less carbonate of lime, and this is due to the gradual removal of the more delicate and smaller shells (see Diagram 11). While these small shells and Coccospheres made up most of the deposit at 275 and 400 fathoms, they were very rare at a depth of 2600 fathoms, though they appeared to be quite as abundant at the surface over the one locality as over the other. The mineral particles were very minute in these soundings, and consisted chiefly of felspars and glassy volcanic fragments. As the entrance of Cook Strait was approached, the mineral particles derived from the coast of New Zealand increased both in number and size, and the pelagic shells diminished, while glauconite, which was absent in the soundings from the middle of the section, again made its appearance. At 150 fathoms the deposit was a Blue Mud with 26 per cent. of carbonate of lime.

Off New Zealand.—The deposits off the east coast of New Zealand in 1100 and 700 fathoms (see Chart 27) were Blue Muds, with a thin characteristic layer of a reddish colour on the surface. They contained only from 4 to 10 per cent. of carbonate of lime, the chief part of the deposit consisting of amorphous and clayey matter and fine mineral particles derived from the neighbouring land. The mineral particles were uniform in size and nature in both localities, but while they were estimated at 21 per cent. in the former, in the latter deposit they made up 25 per cent. Siliceous organisms were few. The dredge brought up pumice stones at both stations.

New Zealand to Tongatabu.—The deposits off the Kermadec Islands in 520, 630, and 600 fathoms (see Chart 27 and Diagram 12) were Volcanic Muds, containing very many large blocks of pumice. A very large fragment of a huge new Hexactinellid Sponge, *Poliopogon gigas*, was brought up from 630 fathoms attached to pumice stones; it measured about 2 feet by 3 feet 6 inches.[1] The deposit at 2900 fathoms was a Red Clay, which gave no trace of effervescence when treated with dilute acid, showing that it did not contain any carbonate of lime. The mineral particles were very small, the bulk of them being less than 0·05 mm. in diameter, and consisted of felspar, magnetite, and hornblende; there were, however, some large fragments of pumice, and the great bulk of the fine washings of the deposit was composed of very minute fragments of pumice.

Off Tongatabu.—When outside a line joining Mallenoah and Atataa Islands dredgings were obtained, first in 18 fathoms, and then in 240 fathoms (see Chart 28). The deposit at both these depths was a Coral Sand containing from 86 to 90 per cent. of carbonate of lime, composed of fragments of Coral, calcareous Algæ, *Orbitolites* and many other

[1] 6·1 by 10·6 decimetres.

Foraminifera, fragments of Polyzoa, Echinoderms, and Molluscs. At the greater depth farther from the reef, the fragments were smaller and the pelagic shells more abundant than in the depth of 18 fathoms nearer the reef. Mineral particles constituted about 3 per cent. in both cases; the fragments were volcanic, with a mean diameter of about 0·5 mm. The general appearance of these deposits in 240 and 18 fathoms is represented in Pl. XIV. figs. 1 and 2.

Off the Fiji Islands.—Off the Fiji Islands (see Charts 29 and 30) the deposits were, with one exception, Coral Muds and Sands containing from 86 to 90 per cent. of carbonate of lime, principally composed of calcareous Algæ and Polyzoa with a large proportion of Foraminifera. In the Coral Sand from 12 fathoms, off Levuka, there were no pelagic Foraminifera, while the minerals were comparatively numerous and large, having a mean diameter of 0·5 mm. In the Coral Muds from greater depths the percentage of pelagic Foraminifera increased, while the minerals were few and small, rarely exceeding 0·08 mm. in diameter. The exception referred to above was that of the deposit from 610 fathoms —a Globigerina Ooze with 80 per cent. of carbonate of lime (see Pl. XIV. figs. 3*a* and 3*b*). In this instance the major part was composed of pelagic Foraminifera, while nearly all the organisms of the shallower deposits were present, though in minute fragments and relatively less abundance. The mineral particles and siliceous organisms were more numerous than in the shallower depths, while there were fewer particles derived from the reefs. Rhabdoliths were observed only in this deposit, and a few brown casts of calcareous organisms remained after treatment with dilute acid. Several pieces of pumice were obtained from 210 and 610 fathoms.

Fiji Islands to the New Hebrides.—The deposits at 1350 and 1450 fathoms (see Chart 27 and Pl. XII. figs. 4*a*, 4*b*) were Globigerina Oozes of a reddish colour, and closely resembled in that respect the Red Clays. They contained 44 and 62 per cent. of carbonate of lime, consisting of Rhabdoliths, Coccoliths, the shells of *Globigerina*, *Orbulina*, *Hastigerina*, *Pulvinulina*, *Sphæroidina*, *Pullenia*, and some bottom-living species. A few of the *Globigerina* shells had still the delicate spines attached as in the specimens taken on the surface. The absence of Pteropod, Heteropod, and other pelagic Mollusc shells from these deposits is somewhat remarkable, for they were very abundant on the surface, and at a similar depth and latitude in the Atlantic they were usually present in considerable numbers. The Foraminifera shells were in some instances quite white, or had a rosy tinge as if lately fallen from the surface, but the great majority were brown coloured, and in some instances black from a deposit of oxide of manganese on their surface. When one of these dark coloured shells from 1450 fathoms is broken three zones can be distinguished, at the centre an internal cast of the shell, then the white carbonate of lime shell itself, and outside this an external cast of the same nature and aspect as the internal one, to which it is connected by little red pillars which have been formed in and fill up the foramina of the shell. These casts do not appear to be formed by a simple filling of the shell, but seem to be due to a chemical combination. There were in these deposits none of the smooth pale yellow and green casts so abundant in the Green Muds along continental shores. If these red coloured casts be treated with warm hydrochloric acid and the iron thus extracted, a number of colourless globules are obtained, which have resisted the action of the acid. It has been found that these casts consist of hydrated silicate containing alumina, lime, magnesia, and alkalies. The mean diameter of the minerals rarely exceeded 0·10 mm., and were usually much smaller; these were felspars, black mica, augite, hornblende, and magnetite. The great bulk of the residue after removal of the carbonate of lime, however, consisted of pumice stone in a fine state of division, with amorphous matter. Radiolaria and Diatoms made up about 1 per cent. of the whole deposit.

The trawling at 1350 fathoms gave many rounded fragments of pumice, from 6 to 8 cm. in diameter, covered with oxide of manganese, and the branch of a tree several feet in length which was carbonised in some places (see Diagram 13).

There were many very productive hauls with the surface nets between the Fiji Islands and the New Hebrides—Pteropods, Heteropods, and pelagic Foraminifera being specially abundant. With the exception of a very large cylindrical species of *Coscinodiscus*, Diatoms were very rare both on the surface and at the bottom. It was observed that the larger Foraminifera, such as *Sphæroidina dehiscens*, *Pulvinulina menardii*, and thick-shelled *Orbulinæ*, were procured in greatest abundance when the tow-net was dragged at a depth of 80 or 100 fathoms.

New Hebrides to Raine Island.—The deposits between the New Hebrides and Raine Island (see Chart 27 and Diagram 13) varied greatly with depth, and were very interesting. At 2650 fathoms not a trace of carbonate of lime could be detected either by the microscope, or by treating the Red Clay with weak acid. At 2450 fathoms there was 1 or 2 per cent. of carbonate of lime, consisting of a few broken fragments of Foraminifera. At 2440 fathoms there was a Red Clay on the surface with 5 per cent. of carbonate of lime, but three inches beneath the surface a much lighter coloured deposit containing a very large number of Foraminifera, and 32 per cent. of carbonate of lime. At 2325 fathoms there was 32 per cent. of carbonate of lime, consisting of the dead shells of pelagic Foraminifera and a few Coccoliths and Rhabdoliths. The condition of things at 2440 fathoms is worthy of special remark. It very frequently happened during the cruise that the deeper layers contained less lime than the surface ones, but only on two or three occasions did it happen that there were more calcareous shells in the deeper layer of the deposit as in this case. The surface layer, it will be observed, was the same in nearly all respects as the deposit in 2450 fathoms 80 miles to the eastward, and the deeper layer resembled that at 2325 fathoms still farther to the eastward, or the deposits in a lesser depth towards Raine Island, which contained over 50 per cent. of carbonate of lime, so that possibly a subsidence of the bottom had taken place subsequent to the formation of the deeper layer. It is clearly illustrated in this section between Api and Raine Islands, that all the other conditions remaining the same or nearly so, the quantity of carbonate of lime found in a deposit is less the greater the depth. It is believed that this basin below 1300 fathoms is probably cut off from the colder water farther south, and, indeed, from general oceanic circulation, below that depth, in this respect approaching to the condition of enclosed seas. In all such basins the surface shells appear to be removed from the deposits at lesser depths than in areas where there is no interruption to free communication arising from the existence of submarine barriers.

The mineral particles in these deposits consisted chiefly of angular fragments of volcanic rocks and minerals, all of small size except the pieces of pumice which were numerous in all the dredgings. There were many manganese particles, and, at the sounding in 1400 fathoms, some of the Foraminifera shells were filled with the peroxide, so that a complete internal cast of the shell was left after treatment with dilute acid. The deposit in 130 fathoms, off Api Island, was a Volcanic Sand containing 13 per cent. of carbonate of lime.

Off Raine Island.—The soundings and dredgings in 135, 150, and 155 fathoms (see Chart 27) showed that the deposit was a Coral Sand, composed of white and brownish coloured fragments of Corals, Molluscs, and Foraminifera shells, with a considerable admixture of calcareous Algæ. Mr. H. B. Brady found in this deposit a larger number of species of Foraminifera than in any other taken during the cruise. Many of the shells were probably washed from the shallower water of the adjoining reefs. The deposit contained 87 per cent. of carbonate of lime, and it was estimated that more than one-half of this consisted of pelagic Molluscs and pelagic Foraminifera. The mineral particles in the deposit consisted of fragments of quartz, felspars, mica, augite, and olivine, and were estimated at 4 per cent.

By treating this deposit with dilute acid, casts of the Foraminifera shells are obtained, the majority of which are of a brick red colour, although a few are of a yellowish, or even greenish, tinge (see Pl. XXIV. fig. 3). They are not so compact or well marked in outline as the white and pale straw-coloured casts usually met with in glauconitic muds, and have very frequently a porous aspect, from the removal of the carbonate of lime which has, in many instances, been associated with the red material forming the casts. If some of the Foraminifera be treated with dilute acid, the action stopped after it has continued for some time, and the substance dried and examined by reflected light, a number of casts of the organisms are seen in carbonate of lime looking quite like milky quartz. If, however, the action be continued, it is seen that they are composed of carbonate of lime as they entirely disappear, leaving a small residue of a reddish colour, or very areolar casts of the shells in the same red substance. Examined in thin sections, it is observed that the shells are filled with a red, yellowish, or greenish matter, frequently extending into the foramina. The shell is at once distinguished from the cast by its structure, transparency, and optical properties.

It is sometimes observed that two or three shells or fragments are cemented by the same red substance forming the casts. This substance when sufficiently transparent appears of a yellowish red colour, and gives sometimes aggregate polarisation, but is never extinguished between crossed nicols. Often the casts enclose small mineral particles. With very high powers it is seen that the structure of the grey carbonate of lime casts is granular, and between crossed nicols it is evident that the grains are crystalline. This is one of the few instances in which it has been possible to point out the deposition of carbonate of lime in the shells forming deposits, and it evidently took place in the deeper layers.

Cape York to Arrou Islands.—The deposits in 6 and 7 fathoms around and near Booby and Wednesday Islands (see Chart 31) consisted of quartziferous sand with from 60 to 78 per cent. of carbonate of lime in the form of large numbers of Foraminifera, fragments of calcareous Algæ, Polyzoa, and shells. None of the Foraminifera, however, were pelagic species. It was estimated that from 15 to 30 per cent. of the sands consisted of mineral grains; these were from 0·5 to 1 mm. in diameter. Between Cape York and the Arrou Islands the depth in the Arafura Sea never exceeded 50 fathoms, usually ranging from 28 to 40 fathoms. The deposit was a greenish mud in all cases, containing from 25 to 50 per cent. of minerals, consisting of fragments of quartz, mica, felspars, glauconite, &c., about 0·2 mm. in diameter. In the dredgings there were fragments of sandstone and other continental rocks. The carbonate of lime in these deposits formed from 23 to 38 per cent., and consisted of the shells of *Textularia* and *Rotalia*, fragments of Echinoderms, Polyzoa, and Molluscs. Siliceous organisms made up 2 to 3 per cent.

Arrou Islands to Banda.—The deposits at 800 and 580 fathoms, between the Arrou and Ki Islands (see Chart 32), were Green Muds containing respectively 14 and 40 per cent. of carbonate of lime; at the shallower depth there were indications of two layers, the bottom layer being more clayey with a blue tinge.

The deposits at Stations 192 and 192A were most interesting. At the first of these (140 fathoms) the sounding tube brought up a specimen of Blue Mud, containing about 8 per cent. of carbonate of lime, and in the second (129 fathoms) the trawls, besides pumice stones, contained several large concretions or fragments of a calcareous rock, differing very considerably from the deposit.

The Concretions or Rock Fragments were of two kinds. First, many more or less rounded agglutinations loosely held together, and from 1 to 7 cm. in diameter. Second, several large honeycombed pieces of rock, several decimetres in diameter, and requiring a sharp blow from a hammer to break them.

Those belonging to the first variety are grey or brown, sometimes slightly greenish, granular, and it can be seen with the lens that they are essentially composed of Foraminifera. An examination of thin slides of these nodules shows that they are agglutinated or coagulated by an argillo-calcareous cement which is not in great abundance. Some of the shells are entirely filled with pale green glauconite, others only partially. The intervals between the shells are not filled up with the cementing matter, and these concretions appeared to be the last phase of disintegration.

Those of the second variety are very irregular in shape, and consist of large pieces of a hard rock traversed in all directions by large and small perforations, with a diameter varying from 1 to 4 centimetres. These blocks have thus a cavernous or coarse cellular appearance. The perforations are covered, like the surface of the rock, with organisms, as Sponges, Polyzoa, &c., and rough to the touch. The smaller perforations have sometimes the appearance of having been produced by lithophagous Molluscs. These concretions have the hardness of calcite ; the fragments freshly broken are white-grey. A microscopic examination shows that they are mainly composed of various species of pelagic Foraminifera. Treated with dilute acid the concretions decompose with effervescence, leaving a residue of 20·44 per cent., essentially composed of amorphous matter and glauconitic casts of the Foraminifera, these last being brown or green and feebly transparent. The greenish casts present most of the characters of true glauconite. In the residue there are also a few grains of felspar and quartz. A section of these concretions resembles in most respects a section of a hardened Globigerina Ooze from tropical regions, and near a continental shore (see Pl. XII. fig. 2). In this case, however, the shells are nearly all filled and cemented by the finely granular carbonate of lime, while in a Globigerina Ooze they are empty. It is not improbable that these large concretions or rock-fragments are hardened portions of a deep-sea deposit formed at a much greater depth, and subsequently elevated into the position in which they were found, probably by the same elevation as that which upheaved the neighbouring islands.

The deposit at 2800 fathoms was a fine-grained Volcanic Mud containing only a trace of carbonate of lime in the form of a few *Pulvinulina* shells. Mineral particles of volcanic origin made up about 60 per cent.; these were angular fragments of felspars, volcanic glass, augite, magnetite, and andesitic lapilli, having a mean diameter of 0·2 mm. There was also 5 per cent. of Sponge spicules, Radiolaria, and Diatoms. At 200 and 360 fathoms close to Banda (see Chart 33) the deposits consisted essentially of volcanic materials with a few pelagic Foraminifera. The dredge brought up several fragments of volcanic rocks and pumice measuring from 2 to 10 centimetres in diameter, Corals, siliceous Sponges, and calcareous Algæ.

In 17 fathoms off Banda the bottom was a sand or gravel with 52 per cent. of carbonate of lime made up of Foraminifera, Gasteropod, and Lamellibranch shells, Echinoderm fragments, Corals, and calcareous Algæ.

Banda to Amboina.—The deposit in 1425 fathoms (see Chart 31) was a Blue Mud containing 31 per cent. of carbonate of lime. The surface layer, about half an inch in thickness, was brownish in colour, while the deeper ones were blue and very compact.

Pelagic Foraminifera and Coccoliths were abundant. The mineral particles consisted of quartz, mica, volcanic glass, magnetite, felspar, pumice, and fragments of rocks.

The trawl brought up a considerable quantity of mud, which, with the exception of a few lumps, all belonged to the brownish surface layer. Mixed up with the mud were many large fragments of pumice, pieces of wood, leaves, and fragments of cocoa-nuts and other fruits. As was usually the case when the trawl brought up mud from the immediate surface layer, there was a large quantity of the weed-like branching Rhizopod described by Mr. H. B. Brady under the name of *Rhizammina algæformis*, and in addition many deep-sea animals.

Off Amboina in 15 to 20 fathoms the deposit consisted chiefly of Gasteropod and Lamellibranch fragments, while *Heterostegina complanata*, var. *granulosa*, was largely represented. In addition there were mineral fragments consisting of quartz, felspars, and particles of volcanic rocks.

Molucca Passage.—After leaving Amboina two soundings were obtained in the Molucca Passage, in 825 and 1200 fathoms (see Chart 31 and Diagram 14). The soundings were not successful, but from the latter depth sufficient material was obtained to indicate that the deposit was a Blue Mud. At 825 fathoms the trawl brought up large irregular fragments of a honeycombed conglomerate, overgrown with *Serpula*, Polyzoa, and Sponges. The largest fragment measured 12 by 8 inches (30 by 20 centimetres), and was not unlike that obtained at Station 192A, but was much harder and the organisms were less apparent. Thin sections examined by the microscope showed that the conglomerate was composed of Foraminifera and calcareous Algæ cemented together into a hard crystalline limestone, which on analysis yielded 94 per cent. of carbonate of lime. This rock, unlike that from Station 192A, would seem to have been formed in comparatively shallow water near land. A few Coral fragments were also brought up in the trawl.

Celebes Sea.—Four soundings were taken in the Celebes Sea at 2150, 2600, 250, and 2050 fathoms (see Chart 31 and Diagram 14). The deposit at 2150 and 2600 fathoms was a Volcanic Mud, the great bulk of which was composed of broken-down fragments of pumice and clayey matter, while at 2050 fathoms, near the coast of Mindanao Island, it was a Blue Mud with a considerable proportion of quartz grains among the mineral particles. There were only slight traces of carbonate of lime, the highest percentage (1·75) being found in 2050 fathoms; this was derived from a few fragments of Pteropods and pelagic Foraminifera shells. In each case there were two layers, the upper layer oozy and of a reddish colour, the lower compact and of a blue colour. At 250 fathoms the deposit was a Green Mud; only a small quantity was obtained, insufficient for detailed examination. The trawling in 2150 fathoms (Station 198) yielded several fragments of volcanic rock, some palm fruits, and pieces of wood and bark. *Globigerina*, *Pulvinulina*, *Orbulina*, and *Pullenia* shells were very numerous in the deeper hauls with the surface tow-nets. Some of the spines on the *Globigerinæ* were very long and delicate, being eleven times the diameter of the shell.

Sulu Sea.—The two soundings in the Sulu Sea at 2550 and 2225 fathoms (see Chart 31 and Diagram 14) were Blue Muds, containing in the former a trace, in the latter 15 per cent., of carbonate of lime, derived principally from pelagic Foraminifera. The greater part of the deposits is made up of amorphous and clayey matter. At 2225 fathoms there were two layers, upper red, lower blue; little difference could be detected between them except that of colour. There was evidence of the same arrangement in layers in the deposit in 2550 fathoms.

Passages among and between the Philippine Islands.—Several soundings were taken in these passages in October and November 1874 and January 1875 (see Chart 31 and Diagram 14). At 700 and 705 fathoms the deposit was a Blue Mud, with 3 to 11 per cent. of carbonate of lime. The mineral particles were larger and more numerous in the latter than in the former. The deposit from 375 fathoms was a Green Mud containing 36 per cent. of carbonate of lime largely made up of the shells of pelagic Foraminifera; glauconite, numerous casts, and many oval arenaceous bodies, believed to be the excreta of Echinoderms, were observed. The minerals were few and small, and embraced felspars, augite, hornblende, magnetite, and altered volcanic rock fragments. At 100 and 115 fathoms the bottom consisted of Green Mud with from 50 to 56 per cent. of carbonate of lime, derived from shells of pelagic Foraminifera, fragments of Gasteropods, Lamellibranchs, Echinoderms, and Polyzoa. The mineral particles were of a similar nature to those at 705 fathoms with the exception of glauconite, which is absent in the greater depth but present in considerable quantities in these Green Muds. These mineral particles make up from 30 to 40 per cent. After treatment with dilute acids a great many pale and dark green casts of the organisms were observed. These with Sponge spicules, Radiolaria, and arenaceous Foraminifera were estimated to form 3 to 4 per cent. The deposit in 95 fathoms was a Blue Mud containing about 36 per cent. of carbonate of lime, which consisted of a large number of pelagic and other Foraminifera, fragments of Echinoderms, Molluscs, and Polyzoa. This and the following station are within an area known as the *Euplectella* ground, where the greatest number of these Sponges was obtained. The siliceous organisms formed fully 10 per cent. Glauconite is found among the minerals, while abundant casts of the organisms remain after treatment with dilute acid. This seems to be a Green Mud in process of formation and resembles that obtained off the coast of Australia, near Sydney.

China Sea.—In the voyage to Hong Kong and back two soundings were obtained in 2100 and 1050 fathoms (see Chart 31 and Diagram 14). The deposits were Blue Muds, containing in the former a trace, in the latter 22 per cent., of carbonate of lime chiefly composed of pelagic organisms. The mineral particles made up from 5 to 10 per cent., consisting of quartz, felspars, hornblende, augite, magnetite, and volcanic glass;

siliceous organisms made up 5 to 10 per cent. Two or three rounded nodules of pumice, 1 to 3 centimetres in diameter, were obtained from 1050 fathoms.

Meangis Island to Admiralty Islands.—In this section (see Chart 31 and Diagram 15) the deposits presented some points of considerable interest. At 500 fathoms, near Meangis Island, the deposit was a Blue Mud with 34 per cent. of carbonate of lime, made up principally of pelagic Foraminifera, and over 20 per cent. of mineral particles, including felspars, quartz, augite, hornblende, magnetite, and pumice. In the trawl were many fragments of trachytic tufa. The deposit from 2550 fathoms was a Red Clay containing no carbonate of lime, and comparatively few mineral particles, which were volcanic, the great mass of the material being made up of fine amorphous and clayey matter. The trawl brought up from this depth several fragments of pumice about the size of a hen's egg; these all contain porphyritic minerals, and are in some cases slightly impregnated with manganese. At 1675 and 2000 fathoms were found Globigerina Oozes with 49 and 35 per cent. of carbonate of lime respectively. Mineral particles were few and small, and consisted of felspars, pumice, augite, and magnetite. Fewer Coccoliths and Rhabdoliths were present in the greater depth. The trawl brought up from 2000 fathoms a considerable number of pumice stones varying in size from that of a marble to that of a hen's egg. The surfaces of most of these were impregnated with manganese.

At 2000 fathoms nearer the coast of New Guinea the deposit was a Blue Mud containing 13 per cent. of carbonate of lime, chiefly derived from remains of surface Foraminifera. The mineral particles were exceedingly few and small, and consisted of fragments of felspar, augite, volcanic glass, and quartz. Two or three small pellets of pumice and several worm tubes were obtained in the sounding tube. The deposit in 1070 fathoms, between New Guinea and the Admiralty Islands, was a Blue Mud with a reddish surface layer, and contained 17 per cent. of carbonate of lime. No difference could be detected in composition between the two layers. Mineral particles made up 10 per cent., but the mass of the deposit was fine amorphous clayey material. The trawl brought up a large quantity of mud, large pieces of pumice, fragments of wood and fruits, Pteropod and *Ianthina* shells, and nearly two hundred specimens of deep-sea animals; the net was covered with a branching Rhizopod. The pieces of pumice varied in size from that of a pea to that of a hen's egg, and were slightly impregnated with manganese, and overgrown by *Serpula* and *Hyperammina vagans*. Siliceous organisms made up 4 per cent.

Humboldt Bay, New Guinea.—The deposit in 37 fathoms was a Blue Mud containing 29 per cent. of carbonate of lime, derived from pelagic and other Molluscs, bottom-living and pelagic Foraminifera, Ostracodes, fragments of Echinoderms, and calcareous Algæ. The mineral particles with a mean diameter over 0·05 mm. are estimated to make up 20 per cent., while the fine washings largely consist of smaller mineral particles. A few green casts of Foraminifera remained after treatment with dilute acid.

Off Admiralty Islands.—From 16 to 25 fathoms in Nares Harbour (see Chart 34) the bottom consisted of Coral Sands and Muds yielding on analysis about 87 per cent. of carbonate of lime, coming from fragments of Coral, calcareous Algæ, Lamellibranchs, Gasteropods, pelagic and bottom-living Foraminifera. Many of the large fragments were overgrown with *Serpula* and Polyzoa. Mineral particles were few and small, and consisted of pumice, felspar, volcanic glass, augite, magnetite, quartz, and some manganese grains. A few imperfect casts of the organisms remained after treatment with dilute acid. From 150 fathoms, about a mile from the reef, traces of a greenish coloured Volcanic Sand were obtained.

Admiralty Islands to Japan.—The deposits between the Admiralty Islands and Japan (see Chart 31) were of very high interest, chiefly from the large number of Radiolaria present in them, and also from the almost complete absence of carbonate of lime in the deeper soundings. In depths greater than 2400 fathoms there was either no carbonate of lime in the deposit or only a small percentage, as for instance in 2450 fathoms in lat. 2° N., where there was 6 per cent., due to the presence in the deposit of a few broken fragments of pelagic Foraminifera shells. On the other hand, there was 79 per cent. of carbonate of lime in the deposit at 1850 fathoms on the Caroline Islands plateau, which was a Globigerina Ooze made up principally of the shells of pelagic Foraminifera, Coccoliths, and Rhabdoliths. The absence of the shells of Pteropods, Heteropods, and other pelagic Molluscs from this deposit is worthy of note, as well as the absence of the Foraminifera shells from all the deeper deposits, as these organisms were very numerous at the surface throughout the whole region. As already stated, siliceous shells and skeletons were especially abundant in some of the deposits in this section, more numerous than in any deposits previously met with during the cruise. In one instance these beautiful little organisms made up about four-fifths of the deposit, which was in consequence called a Radiolarian Ooze. This was the case in the deepest sounding, viz., 4475 fathoms, the greatest depth from which a specimen of the bottom had hitherto been obtained. On this occasion the sounding tube had sunk about 3 or 4 inches (8 or 10 centimetres) into the bottom and brought up a section to that extent. The layer, which formed the upper surface at the bottom of the sea, was of a reddish or chocolate colour, and contained, besides the Radiolarian and Diatomaceous remains, numerous small round pellets of manganese peroxide, fragments of pumice, and clayey matter. The deeper layers were of a pale straw colour, and resembled both in appearance and touch the Diatom Ooze from the Antarctic Ocean. These deeper layers had a laminated structure, and were very compact and difficult to break up, being composed of felted masses of Radiolaria and frustules of Diatoms.

Pumice was very abundant in all the deposits, the trawl frequently bringing up numerous rounded pieces, many of them partly decomposed and coated with manganese peroxide. The mineral fragments in the deposits appeared to be chiefly derived from the pumice, except in the soundings close to the Japan coast. All the deeper deposits were brown or chocolate coloured, due to the presence of manganese. A glance at Diagram 16 shows the relationship between the depth and percentage of carbonate of lime.

The surface fauna and flora was especially rich and abundant throughout. In the region of the Counter Equatorial Current, between the Equator and the Caroline Islands, pelagic Foraminifera and Mollusca were caught in great numbers in the surface-nets, surpassing in this respect anything previously observed. This fact is most probably in relation with another, which may be pointed out. In this region the soundings in 2325 and 2450 fathoms contained respectively 52 and 7 per cent. of carbonate of lime, whereas at 2300 fathoms, in lat. 14° 44′ N., only a few broken fragments of *Globigerina* shells could be detected on microscopic examination, and at 2450 fathoms, in lat. 19° 24′ N., there was not a trace of carbonate of lime shells in the ooze. This shows apparently that where there are numerous calcareous shells at the surface their remains may be found at greater depths at the bottom than where relatively less abundant at the surface. The pelagic Foraminifera appear to float about in great banks; one day immense numbers of *Pulvinulina* would be taken in the net, the next day *Pullenia* would be most abundant, and *Pulvinulina* nearly or quite absent from the hauls. The heavier shelled specimens were usually taken when the nets were dragged 100 or 150 fathoms beneath the surface. Between latitudes 10° and 20° N., Oscillatoriæ were very numerous at the surface, and Diatoms, especially a large cylindrical *Ethmodiscus*, Castracane, were more abundant than in the tropical waters of the Atlantic far from land. The great abundance of Radiolaria and Diatoms is specially noteworthy.

Off Japan.—The soundings taken off the coast of Japan and in the Inland Sea (see Chart 35) proved to be Green and Blue Muds. Those in the Inland Sea, from depths of 8 to 15 fathoms, were Blue Muds containing from 4 to 11 per cent. of carbonate of lime, consisting of a few Foraminifera, fragments of Echinoderms, Molluscs, &c. There were, however, no pelagic Foraminifera shells, nor were any of these organisms found in the surface-net gatherings during the cruise in the Inland Sea. The bulk of these deposits was made up of mineral matter, 40 to 50 per cent. being composed of fragments over 0·05 mm. in diameter, while the great mass of the fine washings consisted of finer mineral particles. Many Diatoms were observed.

The deposits from 345 to 775 fathoms off the coast were Green Muds containing from a trace to 5 per cent. of carbonate of lime, of which pelagic Foraminifera formed a considerable proportion. Mineral particles over 0·05 mm. in diameter made up from 50 to 80 per cent., and consisted of felspars, magnetite, augite, hornblende, glauconite, quartz, volcanic glass, and pumice. In all these cases the mean diameter was about 0·20 mm., while green coloured casts of the Foraminifera remained after treating a portion of the deposits with dilute acid. The Green Muds from Stations 236 and 236A might equally well be designated Blue Muds, owing to the relatively small quantity of glauconite and the presence in some quantity of quartz fragments.

The deposits from depths greater than 1000 fathoms off the coast were Blue Muds containing from a mere trace to 4 per cent. of carbonate of lime, consisting to some extent of remains of pelagic organisms. In these deposits there were two layers—the upper red and the lower of a green or blue colour. Mineral fragments formed from 10 to 30 per cent. of the whole; these were of a volcanic nature. From 1875 fathoms the trawl brought up several pumice stones and many large blocks having the same mineralogical composition and clastic elements as the mud itself; these appeared to be indeed simply conglomerated portions of the bottom. Hardened conglomerations of deposit were also obtained from 420 fathoms.

Japan to the Sandwich Islands.—The deposits between Japan and the Sandwich Islands (see Chart 36) were most interesting. The deposit in 1875 fathoms, off Japan, has already been noticed. In all the greater depths there was no carbonate of lime in the deposits, but it is instructive to notice that at two stations where the depth was less than the average, viz., 2300 and 2050 fathoms, there was respectively 17 and 56 per cent. of carbonate of lime, consisting chiefly of the shells of pelagic Foraminifera; this clearly shows, as has been already pointed out, that the amount of carbonate of lime deposited is in inverse relation to the depth, when as in this instance the surface conditions are the same or nearly so. It is to be noticed, however, that in 2225 fathoms close to the Sandwich Islands there was only a trace of carbonate of lime. A sounding (Station 247), where the depth was 2530 fathoms, was remarkable. In the upper part of the section brought up by the sounding tube there was a reddish clay without any carbonate of lime; this layer was about an inch in thickness, and was somewhat sharply marked off from the lower layers, which were of a much lighter colour, and contained about 10 per cent. of carbonate of lime in the form of shells of pelagic Foraminifera. This condition of things might be explained by supposing that after the lower layers had been laid down, a subsidence of the bottom had taken place to the extent of 200 or 300 fathoms. All the deposits from the Japan coast to the 170th meridian of west longitude contained a very large number of the remains of surface-living siliceous organisms, chiefly Radiolaria. As the Sandwich Islands were approached, the siliceous organisms almost disappeared from the deposits, which were then almost wholly composed of the triturated fragments of pumice and amorphous clayey matter. For the relative depths and percentages of carbonate of lime, see Diagrams 17, 18, and 19.

There were eleven trawlings and two dredgings during the trip, but on four occasions the line parted and the trawls with a considerable length of line were lost. The others were fairly successful and productive. On all occasions the bag of the trawl contained numerous pieces of pumice and many manganese nodules. Some of the rounded fragments of pumice were quite fresh and unaltered; others had undergone profound alteration, and were frequently coated with successive layers of the peroxide of manganese. These pieces of pumice seem to have formed the centres of most of the manganese nodules taken in the North Pacific, but on several occasions the nuclei were teeth of sharks—*Oxyrhina*, *Lamna*, and *Carcharodon*—and in one instance a siliceous Sponge (*Farrea*) occupied the centre of the nodule. On the 12th July, from 2740 fathoms, the dredge contained a large tubfull of these dark brown manganese nodules, which, when rolled out on the deck, somewhat resembled in appearance a lot of potatoes, the largest being about the size of cricket balls.

Off Sandwich Islands.—The deposits near the Sandwich Islands (see Chart 37) were Volcanic Muds and Coral Sands. At 310 fathoms only a trace of mud was got on the beam of the trawl, while in the trawl was a piece of black volcanic ash and a portion of branching Coral (*Gorgonia*). In Honolulu Harbour the bottom at 4½ fathoms was a Volcanic Mud with 10 per cent. of carbonate of lime. This mud extended only to the reefs, for beyond the bottom consisted of Coral Sand with 88 per cent. of carbonate of lime. The minerals, however, were in both cases of volcanic origin.

Sandwich Islands to Tahiti.—The deposits between the Sandwich Islands and Tahiti (see Chart 38) presented many points of great interest. The mineral particles consisted of minute fragments of felspars, augite, hornblende, magnetite, and vitreous particles, magnetic (cosmic) spherules, and crystals of phillipsite, together with many pumice stones, palagonite, and manganese nodules. At each station these minerals varied much as to their relative abundance.

Between Hawaii and the 7th parallel of north latitude the depths ranged between 2650 fathoms and 3000 fathoms; the first two soundings were Volcanic Muds, the next in 3000 fathoms a Red Clay, the remaining four being Radiolarian Oozes consisting very largely of the remains of Radiolaria and Diatoms, these organisms becoming more numerous as the distance from Hawaii increased. There was hardly a trace of carbonate of lime in these deposits. The next three soundings were between the 6th parallel north and 1st parallel south latitude, the depths being 2550, 2925, and 2425 fathoms, and the deposits contained respectively 21, 71, and 81 per cent. of carbonate of lime, chiefly in the form of the shells of pelagic Foraminifera. The reason why such a relatively high percentage of carbonate of lime was found in these depths is probably explained by the fact that the pelagic Foraminifera and Molluscs were exceedingly abundant in the Equatorial and Counter Equatorial Currents which occupy the surface at these stations. In these deposits the Radiolaria and Diatoms were likewise numerous. The next three soundings, between 3° and 8° S., ranged between 2350 fathoms and 2750 fathoms, and were made up largely of Radiolaria and Diatoms, but contained in the surface layers a considerable number of pelagic Foraminifera shells. When the tube penetrated deeply into the deposit the deeper layers did not show any traces of carbonate of lime. The deposit at 11° 20′ S. and 150° 30′ W. in 2610 fathoms was a dark chocolate-coloured clay, containing an immense number of crystals of phillipsite, and together with these many fragments of palagonite and small nodules of manganese peroxide. The crystals of phillipsite made up the principal part of the deposit; these had been present in many of the previous deposits, but never in such abundance as in this instance. There was no carbonate of lime, and Radiolaria, which had been so abundant in previous deposits in this section, were only represented by a few specimens. The same remark as to the absence of Radiolaria applies to the next two stations, where the depths were 2350 and 2325 fathoms respectively, but there was in these 28 and 9 per cent. of carbonate of lime, which was due to the presence of calcareous Foraminifera. The deposit in 1525 fathoms was a Volcanic Mud containing 20 per cent. of carbonate of lime (see Chart 38 and Diagram 19).

In every instance the dredgings and trawlings yielded some manganese nodules and pumice, but on two or three occasions the manganese nodules were in extraordinary abundance. From 2750 fathoms on the 11th September there was over a peck of heavy, very compact, oval-shaped nodules. The largest were 10 centimetres in width and 5 centimetres in depth; the upper surface was smooth, while the under one was rough and irregular. Although differing in size, most of these nodules had the same shape, indeed it may be remarked that there is generally a close resemblance both in composition and shape and sometimes in size among the nodules from any single dredging. Among the nodules were sixteen sharks' teeth of considerable size, two being those of *Carcharodon*, nine *Oxyrhina*, and five *Lamna;* some of these were deeply imbedded in deposits of manganese. There were in addition to the above eight earbones of Cetaceans belonging to the genera *Globiocephalus*, *Mesoplodon*, and species of Delphinidæ.

On the 16th September, from 2350 fathoms, the trawl brought up more than half a ton of manganese nodules, which filled two small casks. The great majority of these nodules were small and nearly round, resembling a lot of marbles with a mean diameter of three quarters of an inch. The nuclei of these nodules were generally palagonite or other volcanic material, but very frequently small sharks' teeth or fragments of bone. Among the nodules were counted two hundred and fifty sharks' teeth, without taking into account those less than half an inch in length. Three of the teeth belonged to *Carcharodon*, being from 2 to 2½ inches (5 to 6·3 centimetres) across at the base of the dentine. Ten resembled those of *Carcharias*, and the remainder were referred to the genera *Lamna* and *Oxyrhina*. The Cetacean bones among the nodules consisted of two tympano-periotic bones of *Mesoplodon*, eight separate petrous bones, and six tympanic bullæ belonging to *Globiocephalus*, *Delphinus*, and *Kogia* (?).

Off Tahiti.—So irregular was the ground from the reef out to 35 fathoms that dredging was almost, if not quite, impossible; still by means of the swabs and tangles some Corals were obtained. From 35 to 40 fathoms down to 150 fathoms dredging was equally difficult. Here a number of Sponges, Alcyonarians, Corals, and other invertebrates were obtained. Beyond 150 fathoms the bottom was a Coral Sand with volcanic minerals and pelagic shells. The soundings taken by the ship at depths of 420, 590, 620, and 680 fathoms showed the presence of a Volcanic Mud, containing from 19 to 25 per cent. of carbonate of lime, derived from coral debris, fragments of Pteropods, Gasteropods, Coccoliths, with pelagic and other Foraminifera. The mass of the deposits was formed of fine mineral fragments (see Chart 39).

Tahiti to Valparaiso.—As might be expected from the undulating nature of the bottom, and the varying distance from land, the deposits presented considerable variety during the trip between Tahiti and Valparaiso (see Chart 38). In all depths less than 2000 fathoms the deposit was a Globigerina Ooze with over 50 per cent. of carbonate of lime, the highest percentage being 84 in 1600 fathoms. As the 40th parallel south was approached the purely tropical species of pelagic Foraminifera—such as *Globigerina conglobata*, *Sphæroidina dehiscens*, *Pulvinulina tumida*, *Pullenia obliquiloculata*—disappeared both from the surface waters and from the deposits at the bottom. At the depth of 1600 fathoms above referred to the deposit was chiefly composed of the following species, which were mostly dwarfed:—*Globigerina bulloides*, *Globigerina inflata*, *Globigerina dubia*, *Globigerina æquilateralis*, *Orbulina universa*, *Pulvinulina canariensis*, *Pulvinulina micheliniana*, and *Pulvinulina menardii*. There were a few fragments of Pteropods in the deposit from 1500 fathoms, but with this exception the shells of pelagic Mollusca were entirely removed from the bottom.

In depths greater than 2000 fathoms there was less than 50 per cent. of carbonate of lime, viz., 46 per cent. at 2075 fathoms, 26 per cent. at 2375 fathoms, still less in 2400 fathoms, and scarcely a trace in 2600 fathoms, thus showing a gradual diminution in the number of calcareous shells with increasing depth (see Diagrams 19, 20, and 21).

At several stations the sounding tube had penetrated over a foot into the deposit, and on two occasions, viz., at 2075 and 2270 fathoms, there was much less carbonate of lime in the lower layers than in the upper ones; but on another occasion, in 2335 fathoms, the arrangement was the reverse of this, a Red Clay with only a few calcareous shells occupying the surface, and a Globigerina Ooze with very many calcareous shells forming the deeper layers. There were very few remains of siliceous organisms in all these deposits, in which respect they are in marked contrast to the deposits of the Central and West Pacific.

The deposits in 2225 fathoms (see Chart 38) and 2160 fathoms off the coast of South America (see Chart 40) were Blue Muds, similar in all essential respects. The former contained 6, the latter 15, per cent. of carbonate of lime, which consisted chiefly of the shells of *Globigerina* and *Orbulina* and Coccoliths. The mineral particles consisted of quartz, mica, felspars, augite, hornblende, palagonite, and glauconite. It is worthy of note that glauconite was not observed in the deposits after leaving the coast of Japan till approaching Valparaiso, in 2225 fathoms, and with some exceptions the same remark applies to quartz grains. The trawlings on both occasions were very productive, some pumice stones and a few manganese nodules being obtained from 2160 fathoms. At 41 fathoms a Blue Mud was obtained, containing only a trace of carbonate of lime, in which the mineral particles were very few and very small for a shore deposit; the mass of the mud was amorphous and clayey matter of a green-blue colour.

The various dredgings and trawlings were successful with one exception, when the line parted and a trawl with 1600 fathoms of line were lost. The number of animals was not large. From 2550 fathoms there were several siliceous Sponges and Annelids, and two specimens of *Brisinga*, along with some Shrimps and a Scopelid Fish (*Bathypterois longicauda*, Günther) which probably did not come from the bottom. In several trawlings in depths between 2000 and 2385 fathoms there were again several siliceous Sponges, a Holothurian (*Oneirophanta mutabilis*, Théel), *Hymenaster echinulatus*, Sladen, several Annelids and Hydroids, together with a few Fish and Crustaceans which probably came from intermediate depths. In depths less than 2000 fathoms animals were not much more abundant. The best haul was in 1825 fathoms, including the following:—*Ophiomusium lymani*, Wyv. Thomson; *Ophiotholia supplicans*, Lyman; *Cystechinus wyvillii*, A. Agassiz; and *Polystomidium patens*, Hertwig. In addition to the animals here mentioned there were of course at all the stations many Foraminifera living on the bottom—some attached to the nodules, some living in the mud, with either arenaceous or calcareous tests. There were many surface animals taken in the tow-nets during each day of the cruise, but the number of forms was much less than in the tropical waters.

By far the most interesting result of these trawlings and dredgings was the great number and variety of sharks' teeth, bones of Cetaceans, manganese nodules, volcanic lapilli, and zeolitic minerals procured in all the greater depths, especially towards the centre of the Pacific, all of which will be referred to in detail in subsequent chapters.

Valparaiso to the Gulf of Peñas.—The deposit at 1375 fathoms, 20 miles to the eastward of Juan Fernandez (see Chart 40), was a Globigerina Ooze containing 54 per cent. of carbonate of lime, which consisted of the shells of Foraminifera, a few fragments of Pteropods, Echinoderms, and Polyzoa. The mineral particles were chiefly of volcanic origin, and among them were very many fragments of palagonite.

The trawl contained over one hundred deep-sea animals, and fragments of palagonite, pumice, and tufa. The trawl appeared to have caught in something at the bottom, for the accumulators were stretched to their utmost before it was finally freed. When it came to the surface the net was not torn, but the beam was scored and marked with streaks of black manganese peroxide. The fragments of tufa in the trawl were coated with manganese on one side, and appeared to have been torn away from larger masses, so that here as well as at several other stations there were indications that the bed of the ocean was uneven, probably from volcanic disturbance.

At 1450 fathoms, 330 miles westward from Chiloe Island, the deposit was again a Globigerina Ooze containing 82 per cent. of carbonate of lime. The mineral particles were chiefly minute fragments of basic volcanic glass and palagonite, and peroxide of manganese. The pelagic Foraminifera in the deposit were chiefly shells of *Globigerina* with a few of *Orbulina* and *Pulvinulina*, and all these were very small and dwarfed, in this respect agreeing with those taken on the surface by means of the tow-nets.

The trawl again brought up a large number of animals and some manganese nodules. Some of these latter appeared to have been fragments torn from larger masses, and some had nuclei which seemed originally to have been portions of the ooze itself. This association of manganese nodules with altered volcanic fragments in a Globigerina Ooze was frequently observed during the Expedition.

The deposit in 1325 fathoms was a Blue Mud containing 26 per cent. of carbonate of lime, made up of pelagic and other Foraminifera, fragments of Polyzoa, Echini spines, Ostracode shells, and fragments of other calcareous organisms. The mineral particles consisted chiefly of quartz and fragments of rocks and minerals derived from the continent.

Gulf of Peñas to Sandy Point through Magellan Strait.—The deposits in the Messier and Sarmiento Channels and Magellan Strait were in all cases Blue Muds containing generally very little carbonate of lime, and consisting mostly of debris from the neighbouring mountains. At Stations 308 and 311 there was 29 and 34 per cent. of carbonate of lime respectively. These deposits were forming in more or less open water, or in water affected by the ocean; the former was situated at the junction of Trinidad Channel with Conception Channel, the latter in the open water of Sea Reach (see Chart 41). Pelagic Foraminifera were only represented by a few stray specimens of *Globigerina*, and on the surface only a few of these shells were noticed, the deposits and surface gatherings in these enclosed channels thus being in marked contrast to what are found in the open sea, at some distance from land. The mineral fragments proper made up from 1 to 75 per cent. of the muds, and consisted of quartz, felspars, hornblende, mica, pumice, magnetite, and lapilli. Casts of organisms were observed in one or two cases.

In addition to the Challenger collections, the deposits from many lines of soundings, carried out by other ships, have passed through our hands; several thousand samples of deposits from nearly all regions of the great ocean basins and from many enclosed seas have thus been examined in the same way as the Challenger specimens. The general results are exhibited on Chart 1, which will be specially referred to when dealing with the geographical and bathymetrical distribution of deposits in a subsequent chapter. However, it may here be pointed out that the examination of these additional specimens confirm all the general conclusions indicated in the foregoing remarks on the Challenger sections across ocean basins and enclosed seas. They indicate a greater abundance of the remains of carbonate of lime organisms in the deposits from tropical regions,—those of pelagic surface-living organisms abounding in the deposits from deep water removed from the shores of continents and islands, and those of bottom-living or attached organisms abounding in the deposits from shallower waters near shore. The number of species of pelagic shells found in the deposits decreases in proportion as the colder waters of the polar regions are approached, till in the Globigerina Ooze of the Norwegian Sea only two species of pelagic Foraminifera are present.

Everywhere a general, if fluctuating, decrease in the quantity of carbonate of lime in the deposits is indicated with increasing depth, till in the greatest depths of the ocean hardly a trace of calcareous shells can be detected in the Red Clays or Radiolarian Oozes. This absence of carbonate of lime from the deeper deposits evidently does not in any way depend on the conditions at the surface of the ocean, for the tow-nets showed that the calcareous organisms were as abundant over the areas where none of these dead shells were found in the deposits as over those areas where they made up the principal part of the deposit in shallower depths. However, in latitudes where these shells are less numerous at the surface, the dead shells are removed from the deposits in lesser depths than in latitudes where they are more abundant. In like manner, on approaching the coasts, excepting always those shores which are fringed by coral reefs, a similar decrease in the percentage of carbonate of lime is observed, in this case, however, due to the preponderance of land debris in terrigenous deposits.

Glauconitic grains, glauconitic casts of the calcareous organisms, glauconitic and phosphatic nodules, have been found in a large number of samples of deposits from the deeper water along a great many continental shores, associated with mineral particles derived from the disintegration of continental rocks. As in the case of the Challenger explorations, these materials have been found only in exceptional circumstances towards the central regions of the great ocean basins, as for instance where the sea is occasionally affected by floating ice or by winds blowing directly from desert lands.

In the deepest water of the Indian Ocean, and in portions of the Pacific Ocean, Radiolarian Ooze, Red Clay, zeolitic and manganiferous deposits have been discovered in quite similar positions and conditions to those that were investigated by the Challenger naturalists in the Pacific, and the same may be said of Globigerina Ooze, Diatom Ooze, Pteropod Ooze, and the several varieties of terrigenous deposits in other regions.

CHAPTER III.

ON RECENT MARINE FORMATIONS AND THE DIFFERENT TYPES OF DEEP-SEA DEPOSITS: THEIR COMPOSITION, GEOGRAPHICAL AND BATHYMETRICAL DISTRIBUTION.

a. Recent Marine Formations in General.

In the preceding chapters we have described the methods employed in the study of Marine Deposits; thereafter we have given detailed descriptions of all the specimens of these deposits collected during the Challenger Expedition, and have pointed out some of the principal variations which these undergo with change of depth and other conditions.

In the present chapter we shall discuss the various kinds of marine formations now in process of being laid down on the floor of the ocean, and, as the Challenger investigations lay for the most part in the great ocean basins, we shall deal more especially with the different types of deposits discovered in the deep sea. Indeed, shallow-water and littoral formations will only be referred to incidentally and by way of illustration in the present work, which is devoted to a consideration of Deep-Sea Deposits.

What are we to understand by the deep sea? In this Report the term "deep sea" is applied to all depths of the ocean exceeding 100 fathoms (183 metres). We have been led to adopt this somewhat arbitrary limit from a number of considerations. The 100-fathom line is well delineated on all charts. All soundings in depths less than 100 fathoms are regarded by marine surveyors as useful for navigational purposes, and their positions are in consequence carefully entered on the charts along all coasts. In this way it happens that the 100-fathom line is at the present time the best defined of all the bathymetrical contour lines. Soundings beyond 100 fathoms were exceptional until within the last thirty years, when, in connection with telegraphic construction, it became necessary to ascertain the relief as well as the nature of the bottom from soundings along many lines across the great oceans.

Although there is no sudden or well-marked change in the nature of the deposits at a depth of 100 fathoms, still along all coasts bordering the great oceans this appears to be the average depth at which, in proceeding seawards, great abundance of fine amorphous particles settle permanently on the bottom. At about this depth the bottom is in general rarely disturbed by the action of currents or waves, and sunlight and vegetable life are nearly, if not quite, absent;[1] beyond 100 fathoms we have, as a rule, muds and oozes, while within the 100-fathom line sands and coarser deposits prevail.

[1] See P. M. Duncan, "On Some Thallophytes parasitic within recent Madreporaria," *Proc. Roy. Soc.*, vol. xxv. pp. 238-257, 1876.

Notwithstanding some exceptions, due to special conditions, as, for instance, on deep ridges between oceanic islands, where gravelly deposits are found, or in bays, fjords, and enclosed seas, where mud is met with in shallow water, it may be said that, along all coasts situated in or fronting the great oceans, 100 fathoms is the average depth at which fine mud or ooze commences to form. At about this depth the deposits on the whole assume a greater uniformity of composition and grain, and the signs of mechanical action tend to diminish or completely disappear. The greater the extent and depth of the ocean, the greater the depth to which wave-movement extends, and consequently the greater is the depth at which the mud-line is formed around the coasts,[1] but the average depth of this mud-line may be taken as approximately about 100 fathoms.

Not only is the 100-fathom line important as a dividing line between Deep-Sea and Shallow-Water Deposits, but in the physical relief of the globe it appears to mark the outer and upper limits of the continental masses, all within that line (the continental shelf) belonging to the continental plateaus, while beyond the 100-fathom line there is a relatively rapid descent of the sea-floor to the level of the depressed regions of the oceanic basins. This is shown by the fact that, while the area of the ocean between the shore-line and a depth of 100 fathoms is estimated at over ten millions of square miles, the area between the 100-fathom line and the 500-fathom line—in other words, the area of the ocean's bed taken in by a descent of the next 400 fathoms—is estimated at only about seven millions of square miles.

Marine Deposits as a whole may be arranged, from the point of view of their relative geographical and bathymetrical position, into three groups, viz., (1) DEEP-SEA DEPOSITS, formed beyond the 100-fathom line; (2) SHALLOW-WATER DEPOSITS, formed between the 100-fathom line and low-water mark; and (3) LITTORAL DEPOSITS, formed in the space between high and low water marks. From the point of view of their composition, as well as of their geographical and bathymetrical position, Marine Deposits may be separated into two great divisions, viz., (I.) PELAGIC DEPOSITS—those formed towards the centres of the great oceans, and made up chiefly of the remains of pelagic organisms along with the ultimate products arising from the decomposition of rocks and minerals; and (II.) TERRIGENOUS DEPOSITS—those formed close to continental and other lands, and largely made up of transported materials immediately derived from the disintegration of the land masses.

The relations of these large groups to each other, and their subdivisions, are exhibited in the following scheme, which is the first attempt at a systematic classification of Marine Deposits as a whole.[2]

[1] Stevenson, "On the Destructive Effects of the Waves of the Sea on the North-East Shores of Scotland," *Proc. Roy. Soc. Edin.*, vol. iv. pp. 200, 201, 1859.

[2] A very large number of names have been given to deposits in the littoral and shallow-water zones by geologists, physical geographers, and marine surveyors, viz., muds, oozes, sands, boulders, gravels, with various qualifying words indicating their colour, physical aspect, or composition, such as blue, red, yellow, black, soft, coarse, angular,

Marine Deposits.

1. Deep-Sea Deposits, beyond 100 fathoms.	Red Clay. Radiolarian Ooze. Diatom Ooze. Globigerina Ooze. Pteropod Ooze.	I. Pelagic Deposits, formed in deep water removed from land.
	Blue Mud. Red Mud. Green Mud. Volcanic Mud. Coral Mud.	II. Terrigenous Deposits, formed in deep and shallow water close to land masses.
2. Shallow-Water Deposits, between low-water mark and 100 fathoms.	Sands, gravels, muds, &c.	
3. Littoral Deposits, between high and low water marks.	Sands, gravels, muds, &c.	

In the above classification of Marine Deposits it will be observed that those forming in the shallow-water and littoral zones surrounding the land masses are not included in the term Deep-Sea Deposits, and in consequence the deposits of these zones do not fall to be considered in detail in this Report. Shallow-water and littoral formations had

rounded, siliceous, calcareous, &c. The same terms have been applied also to Deep-Sea Deposits, with the addition of further modifying expressions. Murray in his preliminary report adopted various new names for the deep-sea deposits collected by the Challenger Expedition, and these were more fully defined in a subsequent paper by Murray and Renard. Schmelck applies the following terms to the deeper deposits of the Norwegian Sea—Biloculina Clay, Transition Clay, and Grey Clay; and to the shallower deposits—Rhabdammina Clay and Volcanic Clay. Delesse used the terms—Calcaire tendre ou crayeux, Vase, Vase sableuse, Vase calcaire, Sable vaseux, Vase graveleuse, Argile, Gravier, &c. Agassiz makes use of the terms—Volcanic Shore Deposit, Siliceous Shore Deposit, Coral Ooze, Clay, Modified Globigerina Ooze, Modified Pteropod Ooze, Fine Telluric Silt. (See Murray, *Proc. Roy. Soc.*, vol. xxiv. pp. 471–532, 1876; Murray and Renard, *Proc. Roy. Soc. Edin.*, vol. xii. pp. 495–529, 1884; Schmelck, Norwegian North Atlantic Expedition, Chemistry, part ix., Christiania, 1882; Delesse, Lithologie du Fond des Mers, 2 vols. and atlas, Paris, 1871; Agassiz, Three Cruises of the "Blake," 2 vols., Boston and New York, 1888; Issel, Note geologiche sugli alti fondi marini, *Bull. Soc. belge de Geologie*, etc., 1888, p. 19; Thoulet, Océanographie (Statique), Paris, 1890; Gümbel, Die mineralogisch-geologische Beschaffenheit der auf der Forschungsreise S.M.S. "Gazelle" gesammelt Meeresgrund-Ablagerungen, Forschungsreise S.M.S. Gazelle, Theil ii., Physik und Chemie, Berlin, 1890.) Nearly all the above terms are more or less indefinite and uncertain in their application, and, with the exception of our own nomenclature, no systematic attempt has been made to define the sense in which they should be used; the same is the case with other terms not here referred to. The classification which we have adopted was suggested some years ago in our joint paper, and generally accepted in the principal text-books of geology (Geikie, de Lapparent, Credner, etc.); this nomenclature is by no means all that could be desired as to the choice of the terms employed, for sometimes these indicate the composition of the deposit, sometimes only the colour. We believe, however, that it is better, in the present state of our knowledge, to retain terms now in use than to introduce new ones, to which it would be difficult to attach more definite meanings. With the help of the definitions given in this work future observers should have no difficulty in recognising any specimen from the deep sea as belonging to one or other of the types named in the above classification and described in detail in this chapter.

indeed been treated, more or less fully, by many writers on Geology and Physical Geography long before the recent deep-sea investigations were undertaken, and hence there is less necessity to dwell on them in this place. Our remarks will therefore be limited to indicating the principal physical conditions and essential characters of the deposits in each of the above-mentioned zones.

Littoral Deposits.—These deposits are formed between high and low water marks, and if we take the length of the coast lines of the world at 125,000 miles,[1] and the average width of this zone at half a mile, then, at the present time, these deposits are now forming over an area of 62,500 square miles[2] of the earth's surface. The littoral zone is the one in which boulders, gravels, sands, and all coarser materials accumulate, though occasionally muds may be met with in sheltered estuaries. Generally speaking, the nature of these deposits is determined by the local character of the adjoining lands and the nature of the organisms living on the neighbouring coasts in shallow water. The heavier materials brought by rivers from high terrestrial regions, or thrown up by the tides and waves of the sea, are here arranged with great diversity of stratification through the alternate play of the winds and waves. Twice in the twenty-four hours the littoral zone is covered by water, and exposed to the direct rays of the sun or the cooling effects of the night. There is a great range of temperature, mechanical agencies produce their maximum effects, and the whole of the physical conditions are of the most varied character, while the fact that the zone is inhabited by both marine and terrestrial organisms introduces still greater diversity. The evaporation of the sea-water that flows over marshes and shallow basins leads to the formation of saline deposits in this zone.

Shallow-Water Deposits.—These deposits are laid down in the zone of the ocean comprised between low-water mark and the 100-fathom line; they cover, consequently, about ten millions of square miles of the earth's surface. Fundamentally they have the same composition as the deposits of the littoral zone, with which they are continuous at their upper limit, while at their lower limit they pass insensibly into the Deep-Sea Deposits in the seaward direction. The fragments of which these deposits chiefly consist are smaller than those of the littoral zone and larger than those of the deep-sea regions. Gravels, sands, and coarse materials prevail, but in cup-shaped depressions and enclosed basins there are muddy deposits. While some of the deposits are wholly composed of inorganic debris derived from the disintegration of the adjoining lands, others are almost wholly made up of organic remains, as, for instance, in the vicinity of coral reefs. The mechanical effects of erosion are everywhere present, produced by the combined action of tides, currents, and waves, these being well marked in the shallower depths of the zone, and less and less so as the 100-fathom line is approached. There is a great range of temperature, varying with latitude and the seasons of the year. The

[1] About 200,000 kilometres.

[2] About 160,000 square kilometres.

forms of vegetable and animal life are very numerous, the former being especially so in the shallower water where there is abundant sunlight. Zoologists have divided this region into several sub-zones, such as Laminarian, Coralline, and Coral zones.

Deep-Sea Deposits.—The deposits of this vast zone or region extend from the 100-fathom line down to the greatest depths of the ocean, and they cover considerably more than one-half of the earth's surface. Gravels and sands, which prevail in shallow water, are only accidentally met with in the deep-sea areas. Muds, organic oozes, and clays are the characteristic deposits, and in their physical properties they present great uniformity. In special regions where the surface waters are affected by floating ice a greater diversity is introduced from the varied nature of the transported materials. Tides, currents, and waves produce some mechanical effects at the upper limits of the deep-sea region, but on the whole there is an absence of the phenomena of erosion, and mechanical actions would appear to be absent except in the case of submarine eruptions. The depth is too great for sunlight to penetrate, and vegetable life, if present, is limited to the deposits near the 100-fathom line. Animal life, on the other hand, appears to be present everywhere throughout the deep sea, being more abundant, however, in the shallower depths near continental shores. The temperature is below 40° F. throughout the larger part of the area, and if subject to variation with latitude or change of season, these changes affect only the depths immediately beyond the 100-fathom line. Throughout the whole region there is a very uniform set of conditions. In the shallow-water and littoral zones, owing to the rapid accumulation and the mechanical effects of transport and erosion, the effects of chemical modification are not apparent in the deposits, but in Deep-Sea Deposits, in consequence of the less rapid rate of accumulation, absence of transport, the nature and the small size of the particles, many evident chemical reactions have taken place, resulting in the formation *in situ* of glauconite, phosphatic and manganese nodules, zeolites, and other secondary products. As we descend from the 100-fathom line into deeper water and approach the central regions of the great ocean basins, the deposits undergo a change, arising from a diminution in the number and size of particles derived directly from the land, together with an increasing abundance of amorphous matter arising from the ultimate decomposition of minerals and rocks, and accompanied in all moderate depths by an increase of the remains of pelagic organisms. We thus pass insensibly from those Deep-Sea Deposits of a terrestrial origin, which we call "Terrigenous," to those Deep-Sea Deposits denominated "Pelagic," in which the remains of calcareous and siliceous organisms, clays, and other substances of secondary origin, play the principal role.

With these introductory observations on Marine Deposits in general, we now proceed to consider the special subjects of this Report,—the nature, composition, and distribution of Deep-Sea Deposits.

b. The Different Types of Deep-Sea Deposits.

I. *Pelagic Deposits.*

We have just indicated that the deposits of the deep sea may be divided into two great groups distinguished by the terms "Pelagic" and "Terrigenous." Pelagic deposits are situated at a considerable distance from land, and for the most part in the greatest depths of the ocean. It is only in exceptional circumstances that sandy or other particles immediately derived from the land make up any considerable portion of these deposits. The most characteristic minerals are derived from volcanic eruptions, floating pumice, or are of secondary origin formed *in situ*. The remains of pelagic organisms that have fallen from the surface form the principal part of many of these deposits, as indicated by the names: Pteropod, Globigerina, Diatom, and Radiolarian Oozes. In some of the deeper regions of the ocean these organic oozes are replaced by Red Clays, formed for the most part by the disintegration of rocks and minerals *in situ*.

Generally speaking, the physical conditions in the areas occupied by the pelagic deposits are very uniform; the temperature is near the freezing-point of fresh water, and the range never exceeds 7° F., being constant throughout the year at any one locality. Sunlight and vegetable life are absent, and, although animals belonging to all the principal groups are present, there is no great wealth either in the number of individuals or of the species, though many of the latter may present archaic characters. There are but few indications of change of any kind, and the rate of accumulation of some of these pelagic deposits must be exceedingly slow, so that we apparently find the remains of Tertiary species lying on the sea-floor alongside those of species inhabiting our present seas. With some doubtful exceptions, it has been impossible to recognise in the rocks of the continents formations identical with these pelagic deposits.[1]

Before commencing the description of the different types of Deep-Sea Deposits, it may be well to repeat that while it is easy to distinguish one kind of Deep-Sea Deposit from another when dealing with typical samples, this becomes less and less easy when, with a change of conditions, a deposit gradually changes its characters and slowly assumes those of another. In this way it happens that there is at many points in the ocean a gradual transition from the one type of deposit into another, and generally it may be said that there is no sharp and distinct line limiting the areas occupied by the various kinds of deposits either in depth or geographical extension, as might be supposed from an examination of our map representing the distribution by means of colours.

We commence the consideration of pelagic deposits, taking first the most characteristic type,—the clays formed in the greatest depths and greatest distance from dry land.

[1] J. B. Harrison and A. J. Jukes-Browne, *The Geology of Barbados* (published by authority of the Barbadian Legislature), 1890; H. A. Nicolson, *Trans. Edin. Geol. Soc.*, vol. vi. p. 56, 1890; G. J. Hinde, *Ann. and Mag. Nat. Hist.*, ser. vi. vol. vi. p. 45, 1890.

RED CLAY.

This deposit is spread over the greater depths of the ocean remote from land; it is the most widely distributed and probably the most characteristic of all the Deep-Sea Deposits. The nature and origin of this Red Clay has been the subject of much discussion and speculation ever since the deposit was first discovered in the Atlantic by the Challenger naturalists in depths exceeding 2400 fathoms, on the voyage between Tenerife and the West Indian Islands. It was at first believed to be the most minutely divided material, the ultimate sediment, so to speak, produced by the disintegration of the land, which, held in suspension in sea-water, was distributed to great distances by ocean currents. In 1874 Wyville Thomson expressed the opinion that the Red Clay was primarily of organic origin, being "essentially the insoluble residue, the *ash*, as it were, of the calcareous organisms which form the *Globigerina* ooze, after the calcareous matter has been by some means removed." He further suggested "that clay, which we have hitherto looked upon as essentially the product of the disintegration of older rocks, under certain circumstances, may be an organic formation like chalk," and that the fine smooth homogeneous clays and schists familiar to the student of palæozoic geology had an origin similar to that of the Red Clay.[1] These views were subsequently supported by Professor Huxley and other writers.[2] In 1877 John Murray published his reasons for believing that the clayey matter in Marine Deposits far from land is principally derived from the decomposition of aluminous silicates and rocks spread over the oceanic basins by subaerial and submarine eruptions,[3] and this view will be the one adopted in the present work, although M. Renard is inclined to attribute a more important role to submarine eruptions than is admitted by Murray. Colloid clayey matter coming in suspension from the land may, it is admitted, play some part in the formation of this deposit.

In the Tables of Chapter II. there are 70 of the samples procured by the Expedition described under the head of Red Clay. In depth these range from 2225 fathoms at Station 259 to 3950 fathoms at Station 238, the average depth being 2730 fathoms.

The name Red Clay is retained not only on account of its historical interest, but because it appears sufficiently expressive of the nature and appearance of the deposits included under the appellation. The amount of clayey matter and the colour vary greatly in different samples, but the hydrated silicate of alumina is always present, so as

[1] *Proc. Roy. Soc.*, vol. xxiii. p. 47.

[2] Huxley, *Manual of the Anatomy of the Invertebrated Animals*, London, 1887; see also *Nature*, vol. xi. pp. 95, 116; vol. xii. p. 174.

[3] "On the Distribution of Volcanic Debris over the Floor of the Ocean," &c., *Proc. Roy. Soc. Edin.*, vol. ix. pp. 247–261. Wyville Thomson (Voyage of the Challenger, "Atlantic," vol. ii. p. 299) allows that these volcanic materials form an important element in the Red Clay, but he still holds that the source he originally suggested has contributed no inconsiderable share towards the formation of this deposit. [Subsequently, however, he abandoned the view that calcareous shells contained silicate of alumina.—J. M.]

to give to the sediment a more or less claycy character, and red is the prevailing colour. In the North Atlantic and some other regions the colour is brick-red from the presence of peroxide of iron intimately mixed with the clay, which often covers the minute mineral particles with a red coating. In the South Pacific over large areas and in the Indian Ocean the deposit assumes a dark chocolate colour, from the presence in great abundance of very minute round grains of peroxide of manganese.[1] It sometimes happens that the deposit has a bluish, rather than a red, tinge; this is the case when the specimen is from a region adjacent to a continent where large rivers throw their detrital matter into the ocean, and the colour is largely due to the presence of sulphide of iron and organic matter, as in the characteristic Blue Muds. When the carbonate of lime in the sample reaches 20 or 25 per cent. the colour becomes grey from the admixture of the white Foraminifera shells, although the residue on removal of the carbonate of lime has a distinct red colour. It was to specimens of this nature that the name "Grey Ooze" was applied by Murray and Thomson in the preliminary reports on the results of the Challenger Expedition.[2] The immediate upper layer when brought up in the dredge or sounding tube is thin, watery, and often has a lighter colour than the deeper layers, which are much more dense. It occasionally happened that the sounding tube penetrated nearly two feet into the deposit, and in such cases the lower end of the tube was filled with a very stiff, hard, compact clay. Sometimes there was considerable difference in colour and chemical composition between the different layers—usually depending on the greater or less percentage of carbonate of lime present. In the North Pacific the upper or surface layer was generally darker than the under layers, but this was not the case in the other regions. In some places the deposit had a mottled appearance, there being some spots where the red or chocolate colour was discharged and the clay had assumed a yellow colour. A mottled appearance is sometimes, however, due to the presence in great abundance of small manganese nodules and grains of pumice, or of altered volcanic glass and rocks.

Like clays in general, the Red Clay is soft, plastic, and greasy to the touch; it can readily be moulded into any form between the fingers after the manner of dough. It exhales when breathed on the peculiar odour of clay. Like all clays containing iron it generally becomes redder when burned; it sticks to the tongue when dry, and requires a great heat to render it perfectly free from water. When dried it cakes into a hard compact mass that can only be broken with the blow of a hammer or other hard instrument. Should the hardened fragments be placed in water they break down slowly, as is the case with other clays. A fragment placed before the blow-pipe will fuse into a black, often magnetic bead, behaving in this respect like the variety of clay known by the name of "felspathic mud;" this property may be attributed to the minute volcanic mineral particles which are always present in varying proportions. If one of these half-dried lumps be rubbed briskly with the back of the finger-nail or any hard, smooth body, the

[1] See Pl. XXII. fig. 1.

[2] *Proc. Roy. Soc.*, vol. xxiii. pp. 32–49, 1874.

surface assumes the glazed appearance and characteristic shining streak peculiar to all the varieties of clay.

In the great majority of cases the Red Clay presents a homogeneous appearance to the naked eye and is smooth and soapy to the touch, but not unfrequently there are numerous pellets of peroxide of manganese, zeolitic crystals, fragments of pumice and minerals, which if they be not visible to the naked eye can be readily detected by the gritty feeling when the deposit is passed between the fingers. Although as a rule homogeneous when examined in small quantity, still if examined in masses the layers of Red Clay would undoubtedly present a very heterogeneous character, although the paste or matrix might appear homogeneous, for in some regions of the South Pacific thousands of sharks' teeth, bones of Cetaceans, large and small fragments of pumice, and other volcanic materials, are imbedded in the deposit, together with manganese nodules formed around these remains, or having other substances as nuclei. In all the red clay regions the dredge gave evidence that occasionally one or other of these foreign matters was present in considerable abundance, and at Station 281 there was evidence of a thin layer of true volcanic ashes.[1]

The basis or permanent substratum of the deposit is the hydrated silicate of alumina ($2SiO_2,Al_2O_3 + 2H_2O$), composed of colourless amorphous particles without crystallographic outlines or trace of mechanical action, behaving as isotropic between crossed nicols. Like all ordinary clays, however, it is impure from the admixture of foreign substances, the hydrated silicate of alumina never making up even in the purest samples more than one-half of the deposit, and generally much less, as shown by the analyses. It is well known that a pure clay is only found in those cases where it has been transported: clay formed *in situ* is never pure; it always contains an admixture of the different minerals, or of decomposition products, of the altered rocks, from which the clay has had its origin, and the greater part of the materials of a Red Clay from the deep sea appears to have originated in this way.

When a specimen of Red Clay from the greatest depths of the ocean is treated with dilute hydrochloric acid, either no points of effervescence are observed, or at the most only a few isolated spots, and chemical analysis does not show more than 1 or 2 per cent. of carbonate of lime to be present. A microscopical examination in such cases will sometimes show a few broken fragments of pelagic Foraminifera. An examination of specimens from lesser depths in the same region will, however, reveal a considerable number of these calcareous organisms, and they may be sufficiently abundant to make up 20 per cent. of the whole deposit. The carbonate of lime present in the Red Clay consists principally of the remains of calcareous organisms which live in the surface waters of the region from which the specimen has been collected, and among these pelagic Foraminifera are the most abundant, such as species of *Globigerina*, *Pulvinulina*, *Sphæroidina*, and *Pullenia*, together with a few Coccoliths or Rhabdoliths. To these

[1] See Pl. XXI. fig. 2.

may be added a few bottom-living Foraminifera, such as *Miliolina*, *Textularia*, and others, with remains of Echinoderms, Molluscs, and a few teeth of fish and Cephalopod beaks. It is very seldom, if indeed it ever happens, that the shells of Pteropods, Heteropods, and Coccospheres are found in a characteristic Red Clay from the deep sea.

In the above 70 samples Globigerinidæ are represented in 43 cases, bottom-living Foraminifera (Miliolidæ, Textularidæ, Lagenidæ, Rotalidæ, Nummulinidæ) in 34 cases, teeth of fish in 34 cases, Echinoderm fragments in 22 cases, Ostracodes in 10 cases; Lamellibranchs, Gasteropods, Brachiopods, otoliths of fish, Polyzoa, Cephalopod beaks, and bone fragments are more sparingly represented, while remains of Pteropods, Coccospheres, Coccoliths, and Rhabdoliths occur in a few exceptional cases.

The carbonate of lime in these Red Clays ranges from 0 in 13 cases, and traces in 21 cases, to 28·88 per cent. at Station 30, in 2600 fathoms—the average percentage of carbonate of lime in these 70 samples being 6·70 per cent. The relation of the carbonate of lime to depth is shown thus—

18 samples	from 2000 to 2500	fathoms	contain on the average	8·39	per cent.	$CaCO_3$
42 „	2500 to 3000	„	„	7·16	„	„
7 „	3000 to 3500	„	„	0·88	„	„
3 „	over 3500	„	„	2·38	„	„

One doubtful sample from 3875 fathoms, where there was almost certainly an admixture of carbonate of lime from another station, causes the rise in the last subdivision over 3500 fathoms; otherwise the carbonate of lime would be represented merely by traces at these depths.

The remains of pelagic organisms with siliceous shells, skeletons, and frustules, are widely distributed in the Red Clay areas, though occasionally they would appear to be entirely absent from the deposits of these regions. When the Radiolarian remains increase in number so as to form a very considerable portion of the deposit, as in some tropical areas of the Pacific and Indian Oceans, the Red Clay passes into Radiolarian Ooze; when the Diatom remains in like manner increase, as in the Southern Ocean, the Red Clay passes into a Diatom Ooze, and in other regions into a Globigerina Ooze, or Blue Mud. The siliceous spicules of Sponges are found sometimes sparingly, sometimes in considerable abundance, in nearly all samples of Red Clay.

The mean percentage of siliceous organisms is 2·39. Radiolaria were observed to be present in 61 cases, Sponge spicules in 49 cases, Diatoms in 32 cases, arenaceous Foraminifera (Astrorhizidæ, Lituolidæ, Textularidæ) in 49 cases, and glauconitic casts of calcareous organisms in 2 cases.

According to the Challenger researches, life appears to be universally distributed over the floor of the ocean, but to be much less abundant on the red clay areas than on any of the other kinds of Marine Deposits, and apparently to reach its zero in the greatest depths far from land. Even in the greatest depths, however, the remains of arenaceous Foraminifera and Annelids are to be found, while fishes and representatives of nearly all the invertebrate groups, such as Hexactinellida, Monaxonida, Asteroidea, Echinoidea, Crinoidea, Actiniaria, Polyzoa, Ophiuroidea, Holothurioidea, Tunicata, and Lamellibranchiata, have been dredged and trawled from the red clay areas. The fragments of all the hard parts of these organisms may be met with sparingly in specimens of Red Clay, but not in nearly such abundance as might be expected.

When there are no remains of calcareous organisms in a Red Clay, or when in the laboratory these have been removed by dilute hydrochloric acid, the deposit or resulting residue is found to contain, in addition to the hydrated silicate of alumina and the remains of siliceous organisms above referred to, a large number of inorganic elements of a varied nature, derived from widely different sources. In the above-mentioned 70 samples, the average percentage of residue is 93·30. The most constant and widely distributed of these extraneous materials are fragments of pumice belonging to the acid, neutral, and basic types of volcanic rocks. Rounded and angular fragments of these were dredged and trawled in great numbers from all depths, and in nearly all regions of the ocean, varying in size from masses larger than a man's head down to the minutest particles. These were met with in all states of disintegration, some having undergone little decomposition, while others were surrounded by zones of alteration, or were so decomposed that the structure of the areolar pumice could with difficulty be recognised; this was especially the case when the fragments were surrounded with a coating of peroxide of manganese or formed the nuclei of manganese nodules.[1] All the mineral species usually found in the different varieties of pumice are accordingly present in the Red Clay, such as sanidine, plagioclase, augite, hornblende, magnetite, &c., and these, together with the glassy splinters and fragments of the pumice, are universally present and characteristic of these deposits. Palagonite, which arises from the decomposition of the basic volcanic glasses, is likewise universally distributed, and in some regions of great extent there are numerous fragments of basaltic glass, basalt, and augite-andesite.[2] The peroxides of iron and manganese are found throughout the Red Clays in the form of minute grains or coatings, sometimes one of these oxides and sometimes the other predominating, each giving its characteristic tint to the deposit. When these oxides are deposited as concretions around organic remains and other nuclei, they form the now familiar manganese nodules, especially abundant in those red clay deposits where the debris of basic volcanic rocks are present and have undergone great alteration.[3] Minute black magnetic spherules, often with a metallic nucleus, which are regarded as having, together with other particles, a cosmic origin, are probably everywhere present

[1] Murray, *Proc. Roy. Soc. Edin.*, vol. ix. pp. 249–252, 1877.
[2] See Pl. XVI. figs. 1–3; Pl. XVII. figs. 1, 2; Pl. XVIII. figs. 1–4; Pl. XIX. figs. 1, 2, 4; Pl. XXI. figs. 1, 2.
[3] See Pl. XXVIII. figs. 1–5; Pl. XXIX. figs. 1–4.

in Deep-Sea Deposits, though they are much more abundant in some of the red clay regions than in other deposits.[1] Dr Gibson has shown that the manganese nodules from these Red Clays contain a very large number of the rarer metals.[2]

Besides the constituents that have just been enumerated, which must be regarded as characteristic or essential components of a Red Clay, there are others to be noted that are accidental or exceptional. In the Atlantic off the western coasts of Northern Africa, it is well known that the Harmattan winds carry at certain seasons of the year large quantities of dust far out into the Atlantic Ocean, and in the Red Clays of this region these wind-borne particles make up a very appreciable portion of the deposit. In like manner the wind-borne particles from the desert regions of Australia can be traced in the red clay deposits to the west and south of that island continent.[3] There are many well-observed instances of volcanic ashes from subaerial eruptions having been carried immense distances by the winds before they fell upon the land or the ocean, and we find evidence of these in pelagic deposits. It is in every way probable that similar eruptions take place under water, and the ashes therefrom are in like manner widely distributed over the floor of the ocean.[4] We have some excellent examples of these showers of ashes, whether from submarine or subaerial sources, on the red clay areas. One of these is figured in Pl. IV. fig. 3, where the coarser particles have fallen on the Red Clay with manganese nodules, and these again have been covered with finer and finer layers of the same materials, the whole being solidified into a compact mass, which subsequently has undergone great alteration.[5]

Among the secondary products arising from the decomposition of the basic volcanic rock-fragments present in these deposits are zeolitic crystals resembling *phillipsite* in all essential particulars, these being especially abundant in some Red Clays from the South Pacific and Indian Oceans.[6]

Wherever the surface waters of the ocean are affected annually, or occasionally at long intervals, by floating ice, the icebergs bear a variety of mineral matters from the land of colder latitudes to great distances, and ultimately falling to the bottom they form part of the Red Clay and other deposits in great depths. These ice-borne fragments, consisting of quartz, felspar, green amphibole, epidote, zircon, tourmaline, &c., and fragments of ancient continental rocks, such as granite, mica-schist, &c., can be traced in the deposits of the Southern Ocean north of latitude 40° S., and in the Western North Atlantic they are widespread as far south as the latitude of the Azores.

In the great majority of the typical Red Clays the size of the mineral particles ranges from 0·1 to 0·85 mm. in diameter, and particles of this size do not as a rule make up more than 1 or 2 per cent. of the whole deposit. It occasionally happens that particles larger than 0·05 mm. in diameter do not make up as much as 1 per cent. of the deposit. On

[1] See Pl. XXIII.
[2] See Appendix II.
[3] See Pl. XXVIII. fig. 2.
[4] See Pl. XXVI. figs. 2–4; Pl. XXVII. figs. 2, 3.
[5] See also Pl. XXI. fig. 2.
[6] See Pl. XXII. figs. 1–4.

the other hand, in some areas the unaltered splinters of pumice, the fragments of volcanic ashes, and minerals from floating ice, may augment considerably in size and abundance and make up 20 per cent. of the deposit. One of the great characteristics of the Red Clay, however, is that the mineral particles over 0·05 mm. in diameter are few in number, and these have generally undergone alteration. The extreme fineness of the mineral particles, indeed, permits the relatively small quantity of pure clay to give a much more plastic character to the deposits than if these particles were of large size.

The mineral particles[1] in the Challenger samples of Red Clay make up on an average 5·56 per cent. of the whole deposit; they are generally angular, being recorded as rounded and angular in eight cases and rounded only in one case, and have a mean diameter of 0·08 mm. They are mentioned as occurring in the following order of abundance:—magnetite (in 62 cases), manganese grains and fragments (55), felspar (53), glassy volcanic particles (45), augite (43), pumice (34), manganese nodules (32), pellets, pieces, and nodules of pumice (31[2]), hornblende (31), palagonite (22), quartz (21), plagioclase (20), mica (19), phillipsite or zeolitic matter (10), cosmic spherules (8), sanidine (7), scoriæ (6), glauconite (6), olivine (5), lapilli (5), rock fragments (5), zircon (3), tourmaline (3), epidote (2), garnet (1).

The Challenger trawlings and dredgings obtained sharks' teeth in 11 cases, and ear-bones and other bones of Cetaceans in 6 cases.

It has been stated that in marine deposits the species of unaltered particles of minerals with a diameter of not more than 0·02 mm. can in many cases be determined (see p. 25), and the fragments of pumice even less than that can also be recognised, but the particles of this size are usually very intimately associated with the clay of the deposit, and generally pass away in decantation with the impalpable matter, which we have denominated "fine washings." These fine washings consist essentially of the hydrated silicate of alumina, mixed with an immense number of recognisable and unrecognisable particles of minute dimensions, derived from all the other materials which combine to form the deposit, such as minerals, Diatoms, and Radiolarians. It is quite natural to conclude that the mineral particles, mixed with the clayey matter in the fine washings, are of the same nature as those of larger size which can be identified, and that quartz, felspar, &c., may be present in a very fine state of division as ultramicroscopic bodies, but this cannot be made out with the microscope, chemical analysis only gives an indication.[3]

[1] See Pl. XXVI. figs. 2–4; Pl. XXVII. figs. 2, 3. [2] In five cases distinctly stated to be covered by manganese.

[3] It is known that clay has the power not only of absorbing and of retaining certain liquids, but that it even possesses a similar property in the case of certain solids of very small dimensions. If, for example, clay be agitated in water, microscopic grains of carbonate of calcium and particles of an organic nature will remain in suspension as long as the water is agitated, but as soon as the water is at rest these are deposited. These particles are thoroughly penetrated by the water, and form a colloid gelatinous mass; the particles are found to be in contact, and so attached the one to the other that it is not possible by the agitation of the water to detach them. This mutual attraction or interpenetration takes place not only with particles of the same nature, with clay for example, but in the case of clay with hydrated peroxide of iron, clay with chalk, clay with organic particles, so that it is difficult, if not impossible, to

The mean percentage of fine washings in the 70 samples of Red Clay is 85·35; the following table shows the relation between depth and percentage of fine washings:—

18 samples	from 2000 to 2500 fathoms,	.	80·44 mean per cent. fine washings.
42 „	2500 „ 3000 „	.	85·80 „ „ „
7 „	3000 „ 3500 „	.	95·28 „ „ „
3 „	over 3500 „	.	80·28[1] „ „ „

The following table shows the average composition of the Challenger samples of Red Clay. It will be noticed that what we have called fine washings make up by far the larger part of the deposit, and it may be stated that the examination of many samples from other expeditions has yielded very similar results:—

Carbonate of Lime,	Pelagic Foraminifera,	4·77	
	Bottom-living Foraminifera,	0·59	
	Other organisms,	1·34	
			6·70
Residue,	Siliceous organisms,	2·39	
	Minerals,	5·56	
	Fine Washings,	85·35	
			93·30
			100·00

Having thus pointed out the general results arising from a careful macroscopic and microscopic examination and analysis of a large number of Red Clays from many different regions of the ocean, it now remains to inquire how far these are confirmed and supported by chemical analysis. It seems rather unnecessary to dwell upon the difficulties connected with the interpretation of chemical analyses of mixed substances, of altered minerals, and of amorphous matters without any determinate composition like those which make up the greater part of Deep-Sea Deposits; there cannot be a discussion of the analytical data in the same sense as if, for example, we had to do with an analysis of a crystalline rock. But when we take into account the data furnished by macroscopic and microscopic examination, we are able notwithstanding to draw some conclusions from the analyses of these deposits.

The following table is compiled from the analyses made by the late Professor Brazier, as previously stated.[2] The various deposits were submitted to the action of hydrochloric acid, and the portion dissolved in the acid was analysed separately; the residue of this operation was afterwards treated with solvents, hence we divide the analytical tables into two divisions, the first containing the data relating to the part soluble in hydrochloric acid, the second those referring to the insoluble portion.

separate these matters by decantation; hence arises in part the heterogeneity of these fine washings (see E. W. Hilgard, "On the Flocculation of Particles," &c., *Amer. Journ. Sci.*, ser. iii. vol. xvii. p. 205, 1879; F. Senft, Die Thonsubstanzen, p. 41, Berlin, 1879).

[1] See p. 193 about sample from 3875 fathoms.

[2] Chap. i. p. 28; for details of analyses, see Appendix I.

				Portion soluble in HCl.										Portion insoluble in HCl.					
Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	$Ca_2 2PO_4$	$MgCO_3$	Cu	Total.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
5	2740	1	8·20	11·03	4·70	3·50	...	56·39	0·70	tr.	0·98	...	77·30	11·00	1·80	0·80	0·50	0·40	14·50
5	2740	2	2·60	12·54	2·15	4·76	...	60·29	0·29	2·09	0·72	...	82·84	9·80	3·13	0·84	0·68	0·11	14·56
7	2750	3	7·45	24·25	6·40	15·42	...	4·11	1·60	tr.	1·20	...	52·98	29·33	6·00	2·54	1·06	0·64	39·57
8	2700	4	8·95	23·00	8·95	9·70	...	16·42	2·24	l.tr.	2·70	...	63·01	20·25	4·20	2·10	0·89	0·60	28·04
9	3150	5	10·40	19·81	8·30	9·75	...	3·11	0·87	g.tr.	1·90	...	43·74	33·30	9·10	2·04	0·47	0·95	45·86
10	2720	6	7·61	24·73	9·73	9·30	...	13·30	0·61	...	1·31	...	58·98	24·53	5·50	2·96	0·23	0·19	33·41
18	2675	7	7·75	22·25	8·25	11·37	...	15·78	0·52	0·42	1·41	...	60·00	21·80	7·00	2·50	0·57	0·38	32·25
19	3000	8	7·44	27·68	12·91	10·33	...	1·49	0·96	tr.	3·10	...	56·47	25·16	7·81	1·57	1·03	0·52	36·09
20	2975	9	7·45	26·00	12·28	11·44	...	3·50	1·47	sm.tr.	2·14	...	56·83	24·40	7·28	2·36	1·18	0·50	35·72
21	3025	10	5·92	24·70	7·04	12·25	...	2·44	0·51	sm.tr.	3·48	...	50·42	30·20	5·51	6·73	0·81	0·41	43·66
27	2960	11	4·25	23·78	6·50	7·83	g.tr.	3·25	tr.	1·67	1·13	...	44·16	35·17	10·19	4·29	1·61	0·33	51·59
160	2600	12	5·00	18·47	10·25	2·82	1·99	36·80	0·29	2·09	0·76	...	73·47	14·51	4·03	2·02	0·79	0·18	21·53
226	2300	13	4·20	28·84	4·80	15·20	1·14	6·11	0·46	g.tr.	0·75	...	57·30	28·55	3·31	5·79	0·45	0·40	38·50
241	2300	14	4·30	26·00	6·00	2·91	1·14	22·63	0·49	2·09	0·94	...	62·20	23·40	5·30	2·20	2·20	0·40	33·50
252	2740	15	3·60	24·89	5·23	13·14	tr.	2·22	0·51	s.tr.	0·41	...	46·40	37·70	7·85	2·60	1·50	0·35	50·00
253	3125	16	4·50	24·70	8·31	7·95	0·55	0·92	0·37	0·19	2·70	...	45·69	37·40	7·75	3·88	0·28	0·50	49·81
256	2950	17	4·50	24·95	6·00	9·77	0·68	1·69	0·42	0·48	1·33	...	45·32	34·82	11·37	2·00	1·14	0·85	50·18
275	2610	18	6·50	32·05	7·45	15·71	3·85	3·74	0·58	0·76	1·96	...	66·10	17·96	6·35	2·35	0·44	0·30	27·40
276	2350	19	2·20	17·30	9·00	9·03	2·28	38·13	0·58	3·44	0·94	tr.	80·70	11·43	4·27	1·07	0·22	0·11	17·10
276	2350	20	(See description of phillipsite.)																
276	2350	21																	
281	2385	22	7·70	32·60	8·80	24·60	2·73	2·50	tr.	s.tr.	3·24	...	74·47	11·27	1·60	3·80	0·84	0·32	17·83
285	2375	23	9·00	24·97	7·50	23·55	14·53	4·07	0·58	0·70	1·13	tr.	77·03	9·43	2·85	1·05	0·55	0·09	13·97

Nos. 1, 2, 5, and 17 are of material obtained from the dredge; Nos. 12, 14, 19, 22, and 23 from the trawl; No. 16 from tow-net at dredge; the rest from the sounding tube.

If we take into account the methods followed by Professor Brazier in making these analyses[1] we should expect to find all the clayey matter under the heading, "Portion soluble in Hydrochloric Acid." He treated the deposits with hydrochloric acid, evaporated them to dryness and re-dissolved them as far as possible; the insoluble residue was, after weighing, treated with boiling caustic potash, and so much of the residue as was then dissolved was looked upon as silica of easy combination, and classed along with the bodies soluble originally in hydrochloric acid. It is evident that the silica with alumina and iron remaining insoluble in the potash was simply indecomposable quartz or silicates. After such a treatment the clayey matter should pass entirely into solution, and to estimate the quantity of this substance we have merely to take account of the data given in the columns showing the substances soluble in hydrochloric acid. It must be remembered, however, that a certain part of the alumina indicated in the soluble portion does not exist as argillaceous matter in the deposit, but comes from the action of the acid and caustic potash upon the aluminous silicates and rocks present in the Red Clay. It has been pointed out that these fragments of rocks and minerals are often highly altered, of very small dimensions, and must necessarily have been partially attacked by the strong reagents used in this method of analysis. It follows then that the figures representing the alumina in the column of soluble substances are too high, if regarded as coming exclusively from matter existing in the form of clay.

The first conclusion arrived at after an examination of the general results presented by the analyses, is the great variety of chemical composition in the deposits comprised under the head of Red Clay. This was already indicated as the result of macroscopic and microscopic examination, but is proved in a very clear way by the figures showing the percentages of matters soluble and insoluble in hydrochloric acid, which vary in each one of the specimens analysed, and show, moreover, that argillaceous and other matters must be present in variable proportions. If we consider the soluble portion, which should give data for estimating the quantity of clay, and take as a point of departure the formula ($Al_2O_3,2SiO_2,2H_2O$), which is that of pure clay, we find that there is always excess of silica. This is the case even in Station 19, 3000 fathoms, where the alumina is represented by the highest figures; admitting that all the alumina is here in the form of clay, we obtain 6·81 per cent. excess of silica. However, as has been already stated, this relatively small quantity of clay suffices to give to a deposit formed of very small particles a decidedly plastic and argillaceous character.[2] The excess of silica can be explained, as we have already indicated, by the presence in the deposit of the siliceous remains of Diatoms, Radiolarians, and Sponges, and probably also from silicic acid in the hydrated or colloid form which is probably always present when clay is forming, still the excess must

[1] See chap. i. p. 28.

[2] In some analyses of clays from the geological formations, presenting all the characteristics of clay, the total amount of alumina is very low; we may quote the plastic clay of Offenbach (14·65 % Al_2O_3), "Tegel" of Baden (12·64 %), Oligocene clay of Hillscheid (14·06 %), Wealden clay of Salzbergen (14·51 %), Devonian dolomitic clay of Quistenthal (11·09 %). See J. Roth, Allgemeine und chemische Geologie, Bd. ii. p. 583, Berlin, 1887.

likewise necessarily come from the decomposition of certain silicates under the action of the acid in the analyses, for instance, from the zeolites, the altered volcanic minerals, glasses, and lapilli. A part of the water shown in the column under the head of *loss on ignition* must also be regarded as belonging to the constitution of clay, another part to hydrated oxide of iron, and to the decomposed volcanic rocks present in the deposit, especially hydrated glasses, of which palagonite is the most constant, and a third part must be referred to the organic substances present.

The percentage of oxide of iron in the soluble portion is very variable, but is occasionally present in greater quantity than the alumina, and shows, as the microscopic examination had already done, that we are dealing with a ferruginous clay. The ferric hydrate is the pigment that colours the clay in the majority of cases, as the hydrated peroxide of manganese does in some special regions. We can indeed by the aid of acids remove these two substances, and thus decolorise the clay. Although in clay iron replaces alumina in many cases, still it appears from the results of microscopic examination that here at least a considerable portion of the hydroxide of iron exists in a free state in the Red Clay, or intimately mixed with manganese as is generally the case in Deep-Sea Deposits.

The carbonate of calcium is present for the most part in the form of shells and skeletons of organisms; the proportion is, however, reduced to a minimum in the Red Clays and Radiolarian Oozes, if a comparison be made with most of the other Deep-Sea Deposits. As to the carbonate of magnesium indicated in all the analyses, it might be that a part came from the debris of organisms where it would be in isomorphic mixture with carbonate of calcium, but the percentage of carbonate of magnesium appears to be proportionally too high to that of the carbonate of calcium to admit this interpretation. It seems therefore probable that the carbonate of magnesium comes from the sulphate of magnesium contained in the sea-water acting on the carbonate of calcium and replacing a part of this carbonate which forms the debris of organisms deposited on the floor of the ocean. In this case we should have an incipient dolomitisation.

The sulphate of lime present in all the analyses doubtless comes from the sulphate of lime contained in sea-water, which impregnates the deposit when freshly collected, and is precipitated with great facility from sea-water when the deposit is placed in alcohol; large crystals of this substance are formed in this way in the bottles in which the deposits were preserved with a small quantity of spirit. It seems well to remember that in the interpretation of all analyses of Deep-Sea Deposits, we have always to take account of the facility with which certain sea-salts are retained in clayey matter. One of the striking properties of this substance is to absorb with avidity and to retain sea-water and its salts; to such an extent is this the case that they are difficult to remove even after repeated washings. In the case of a Globigerina Ooze we have made some experiments bearing on this point, and have shown that after repeated washings with cold water the deposit retained more than 1 per cent. of alkalies not combined with sedimentary materials.

With reference to the percentage, often rather high, of phosphate of lime, it must be referred to the remains of organisms, such as teeth of fish, bones of Cetaceans, and sometimes to small concretions of phosphate of lime, which are met with in some of the deposits; we know from the analyses of clayey matters that phosphates are generally present in these substances. The phosphate of lime may also be due to the pseudomorphic interchange between carbonate of lime and soluble salts of phosphoric acid.

Manganese, which is one of the most constant elements in the Red Clay, is not shown in all the quantitative analyses, but the pyrognostic reactions show its presence everywhere, and it forms in these deposits, along with iron and earthy matters, the ill-defined variety known by the name of wad, and is associated with nickel, cobalt, and barium, and nearly all the rare metals, as shown by Dr. Gibson's analyses. We will return to this subject when dealing with the manganese nodules and their mode of formation.

Regarding now the insoluble part of the deposit, it will be seen that here too there is an excess of silica. It is not possible to explain this excess by the presence of the siliceous remains of organisms, for these do not resist the action of caustic potash. In certain cases the presence of quartz must be admitted, for the quantity of bases is not sufficiently high, but these grains of quartz do not belong normally to the Red Clay which is much more generally due to the decomposition of volcanic materials, in which quartz is relatively rare or absent. We have seen that special conditions, such as atmospheric currents and glacial phenomena, may serve to account for the presence of quartz in certain regions where Red Clays are in process of formation. The microscopic examination of the Red Clays has shown the presence in these deposits of orthoclase, plagioclase, and bisilicates, which contain variable proportions of lime, magnesia, alumina, iron, and manganese; these substances appear in the analyses as the insoluble portion, and must be in the form of anhydrous silicates. The percentage of the alkalies not having been determined, and the presence of volcanic glasses, render it impossible to estimate the relative abundance of the different minerals. The analyses, however, confirm what has been said as to the presence of silicates and silicated rocks in the sediments.

A second series of analyses, made according to the methods pointed out on pages 27 and 28, is tabulated here, the results of which, it will be seen on examination, approach those obtained from the preceding analyses.

Station.	Depth in Fathoms.	No.	SiO_2	CO_2	Al_2O_3	Fe_2O_3	FeO	MnO_2	CaO	MgO	K_2O	Na_2O	H_2O	Total.
9	3150	24	56·89	...	20·28	10·02	...	...*	1·31	2·56	1·91	0·81	6·72	100·50
29	2700	25	42·15	9·82	20·27	7·06	...	...	13·22	2·15	1·12	0·72	3·75	100·26
281	2385	26†	43·32	...	13·96	17·50	4·36	...	5·96	5·89	1·66	1·74	6·41	100·80
286	2335	27	39·10	1·50	15·40	17·93	...	5·75	8·37	2·37	1·27	1·40	8·89	101·98

* Traces of barium, manganese, and phosphoric acid. † In No. 26 the finer parts had been washed away.

The origin of the clayey materials, and the products of the decomposition of the rocks and minerals spread over the floor of the ocean, will be discussed in detail later on, but from what has been stated above it will be evident that the Red Clay must be regarded as essentially a chemical deposit universally distributed in the ocean basins, but only appearing with its typical characters in the greatest depths far from continental land. Microscopic examination and chemical analysis have shown that volcanic rocks and minerals are to be found everywhere distributed in oceanic formations, and that in many regions the most frequent among these belong to the basic series all containing alumina. It is known that these very rocks—basalts, andesites, &c.—give by their decomposition argillaceous matters, so that we are led to conclude that this clayey deposit is chiefly the result of the decomposition *in situ* of these substances, as will be shown at greater length in Chapters V. and VI.

Even admitting that chemical decomposition at the bottom of the sea is not more active than at the surface of the continents, the rocks and mineral fragments would undergo much the same alterations at the bottom of the sea as on the surface of the terrestrial masses, where silicates and aluminous rocks are observed to be decomposed under the influence of water, and transformed into clayey materials, almost always mixed with the other products of decomposition of the rocks and silicates, giving origin to clay. These reactions taking place in the greater depths at the bottom of the sea, where the waters are not subject to any rapid movements, the products of decomposition are not transported to great distances, as is the case on the continents, and therefore, as has been already stated, these clays must be impure. The diffusion can not, moreover, be very rapid, and the chemical bath can act in a slow and constant manner on the solid materials with which it is in contact. Without entering here into the discussion of the question, we seem justified in regarding the greater part of the fine material, as well as the zeolites and nodular masses, of the red clay deposits as having been formed *in situ* through chemical action. This result, as will be shown, is not out of harmony with what we know of the distribution of the material borne down to the ocean from the land.

As far as our knowledge at the present time extends, Red Clay would appear to be the most extensive of all Marine Deposits, being estimated to cover about 51,500,000 square miles, or more than one-fourth of the total area of the globe, as will be seen by an inspection of the accompanying map (Chart 1) showing the distribution of Marine Deposits.

In the Atlantic the area occupied by Red Clay is much less than that occupied by Globigerina Ooze, being estimated at about 5,800,000 square miles. It is found in five detached areas—two in the North Atlantic, one in the eastern, the other in the western portion of the basin, separated by the Dolphin Ridge; three in the South Atlantic, two some distance off the South American coast, the other off the African coast, separated by the Challenger Ridge running north and south towards the centre of the South Atlantic basin. The Red Clay of the Atlantic is usually of a reddish colour, the dark chocolate-coloured variety, with its zeolitic crystals formed *in situ*, found in the Pacific and also in the Indian Ocean, not having been met with in the Atlantic.

In the Indian Ocean, again, the area covered by Red Clay is less than that covered by Globigerina Ooze, being estimated at 4,900,000 square miles. It is found to extend from off the western shores of Australia and the East Indian Islands, south of the equator, across the ocean towards Madagascar, reaching also to a small extent into the Southern Ocean to the south and west of Australia. In the North Indian Ocean there is a small detached patch in the deep water of the Arabian Sea, between the Maldive and Laccadive Archipelagoes and the coast of Africa.

In the Pacific the Red Clay attains its most typical and most extensive development, covering by far the greater portion of the sea-bottom. Its area is estimated at about 40,800,000 square miles. The whole of the deep water of the eastern portion of the Pacific basin is occupied by Red Clay, and it extends more or less uninterruptedly over the western portion, approaching the shores of Japan in the north and of New Zealand in the south. It covers also a considerable tract in the Southern Ocean, where there is a detached area situated some distance off the coast of Chili. There are several detached patches occupying the deeper water between the various groups of islands of Oceania, viz., two small areas in the Coral Sea between the New Hebrides and the north-east coast of Australia; another between New Caledonia and New Zealand; another between the Solomon Islands and the Marshall and Gilbert groups; another between the north coast of New Guinea and the Caroline group, a considerable area in the deep water between the Philippines, Japan, Bonin Islands, Ladrone Islands, and Pelew Islands; a considerable area is also found between Australia and New Zealand, extending into the Southern Ocean.

Radiolarian Ooze.

This deposit, like the Red Clay, is confined to the greater depths of the ocean, indeed, as will be presently pointed out, it has a greater average depth than the Red Clay. The name was adopted during the cruise of the Challenger by Mr. Murray for those deposits which, while resembling Red Clays in most respects, differ from them in containing a much larger number of Radiolarian shells, skeletons, and spicules, together with Sponge spicules and the frustules of Diatoms. There is in short little, if any, difference between these deposits and Red Clay, except what may be attributed to the greater or less abundance of these remains of siliceous organisms. The colour is red, chocolate, or occasionally straw coloured; it is less plastic than the Red Clay, at least the typical examples are so. The peroxides of iron and manganese are everywhere present, as are also fragments of pumice, augite, felspars, hornblende, magnetite, palagonite, chondritic and other cosmic spherules. Manganese nodules and palagonitic fragments are very abundant in some samples, as are also teeth of sharks. With reference to the organisms living on the Red Clay and the Radiolarian Ooze, they appear to be the same in nearly all respects in the two regions both as to the species and their relative abundance.

The deposit was first met with in the Western North Pacific, during the voyage from New Guinea to Japan, in the deepest sounding taken during the cruise, and, with one or two exceptions, the greatest depth hitherto discovered, and still the greatest depth from which a specimen of the bottom has been procured. As this was a highly characteristic Radiolarian Ooze, we will refer to the sample collected at some length. Two soundings were taken at this station (Station 225, lat. 11° 24′ N., long. 143° 16′ E.). The first sounding was in a depth of 4575 fathoms, when only a little of the deposit came up on the outside of the tube. This sounding not being a satisfactory one, a second was taken, when the depth was ascertained to be 4475 fathoms. The tube had sunk fully three inches into the deposit; the upper layers were of a red colour, and contained much more peroxide of manganese than the lower ones, which were of a pale yellow or straw colour, in this respect, as well as in other physical aspects, very much resembling the Diatom Oozes found in the Southern Ocean during the cruise towards the Antarctic regions. The whole of the lower part of the deposit when it came up had a very compact and laminated appearance; the laminated fragments could be easily broken with the fingers, but it was difficult to separate the various components of the deposit the one from the other by shaking the whole in a bottle with water. The Radiolaria, Diatoms, and Sponge spicules appeared to be most abundant in the lower layers. The deposit effervesced a little with dilute hydrochloric acid, and one or two fragments of pelagic Foraminifera were found during the microscopic examination of a large portion of the sample, along with two specimens of *Haplophragmium globigeriniforme*.

The most abundant mineral particles are angular and more or less rounded fragments of volcanic glass in various stages of alteration and of a red-green or yellow colour; they are glossy, and break like resin; some are vesicular, and the vesicles are coated with prismatic zeolites. Besides these altered fragments of volcanic glass, there are grey-black lapilli of andesite and colourless splinters of pumice. There are also fragments of plagioclases surrounded with vitreous matter, crystals of augite, grains of magnetite, and a few cosmic chondritic and native iron spherules.[1]

Argillaceous matter is not very abundant in this sample of Radiolarian Ooze, but there are large numbers of little particles formed by agglomerates of the deposit. These particles have an irregular form, and do not break up under the action of strong hydrochloric acid, which merely removes the iron along with other colouring substances; microscopic examination shows that they are aggregates of the bottom made up of Radiolarians, Sponge spicules, and minute volcanic particles. The tenacity of these little

[1] See Pl. XXIII.

aggregations appears to be greater than that of somewhat similar ones from other stations, and may be due to the cementation of the isolated particles by colloid siliceous matter. In this specimen there are finally some very peculiar white-coloured aggregations composed of minute rhombohedral crystals, which when treated with dilute acids decompose with liberation of carbonic acid, but a flocculent residue is left behind, as well as microscopic granules; we are inclined to consider these crystals as calcite or dolomite. The general appearance of this deposit under the microscope is shown on Pl. XV. fig. 3, and the fine washings are represented on Pl. XXVII. fig. 5.

Professor Haeckel and Dr. Dreyer have recognised in the material from this station no fewer than 338 species of Radiolaria, belonging almost entirely to the two legions: Nassellaria and Spumellaria, only two species being noted belonging to the Phæodaria, while the Acantharia are quite absent, as is nearly always the case in the deep sea, owing to the acanthin skeleton being easily decomposed.[1] The Nassellaria are by far the most abundant in this deposit, the number of species compared with that of the Spumellaria being as 2 to 1; about three-fourths of the Nassellaria, and half of the total Radiolaria, belong to the orders Spyroidea and Cyrtoidea.

A detailed account has been given of this, the deepest sounding, because we consider it the most typical Radiolarian Ooze that has yet been discovered. It is estimated that about 80 per cent. of this sample is made up of the remains of siliceous organisms. The specimens from lesser depths in the Central Pacific and from the tropical regions of the Indian Ocean are less pure. Whenever a Red Clay is estimated to contain 20 per cent. of the skeletons of Radiolaria and siliceous organisms other than Diatoms, it has been classed as a Radiolarian Ooze. There seems to be little doubt that the Radiolaria are, like the calcareous Foraminifera, slowly dissolved by the sea-water after the death of the organisms, for the skeletons and spicules are frequently seen reduced to the merest threads, or in some parts the fenestrated spheres of some species are wholly removed.[2]

In the Tables of Chapter II. nine deposits collected by the Challenger Expedition are described as Radiolarian Oozes, and numerous other samples have been subsequently procured by other expeditions in the Pacific and Indian Oceans. The above-mentioned nine samples range from 2350 fathoms at Station 273 to 4475 fathoms at Station 225,

[1] Haeckel states that "the skeletons of the Phæodaria consist of a compound of organic substance and silica," and regards "acanthin as a substance related to chitin" (see "Report on the Radiolaria," Zool. Chall. Exp., pt. xl. pp. lxix, lxx); he says further that "the Acantharia are entirely wanting [in deep-sea deposits], for their acanthin skeleton readily dissolves" (*l.c.*, p. clv.). Murray records one species of Acantharia (*Pantopelta icosaspis*) from the Diatom Ooze, Station 157, 1950 fathoms, Southern Indian Ocean (see *Scot. Geogr. Mag.*, vol. v. pp. 433, 4, 1889).

[2] If we take into account the molecular state of the silica forming the skeletons of Radiolarians, it is easily conceivable that they may pass into solution in the sea-water after the death of the organisms, but this dissolution cannot be very rapid, as will be seen from the following experiment. Some of the Radiolarian skeletons from Station 266 were treated in a water-bath in a solution of 2 grms. of carbonate of potash, the water being renewed as evaporation went on. This operation was continued for thirty hours with the result that of 0·4725 grm. of Radiolarian skeletons, dried at 110° C., 0·0607 grm. of silica passed into solution, equal to 12·84 per cent. Owing to the difficulty of separating the Radiolarians from the argillaceous matters, it must be pointed out that we were not dealing with pure Radiolarian skeletons. See also Schulze, "Report on the Hexactinellida," Zool. Chall. Exp., pt. liii. pp. 26, 27.

the average depth being 2894 fathoms, which is deeper than the average depth of the Red Clay samples, viz., 2730 fathoms.

The carbonate of lime in these nine samples ranges from a trace in five cases to 20 per cent. in 2550 fathoms at Station 269, the average percentage being 4·01. This carbonate of lime is chiefly made up of pelagic Foraminifera, but the shells of bottom-living species of Rotalidæ and Nummulinidæ are also present. Teeth of fish are mentioned in seven of the samples, and otoliths of fish, Ostracode shells, Echinoderm fragments, Gasteropod shells, and Coccoliths, occur, but never in great abundance.

The residue after the removal of the carbonate of lime by dilute acid, which is red or red-brown, ranges from 80 to nearly 100 per cent. in the nine samples, the average being 95·99 per cent. In this residue the remains of siliceous organisms are estimated to make up from 30 per cent. at Station 273 in 2350 fathoms to 80 per cent. at Station 225 in 4475 fathoms. The remains of Radiolarians make up the principal part of these siliceous organisms, but Diatoms and Sponge spicules are also present, and among arenaceous Foraminifera, species of Lituolidæ and Astrorhizidæ can nearly always be observed.

The mineral particles with a mean diameter of over 0·02 mm. are all angular, and average 0·1 mm. in diameter. They make up from 1 per cent. of the deposit in most cases to 5 per cent. at Station 274 in 2750 fathoms, the mean percentage of mineral particles present in the nine samples being 1·67 of the whole deposit.

The fine washings range from 17 per cent. in 4475 fathoms to 67 per cent. in 2350 fathoms, the average being 39·88. These fine washings are largely made up of the minute undeterminable fragments of siliceous organisms.

The following table shows the average composition of the Challenger samples of Radiolarian Ooze :—

Carbonate of Lime,	Pelagic Foraminifera,	3·11	
	Bottom-living Foraminifera,	0·11	
	Other organisms,	0·79	
			4·01
Residue,	Siliceous organisms,	54·44	
	Minerals,	1·67	
	Fine Washings,	39·88	
			95·99
			100·00

When this average composition is compared with that of the Red Clay, it will be observed that the difference lies almost wholly in the large percentage of the siliceous organisms present in the residue.

The constitution of the Radiolarian Ooze as revealed by the above microscopic examination is confirmed by the two following analyses :—

				Portion soluble in HCl.									Portion insoluble in HCl.					
Station.	Depth.	No.	Loss.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	Ca_32PO_4	$MgCO_3$	Total.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
265	2900	28	4·30	38·75	6·75	11·20	0·57	2·54	0·29	0·65	2·46	63·21	21·02	6·19	3·09	1·85	0·34	32·49
274	2750	29	7·41	46·50	8·32	14·24	3·23	3·89	0·41	1·39	1·50	79·48	9·52	2·20	0·75	0·39	1·25	13·11

No. 28 is of material obtained in the dredge, No. 29 as it came up in the trawl.

These analyses again show, from the totals of the soluble and insoluble portions and by the percentages of the various substances, a great variability in the deposit, depending upon the nature of the materials mixed up with the skeletons of the Radiolaria and other siliceous organisms. On comparing these analyses with those of the Red Clay, we find a much larger percentage of soluble silicic acid in this deposit than in the Red Clay, the deep-sea deposit with which it is most nearly analogous. In one of the above analyses the soluble silica rises to 46·50 per cent.; admitting that a part comes from the hydrated silicates forming the argillaceous matter, from the zeolitic crystals which are very abundant in this deposit, or from the action of the acid and potash on the anhydrous silicates, still a very large part of the silica in the soluble portion of the analysis must come from the skeletons of the Radiolarians, Diatoms, and Sponge spicules. In fact, the examination of these siliceous remains between crossed nicols show them to be composed of amorphous silica; their loss on ignition shows also that they contain water in variable proportions, like opal, some specimens of which lose on calcination from 3 to 9 per cent., and in some cases as much as 20 per cent. of their weight. This hydrated silica, more or less easily attackable by various chemical agents, is almost entirely removed by caustic potash.[1]

The water shown in the analyses must also be regarded as being associated partly with the silica in the siliceous organisms, as well as in combination with the iron and alumina. The percentages of alumina and iron indicate that clay and limonite are present in considerable quantities. What has been said with reference to the analyses of the Red Clays applies also here to the manganese, carbonate, sulphate, and phosphate of lime, and carbonate of magnesia. The relatively small quantity of carbonate of calcium is explained by the great depth of the Radiolarian Oozes, for, as has already been pointed out, carbonate of lime gradually disappears from the deposits with increasing depth. The division referring to the insoluble part shows anew the presence of insoluble silica, of silicates, and of silicated rocks containing alumina, iron,

[1] For a description of the various Radiolarian spicules and their chemical composition, see Haeckel, "Report on the Radiolaria," Zool. Chall. Exp., part xl. pp. lxviii *et seq.* See also Thoulet, "Sur les spicules siliceux d'éponges vivantes," *Comptes Rendus*, tom. xcviii. p. 1000, 1884, and the Challenger Reports on the Hexactinellida, Tetractinellida, and Monaxonida.

calcium, and magnesium; indeed the presence of these silicates was revealed by the microscopic examination of the mineral particles.

The following analysis of a Radiolarian Ooze was made by Dr. Sipöcz:—

Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	P_2O_5	CuO	Co	K_2O	Na_2O	Total.
266	2750	30	16·52	52·85	8·22	5·94	1·74	6·61	4·84	3·99	0·16	tr.	tr.	tr.	100·87

This analysis likewise shows a high percentage of silicic acid, and from the large quantity of water shown by the loss on ignition, the major part of this silica, as well as of the iron and alumina, must be in the form of hydrate. The phosphoric acid, and a part of the calcium, are due to the presence of phosphate of lime in the organic remains. The rather high percentage of magnesia is probably explained by the presence in the deposit of fragments of rocks, containing magnesia and lime, such as the numerous fragments of altered volcanic minerals and glass noticed in the microscopic examination. The foregoing analyses then corroborate the results obtained by the macroscopic and microscopic examination of the Radiolarian Ooze; that is to say, we find the deposit composed of a mass of mineral matters analogous to those met with in the Red Clays, but this deposit is distinguished from the Red Clay by a greater abundance of hydrated silica due to the presence of the organisms which give their name to the deposit.

In addition to the samples of Radiolarian Ooze obtained by the Challenger, other areas of this deposit were discovered by the U.S. ship "Tuscarora" in the Pacific, and by H.M.S. "Egeria" in the Indian Ocean. No specimens of this deposit have as yet been met with in the Atlantic Ocean, and for a variety of reasons it is, indeed, unlikely that a Radiolarian Ooze will be discovered in the Atlantic. By reference to Chart 1 it will be seen that the patches of Radiolarian Ooze in the Pacific are confined to the central and western regions of that ocean, the seven patches shown on the map covering about 1,161,000 square miles. In the Indian Ocean there is a great patch of this deposit, in the deep water of the central eastern region surrounding the Cocos and Christmas Islands, the area of which is estimated at about 1,129,000 square miles.

Diatom Ooze.

Just as the name Radiolarian Ooze was introduced by Mr. Murray to distinguish those deposits in which Radiolarian remains played a prominent part, so the name Diatom Ooze was applied during the Challenger Expedition to distinguish those deposits in which Diatom frustules were exceptionally abundant. Dr. Joseph Hooker,[1] during Sir James

[1] Botany of the Antarctic Voyage of H.M.SS. "Erebus" and "Terror," I. "Flora Antarctica," p. 503, London, 1847; Report of British Association for 1847, pp. 83–85, London, 1848.

Clark Ross's Antarctic voyage, had pointed out the great abundance of Diatoms in the Antarctic Ocean, and in the deposits forming near the great Ice Barrier, but the Diatom Ooze was first met with in its most characteristic form during the voyage of the Challenger between Kerguelen and the Antarctic Ice Barrier, in 1260 fathoms. It was afterwards collected at a good many points in the same region by the Expedition, and subsequently by H.M.S. "Egeria" in the South Indian Ocean. In the North Pacific, south of the Kurile Islands, the "Tuscarora" discovered deposits somewhat similar to the Diatom deposits of the southern hemisphere.

The deposit when collected and when wet has a yellowish straw or cream colour; when dried it is nearly pure white, and resembles flour. Near land it may assume a bluish tinge from the admixture of land detritus. The surface layers are thin and watery, but the deeper ones are more dense and coherent, breaking up into laminated fragments in the same way as the deeper layers of a Radiolarian Ooze. It is soft and light to the touch when dried, taking the impress of the fingers and sticking to them like fine flour, and in most respects has the same physical appearance as the purest samples of Diatomite of fresh-water origin. Small samples appear quite homogeneous and uniform, but in all the soundings there were fragments of minerals and rocks, and gritty particles can generally be felt when the substance is passed between the fingers.

It effervesces with dilute acids, and may contain from 3 to 30 per cent. of carbonate of lime, which consists chiefly of the shells of pelagic *Globigerinæ*, but other Foraminifera, fragments of Molluscs, Polyzoa, Echinoderms, Ostracodes, otoliths of fish, and Cephalopod beaks are usually present in greater or less abundance.

In the Challenger collections there are five specimens of Diatom Ooze, all from the Southern Ocean. These range from 600 fathoms at Station 147A to 1975 fathoms at Station 156, the average depth being 1477 fathoms. In colour these deposits are dirty white, pure white, yellowish, or grey.

The principal part of the deposit is made up of the dead frustules of Diatoms belonging to many genera and species, together with Radiolarian remains, Sponge spicules, and fragments of these siliceous organisms. The estimated proportion of siliceous organisms ranges in the five different specimens from 20 per cent. in 600 fathoms to 60 per cent. in 1975 fathoms, averaging 41 per cent.; this is without taking into account the remains of these organisms in the "fine washings," which are largely made up of their comminuted fragments. Diatoms and Radiolarians were, of course, present in all cases, and Sponge spicules were recognised in all or nearly all the samples; arenaceous Foraminifera were also observed whenever a large quantity of the deposit was examined.

The following is a list of the Diatoms observed in a typical Diatom Ooze from the Antarctic, viz., Station 157, 1950 fathoms :—

**Navicula subtilis*, Greg.
Thalassiothrix longissima, var. *antarctica*, Cl. et Grun.
**Synedra lanceolata*, Cstr.
„ *nitzschioides*, Grun.
„ *filiformis*, Grun.
Thalassionema nitzschiodes, var. *lanceolata*, Grun.
**Trachysphenia australis*, Petit, var. *antarctica*, Schwarz.
**Diatoma rhombicum*, O'Me., var. *oceanica*, nov.
Nitzschia constricta, var. *antarctica*, nov.
†*Rhizosolenia styliformis*, Brightw.
„ *furcata*, n.sp.
**Corethron criophilum*, Cstr.
Hemiaulus antarcticus, Ehrenb. = *Eucampia balaustium*, Cstr., and var. *minor*.
Asteromphalus hookerii (Ehrenb.), Ralfs.
„ forma *buchii*, Ehrenb.
„ forma *humboldtii*, Ehrenb.
„ forma *cuvierii*, Ehrenb.
„ forma *denarius*, Janisch.
„ *darwinii*, Ehrenb.
Hyalodiscus radiatus, O'Me., var. *arctica*, Grun.
**Actinocyclus oliveranus*, O'Me.
Coscinodiscus margaritaceus, Cstr.
* „ *lunæ*, Ehrenb.
„ *excentricus*, Ehrenb.

* Indicates the peculiarly Antarctic species.

Coscinodiscus atlanticus, Cstr., and var.
„ *lineatus*, Ehrenb.
„ *lentiginosus*, Janisch.
„ „ var. *maculata*, Grun.
Coscinodiscus africanus, var. *wallichianus*, Grun.
Coscinodiscus subtilis, Ehrenb.
† „ „ var. *glacialis*, Grun.
„ *tumidus*, Janisch.
„ „ var. *fasciculata*, nov.
Coscinodiscus radiatus, Ehrenb.
† „ *decrescens*, var. *polaris*, Grun.
† *Coscinodiscus decrescens*, var. *repleta*, Grun.
„ *fasciculatus*, A.S.
„ *griseus*, var. *gallopagensis*, Grun. (?)
Coscinodiscus curvulatus, *maculata*, nov.
„ *tuberculatus*, Grev., var. *excentrica*, nov.
Coscinodiscus tuberculatus, var. *antarctica*, nov.
Coscinodiscus elegans, Grev.
„ *robustus*, Grev.
„ „ var. *minor*.
„ *antarcticus*, Cstr. (nov. Grun.).
Coscinodiscus denarius, A.S.
„ *marginatus*, Ehrenb.

† Species also recorded from the Arctic zone.

As all the Diatom deposits, so far as we know, are confined to the Southern or Antarctic Oceans, or to the northern parts of the North Pacific, none of the species of Foraminifera, Radiolaria, or Diatoms characteristic of the tropical regions are found in them; Coccoliths and Rhabdoliths are absent, except in a few of the more northerly samples in the southern hemisphere.

The carbonate of lime varies from 2·00 per cent. in 1975 fathoms to 36·34 per cent. in 600 fathoms, the average being 22·96 per cent. By far the larger part of this carbonate of lime is due to the presence of the dead shells of pelagic Foraminifera, the other carbonate of lime organisms present not making up more than 3 or 4 per cent. of the whole deposit in any case.

The mineral particles vary greatly in nature, size, and abundance in the Diatom Oozes, sometimes volcanic rocks and minerals, sometimes those of ancient and sedimentary formations predominating. This was to be expected, for all the Challenger samples of this deposit lie within the region of floating ice in the southern hemisphere. The minerals range from 3 per cent. in 1950 fathoms to 25 per cent. in 600 fathoms, the average being 15·6 per cent. The mean diameter is 0·12 mm., but rocks and minerals from the Antarctic Continent and islands are found of all dimensions, and are spread over the whole region from their source in the shallow water near the Ice Barrier to north of the latitude of 40° south, for they were dredged in considerable numbers by the Challenger in all the Diatom ooze areas. These consist of fragments of granite, granitite, chloritic sandstone, micaceous sandstone, amphibolite, gneiss, schists and slates, and other ancient and recent volcanic rocks.

The fine washings range from 12·53 in 1260 fathoms to 27·92 in 1975 fathoms, the average being 20·44 per cent.

The average composition of the five samples of Diatom Ooze is as follows:—

Carbonate of Lime,	Pelagic Foraminifera,	18·21	
	Bottom-living Foraminifera,	1·60	
	Other organisms,	3·15	
			22·96
Residue,	Siliceous organisms,	41·00	
	Minerals,	15·60	
	Fine Washings,	20·44	
			77·04
			100·00

The Challenger's trawlings revealed the presence of a large number of deep-sea animals living at the bottom in the Diatom ooze areas; at Station 157, 1950 fathoms, a single haul of the trawl procured over 150 specimens belonging to 77 species and 68 genera.

The following is an analysis of an average sample of the deposit from Station 157, 1950 fathoms:—

				Portion soluble in HCl.									Portion insoluble in HCl.		
Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	Ca_32PO_4	$MgCO_3$	Total.	SiO_2	Al_2O_3	Fe_2O_3
157	1950	31	5·30	67·92	0·55	0·39	...	19·29	0·29	0·41	1·13	89·98	4·72		

In this analysis, even better than in those of the Radiolarian Ooze, the large part taken by the remains of siliceous organisms in the composition of the deposit is rendered evident by the quantity of soluble silica. In the portion soluble in hydrochloric acid and treated with potash the soluble silica amounts to 67·92 per cent. Having regard to the low percentage of alumina and peroxide of iron, with which the silica and water lost on ignition might be combined, it must be admitted that amorphous silica exists in a free state, and that the water must be combined with silica, thus forming hydrated silica, analogous to that which, as we have seen, forms the skeletons of Radiolarians. As the quantity of water is variable for hydrated silica, and as the loss on ignition comprehends also organic substances, it would be useless to lay too much stress on the figures, but it may be said that they represent approximately the mean hydration of opals, viz., about 8 per cent. In this case the soluble silica may be said to make up about three-fourths of the deposit. With the exception of 19·29 per cent. of carbonate of calcium, which is chiefly derived from pelagic Foraminifera and shells of Molluscs, &c., the deposit may be regarded as very pure, for all the substances soluble in hydrochloric acid, except the silica, are represented by very small quantities, in comparison with what is met with in other deposits. In the specimen analysed there can have been but little argillaceous matter or ferric hydrate, and in the insoluble portion the anhydrous silicates are represented by only 4·72 per cent. The specimen taken for this analysis may have been exceptionally pure, for it must be remembered that in the large quantity dredged by the Challenger at this station there were many fragments of rocks of considerable size, and associated with these we would expect to find a larger quantity of argillaceous matter than is indicated in the above analysis.

Another analysis of material from the same station is, properly speaking, one of those portions comprised in our Tables under the headings "siliceous organisms" and "fine washings." The substance analysed had been treated with hydrochloric acid to remove the calcareous organisms, and therefore consisted as nearly as possible of siliceous organisms, chiefly Diatoms, but mixed with these were a few Radiolaria and Sponge spicules.

Station.	Depth in Fathoms.	No.	Loss.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	BaO	K_2O	Na_2O	P_2O_5	Total.
157	1950	32	5·85	90·56	1·31	0·88	0·33	0·30	0·20	0·15	0·40	tr.	99·98

In this analysis, again, the high percentage of silicic acid shows the true nature of the deposit, and considering the percentage of water (loss) and the low percentage of all the bases, it may be concluded that almost all the portion of the deposit here under consideration is composed of a form of hydrated silica derived from Diatom frustules and remains of other siliceous organisms, mixed with a very small quantity of ferruginous clayey matter.

Taking the Challenger researches in conjunction with those of Sir James Ross's Antarctic Expedition and other observations, it seems to be indicated that a great zone of Diatom Ooze of varying width surrounds the South Polar regions, as represented on the accompanying chart. This zone lies for the most part between the Antarctic Circle and the latitude of 40° S., and may be estimated to cover about 10,880,000 square miles of the sea bottom in these regions. There is a small patch of Diatom Ooze in the North Pacific, which may be estimated at about 40,000 square miles.

Globigerina Ooze.

This name was in the first instance applied to the mud collected when sounding out the greater depths of the Atlantic Ocean in connection with telegraph cables, because a large percentage of this mud or ooze was made up of the small Foraminiferous shell named *Globigerina bulloides*. The term Globigerina Ooze, which has become quite familiar and well established, is at once appropriate and distinctive, and is now adopted for all those deposits which are chiefly made up of the Foraminiferous shells belonging to the family Globigerinidæ. The first specimens of the ooze were probably procured by Lieutenant Berryman of the United States Navy in the North Atlantic, and were described in some detail by Ehrenberg and Bailey in 1853. Many subsequent writers have described specimens that were afterwards procured from other regions of the ocean. Were all the deposits which contain 10 or 15 per cent. of these Foraminiferous shells classed as Globigerina Ooze, then this deposit would be by far the most extensive of the deep-sea deposits, for some species of these shells are present in greater or less abundance in all the types of marine formations from Equator to Poles. Near land, however, their presence is sometimes wholly masked by the abundance of land debris or exuviæ of shallow-water organisms, and in the greatest depths of the ocean these shells are absent, or at least do not accumulate on the bottom so as to form a calcareous deposit. In this Report, as a general rule, a deposit has not been classed as a Globigerina Ooze unless it contains over 30 per cent. of carbonate of lime, principally made up of the dead shells of these Foraminifera. There was at one time much discussion as to whether those Foraminifera, which are in this Report called pelagic, lived at the surface of the sea or on the bottom of the ocean; this question has been, we believe, definitely settled in favour of the former view, as will be pointed out in detail later on. The following is a list of the pelagic Foraminifera that were taken in the surface nets during the cruise of the Challenger, and it is the dead shells of these species which, having fallen to the bottom of the sea, make up the principal part of the carbonate of lime present in the great majority of pelagic deposits, and especially in all those denominated Globigerina and Pteropod Oozes:—

Globigerina sacculifera, Brady.
„ *æquilateralis*, Brady.
„ *conglobata*, Brady.
„ *dubia*, Egger.
„ *rubra*, d'Orbigny.
„ *bulloides*, d'Orbigny.
„ *inflata*, d'Orbigny.
„ *digitata*, Brady.
„ *cretacea*, d'Orbigny (?).
„ *dutertrei*, Brady.
Orbulina universa, d'Orbigny.
Hastigerina pelagica (d'Orbigny).
Pullenia obliquiloculata, Parker and Jones.
Sphæroidina dehiscens, Parker and Jones.
Candeina nitida, d'Orbigny.
Cymbalopora (*Tretomphalus*) *bulloides* (d'Orbigny).
Pulvinulina menardii (d'Orbigny).
„ *tumida*, Brady.
„ *canariensis* (d'Orbigny).
„ *micheliniana* (d'Orbigny).
„ *crassa* (d'Orbigny).

The majority of these species are limited to those deposits immediately under warm tropical waters, while only a few of them are met with in deposits from the colder regions of the ocean; it follows that the predominating species in a deposit vary according to latitude, or more correctly according as the surface oceanic currents have a tropical or polar origin, along with other surface conditions of the locality.

The colour of the deposit is white, milky-yellow, rose, brown, or greyish, depending on the nature of the inorganic substances mixed up with the Foraminifera. The prevailing colour is milky-white or rose-coloured far from land, and dirty white, blue, or grey near land, when there is a considerable quantity of detrital matter from rivers in the deposit. It has sometimes a mottled aspect from the presence of manganese grains or volcanic ashes, lapilli, and fragments of pumice. It is fine grained and homogeneous; in tropical regions many of the Foraminifera are visible to the naked eye, while in temperate regions the form of the organisms is, as a rule, indistinguishable without the aid of a lens. When dried a Globigerina Ooze is usually pulverulent, but some specimens which have a low percentage of carbonate of lime cohere slightly.

In the Tables of Chapter II. there are 118 samples of deposits described as Globigerina Ooze. These come from depths ranging from 400 to 2925 fathoms. In addition to these there are a few doubtful cases where a Globigerina Ooze was indicated.

3	samples come	from depths of	less than	500		fathoms.
2	„	„	between	500 and	1000	„
13	„	„	„	1000 „	1500	„
35	„	„	„	1500 „	2000	„
49	„	„	„	2000 „	2500	„
16	„	„	over 2500 fathoms.			

The average depth of the above samples is 2002 fathoms; taking the doubtful samples into account, the average depth would be 1996 fathoms, and excluding those samples from depths less than 500 fathoms, the average depth would be 2049 fathoms. So that the result from these figures agrees with the impression derived from a large experience in the examination of deep-sea deposits, viz., that the depth at which Globigerina Ooze is found in its most typical development is about 2000 fathoms, and it will be noticed that of the 118 Challenger samples 84 come from depths between 1500 and 2500 fathoms.

In addition to the pelagic Foraminifera many other organisms contribute to the carbonate of lime present in a Globigerina Ooze, some of these living in the surface waters of the ocean and others having their habitat at the bottom of the sea; among the former are pelagic Molluscs and pelagic calcareous Algæ. The shells of pelagic Molluscs—Pteropods and Heteropods—are sometimes present in great abundance in tropical and subtropical regions, and then the Globigerina Ooze passes gradually into a Pteropod Ooze in the shallower depths. Coccospheres and Rhabdospheres are regarded as calcareous Algæ, and their remains or broken fragments, Coccoliths and Rhabdoliths, sometimes make up fully 15 per cent. of Globigerina Ooze. In the samples of Globigerina Ooze procured from high northern or southern latitudes the shells of pelagic Molluscs, Coccoliths, and Rhabdoliths, are wholly absent. The remains of calcareous organisms which habitually live on the bottom of the sea, such as Molluscs, Echinoderms, Annelids, Corals, Polyzoa, and bottom-living Foraminifera, are nearly always to be found in a Globigerina Ooze, from whatever region the specimen may have been procured.

The carbonate of lime in the Globigerina Oozes in the Tables ranges from 30·15 per cent. at Station 97 in 2575 fathoms to 96·80 per cent. at Station 343 in 425 fathoms, the average percentage being 64·47. Arranged in depths of 500 fathoms, the samples contained for each zone the following average percentages:—

3	samples	under 500		fathoms,	87·07	mean	per cent.	$CaCO_3$.
2	„	from	500 to 1000	„	68·47		„	„
13	„	„	1000 „ 1500	„	63·69		„	„
35	„	„	1500 „ 2000	„	72·66		„	„
49	„	„	2000 „ 2500	„	61·74		„	„
16	„	over 2500		„	49·58		„	„

This table shows generally a decrease in the quantity of carbonate of lime with increasing depth, but this fact would be still more strikingly exhibited had the samples been all from one region of the ocean, in which the surface conditions were the same, or had the samples from the shallower depths near continents and islands been eliminated, for in these there is always a large admixture of accidental matters derived from land.

The estimated percentage of carbonate of lime due to the presence of the dead shells of pelagic Foraminifera ranges from 25 to 80, the average being 53·10; it will thus be seen that the great bulk of the carbonate of lime present in Globigerina Oozes is referred to the remains of these organisms, which predominate everywhere, and especially in the deposits from the medium depths of the ocean far from land.

The carbonate of lime attributed to the presence of the shells of Foraminifera that live on the bottom of the sea is estimated to average only 2·13 per cent. The carbonate of lime derived from organisms other than Foraminifera, such as Molluscs, Echinoderms, Corals, Sponges, otoliths of fish, calcareous Algæ, Coccoliths, and Rhabdoliths, ranges from 1·16 to 31·77 per cent., the average being 9·24 per cent., and it may be said that these organisms are especially abundant in the shallower depths of the ocean near land.

In the Tables Globigerinidæ are mentioned in all cases (118), *Pulvinulina* (117), Coccoliths (116), Echinoderm fragments (114), Rotalidæ (107), Miliolidæ (105), Rhabdoliths (105), Lagenidæ (77), Textularidæ (71), Ostracodes (64), Pteropods (36), Nummulinidæ (33), otoliths of fish (28), Lamellibranchs (24), Gasteropods (20), Polyzoa (19), teeth of fish (18), Heteropods (11), *Serpula* (10), and Coccospheres, calcareous Algæ, Alcyonarian spicules, Cirripeds, *Dentalium*, Brachiopods, *Cymbalopora*, and Cephalopod beaks (1 to 6 cases).

With a more careful and detailed examination in each case, it is probable that the number of times the above-named organisms occur in the 118 samples would be greatly increased in the majority of instances. However, the above numbers indicate fairly well the relative frequency with which the remains of these calcareous organisms are met with in a Globigerina Ooze during the examination of an average sample. These results, which are confirmed by the examination of a large number of deposits in addition to those of the Challenger, show, as already stated, that by far the larger part of the carbonate of lime in the Globigerina Ooze is derived from the shells of organisms that live in the surface waters of the ocean, principally pelagic Foraminifera, Molluscs, and calcareous Algæ.

The residue is the complement of the carbonate of lime; where the latter is least the former is highest, and *vice versa*. In the above 118 samples the residue ranges from 3·20 to 69·85, and averages 35·53 per cent. The colour of the residues of the Globigerina Oozes is brown in 65, and red in 30, cases, while in other cases it is chocolate, red-brown, rose, fawn, black, grey, and green.

The residue consists of—

(*a*) *Siliceous Organisms.*—These range from 1 per cent. in the majority of cases to 10 per cent. in 4 cases, the average being 1·64 per cent. The Radiolarian remains are the most abundant and the most frequent, then follow the remains of Sponge spicules and the frustules of Diatoms. The arenaceous Foraminifera and the glauconitic and other casts of calcareous organisms are also included under this heading.

The remains of Radiolarians, Diatoms, and siliceous Sponges are almost always present in the Globigerina deposits, but it frequently happens that one or other of these groups cannot be detected until a considerable quantity of the deposit has been examined after removal of the carbonate of lime with dilute acid; in some cases all the siliceous organisms have apparently disappeared, probably as silicate of lime ($CaOSiO_2$), for it may be presumed they were once present in the ooze.[1] At other times they are found to be all present in considerable abundance, and in some localities may make up over 10 per cent. of the whole deposit.

(*b*) *Minerals.*—In the Challenger samples the mineral particles range from 1 per cent. in the majority of cases to 50 per cent. at Station 318, and they average 3·33 per cent. The particles themselves range in size from 0·06 mm. to 0·80 mm., the average being 0·089 mm. in diameter. They are in the majority of cases angular, but in 3 cases they are recorded as rounded, and in 18 cases as rounded and angular.

In the purest samples of Globigerina Ooze, mineral particles are exceedingly rare, and consist for the most part of a few minute fragments of felspar, augite or hornblende, magnetite, volcanic glass, sometimes more or less altered, with which are associated a small quantity of clayey matter and the oxides of iron and manganese. In the less pure samples the residue as a whole increases in bulk and the mineral particles become more numerous, monoclinic and triclinic felspars, augite, olivine, hornblende, and more rarely white and black mica, bronzite, actinolite, chromite, glauconite, quartz, and cosmic dust being then met with. Some of these mineral particles are only present in deposits which are passing, from nearness to land, into terrigenous deposits. In the 118 samples, magnetite is recorded 95 times, felspars (86), augite (82), glassy volcanic particles (63), hornblende (58), quartz (49), pumice (45), manganese (37), mica (31), plagioclase (24), sanidine (21), olivine (19), lapilli (18), glauconite (13), palagonite (10), and enstatite, bronzite, pyroxene, garnet, actinolite, tourmaline, zircon, microcline, serpentine, phillipsite, and magnetic spherules (1 to 5 times). Phosphatic and manganese nodules are sometimes dredged from Globigerina Oozes.

(*c*) *Fine Washings.*—This portion of the residue varies from 1·20 to 64·62 per cent. of the whole deposit, the average being 30·56 per cent. The following table gives the average percentage of fine washings in the samples from each zone of 500 fathoms :—

3	cases	from depths less than	500	fathoms,	9·60	mean per cent.
2	„	from	500 to 1000	„	13·50	„
13	„	„	1000 „ 1500	„	30·85	„
35	„	„	1500 „ 2000	„	22·72	„
49	„	„	2000 „ 2500	„	32·76	„
16	„	over	2500	„	47·73	„

Although not quite regular, this shows a gradual increase in the abundance of fine washings with increasing depth. In the same way, but not quite regularly, the abundance of minerals and their size are shown in the 118 samples to be greater in the shallower depths.

[1] See Murray and Irvine, "Silica and Siliceous Organisms in Modern Seas," *Proc. Roy. Soc. Edin.*, 1891. It is manifest that, wherever alkaline sea-water is in contact with oozes made up of dead siliceous and calcareous organisms, solution of silicic acid must take place, alkaline silicates being formed—$SiO_2 + RCO_3 = RSiO_3 + CO_2$ (see also chapter IV.).

As has been already stated, the residue of a Globigerina Ooze is in all essential particulars the same as a Red Clay from the adjacent regions of the ocean's bed. The trawl and dredge brought up from Globigerina Oozes large pumice stones in 12 instances, manganese nodules 6 times, sharks' teeth and earbones of Cetaceans 4 times, and more rarely phosphatic concretions, pebbles, and aggregations of the deposit. Numerous animals belonging to the fishes and all the invertebrate marine groups have been dredged and trawled from the Globigerina Oozes, life being apparently much more abundant on these than on the Red Clay and Radiolarian deposits.

The following shows the average composition of the 118 Challenger samples of Globigerina Ooze :—

Carbonate of lime,	Pelagic Foraminifera,	53·10	
	Bottom-living Foraminifera,	2·13	
	Other organisms,	9·24	
			64·47
Residue,	Siliceous organisms,	1·64	
	Minerals,	3·33	
	Fine Washings,	30·56	
			35·53
			100·00

The analyses of a large number of Globigerina Oozes, presented in the table on the next page, support the above views as to the composition of the deposit.

The important role played by the remains of calcareous organisms in these deposits is indicated by the high percentage of the portion soluble in hydrochloric acid, and especially by that in the column $CaCO_3$; although the carbonate of calcium varies greatly in the different specimens of Globigerina Ooze, the annexed analyses show that it usually forms more than one-half of the whole deposit, and often rises to a much higher limit. This high percentage of carbonate of lime might be said to efface in a manner the small quantity of other substances mixed with the calcareous organisms. However, the columns showing the loss on ignition, silica, alumina, and iron, indicate small quantities of argillaceous and ferruginous matters, associated with the remains of siliceous organisms. It may be observed that the loss on ignition does not augment with the proportion of carbonate of lime, but rather with an increase of silica, alumina, and ferric oxide, so that the larger part of the loss on ignition is rather to be referred to the water combined with these substances than to organic matters. The sulphate and phosphate of calcium in these analyses are to be attributed, as in the case of the Red Clay, to the presence of sea-water salts and of phosphatic organic remains. There does not seem to be any relation between the percentages of carbonate of lime and carbonate of magnesia as might be expected if the carbonate of magnesia played a role in the original constitution

				Portion soluble in HCl.									Portion insoluble in HCl.					
Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	$Ca_3 2PO_4$	$MgCO_3$	Total.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
1	1890	33	7·91	12·10	5·26	3·95	...	50·00	0·44	l.tr.	1·32	73·07	13·77	3·47		1·26	0·52	19·02
2	1945	34	5·02	9·08	3·23	4·18	...	64·55	0·69	tr.	1·17	82·90	9·08	1·79	0·60	0·33	0·28	12·08
11	2575	35	9·13	12·22	5·61	4·65	...	51·16	1·02	...	1·93	76·59	Principally Al_2O_3,Fe_2O_3,SiO_2					14·28
12	2025	36	8·80	...	19·24	13·74	...	43·93	1·37	fair tr.	1·94	80·22	Residue consisting of soluble SiO_2 with the insoluble silicates.					10·98
13	1900	37	6·63	...	5·86		...	74·50	0·51	small tr.	1·27	82·14	Residue consisting of soluble SiO_2 with the insoluble silicates.					11·23
14	1950	38	4·58	4·60	3·33		...	79·17	1·20	1·12	1·40	90·82	Principally Al_2O_3,Fe_2O_3,SiO_2					4·60
15	2325	39	4·17	9·16	6·25		...	67·60	1·91	l.tr.	2·58	87·50	Principally Al_2O_3,Fe_2O_3,SiO_2					8·33
16	2435	40	9·60	12·00	4·00	7·10	...	52·22	2·32	s.tr.	0·76	78·40	8·00	2·96		0·64	0·40	12·00
17	2385	41	6·84	10·07	2·69	9·05	...	58·40	0·81	1·74	0·68	83·44	Principally Al_2O_3,Fe_2O_3,SiO_2					9·72
64	(2700)	42	7·90	12·96	4·75	5·95	tr.	37·51	0·29	2·80	1·13	65·39	18·75	6·35	1·08	0·41	0·12	26·71
146	1375	43	2·90	6·10	0·91		...	86·36	0·84	...	0·19	94·40	Al_2O_3,Fe_2O_3,SiO_2					2·70
176	1450	44	5·00	9·30	2·00	6·16	...	62·41	0·58	0·84	1·51	82·80	8·20	2·30	1·04	0·40	0·26	12·20
224	1850	45	1·50	1·57	1·25	0·47	...	93·14	0·29	0·28	0·57	97·57	Al_2O_3,Fe_2O_3,SiO_2					0·93
246	2050	46	4·40	16·90	2·92	4·91	1·10	47·57	0·56	1·05	0·83	75·84	15·40	2·90	0·90	0·34	0·22	19·76
293	2025	47	6·80	6·20	1·30	20·94	4·80	54·67	0·46	0·41	0·90	89·68	2·40	0·60	0·30	0·12	0·10	3·52
296	1825	48	2·25	3·06	4·50	0·73	g.tr.	82·55	0·58	2·77	1·13	95·32	1·51	0·61	0·12	0·14	0·05	2·43
297	1775	49	4·10	3·98	1·95	3·69	g.tr.	81·13	0·44	0·19	0·85	92·23	2·77	0·35		0·39	0·16	3·67
300	1375	50	1·70	8·55	4·75	4·50	0·85	62·17	0·29	tr.	0·94	82·05	9·30	3·79	2·06	0·96	0·14	16·25
302	1450	51	1·00	1·83	1·00	1·72	...	91·32	0·73	0·28	0·30	97·18	Al_2O_3,Fe_2O_3,SiO_2					1·82
332	2200	52	2·82	10·37	3·75	1·51	tr.	65·67	0·58	1·74	1·33	84·95	9·06	2·18	0·55	0·33	0·11	12·23
338	1990	53	1·40	1·36	0·65	0·60	...	92·54	0·19	0·90	0·87	97·11	Al_2O_3,Fe_2O_3,SiO_2					1·49

Nos. 34, 42, and 53 are of material obtained from the dredge; Nos. 46, 50, and 51 from the trawl; Nos. 48, 49, and 52 from tow-net at trawl; the rest from the sounding tube. No. 45 had been washed and the finer parts removed.

of the *Globigerina* shells present in these deposits. Take for example a sample with about the highest percentage of carbonate of lime, 91·32 (Station 302), where there is 0·30 per cent. of carbonate of magnesia, while in that with the least carbonate of lime, 37·51 per cent. (Station 64), there is 1·13 per cent. of carbonate of magnesia.[1]

In examining the insoluble portion of the analyses, it will be seen that, generally speaking, this portion indicates that the mineral particles are relatively less numerous than in a Red Clay. In some samples, however, the percentage of silica indicates the presence of quartz and of silicates in some abundance. In all these respects the analyses confirm the macroscopic and microscopic examination in showing the presence of silicates, similar to those in other pelagic deposits, in the residue of a Globigerina Ooze. This view is confirmed by the following additional analysis of a Globigerina Ooze from the Tropical Pacific, at Station 176, in 1450 fathoms:—

Station.	Depth in Fathoms.	No.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	CaO	MgO	K_2O	Na_2O	CO_2	H_2O	Cu	Ni	Co	P_2O_5	Total.
176	1450	56	17·71	4·86	6·80	1·69	35·08	1·64	0·32	0·65	29·10	2·95	tr.	tr.	tr.	tr.	100·80

In comparing the figures in this analysis with those given in the previous table for a sample from the same station, there is a coincidence in most cases, but in some cases there are small divergences which cannot be accounted for by different methods of analysis, and this shows how samples from the same station may vary in composition. This remark is applicable also to the results indicated in the Tables of Chapter II., which again are different from the results of this complete analysis. It will thus be seen that, notwithstanding the care taken in selecting a medium sample, we are in reality not dealing with a homogeneous substance; this is true for all the deposits, as might be expected, and as we have already pointed out. However, the examination of the preceding analysis leads to the same general results as the others; that is to say, the percentage of carbonate of lime is that of a Globigerina Ooze. Along with the carbonate of lime organisms there is a residue composed of argillaceous matters united with hydrated silica, siliceous organisms, and anhydrous silicates containing alumina, iron, magnesia, and alkalies, referable to minerals and fragments of rocks of volcanic origin.

In order to know as exactly as possible the nature of this mineral matter mixed with the remains of *Globigerinæ*, the residues of two samples of Globigerina Ooze have been submitted to a detailed examination. The samples were in the first place boiled for a long time in distilled water to remove the soluble salts. They were then treated with dilute acid

[1] This fact may be easily explained: admitting that the carbonate of magnesia comes from the action of the sulphate of magnesia in the sea-water on the *Globigerina* shells, it will be seen that this action must be stronger on a given quantity of shells, when the rate of their deposition is slow than when they are abundant, and accumulate rapidly in the deposit. It may, however, be urged that the carbonate of magnesia has accumulated in the greater depths simply from the removal of the carbonate of lime in solution.

added in successive small quantities, while the substance was stirred continually, care being taken to have but a very feeble acid reaction during the operation. In this way there was obtained, after complete elimination of the carbonates and phosphates, an impalpable residue presenting a deep brown colour, similar to a Red Clay when wet and yellowish brown when dry. The physical characters resemble those of an impure argillaceous substance coloured by iron; before the blow-pipe it melts into a black vesicular glass, like ferruginous felspathic mud. These two residues from the Globigerina Ooze of Stations 224 and 338 were then analysed, with the following results:—

Station.	Depth in Fathoms.	No.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	CaO	MgO	K_2O	Na_2O	H_2O	Ba	P_2O_5	Total.
224	1850	57	64·16	15·13	8·19	tr.	1·66	1·79	1·01	0·90	7·10	tr.	tr.	99·94
338	1990	59	50·47	18·01	12·75	3·00	1·71	2·44	1·11	1·05	10·93	tr.	tr.	101·47

These two analyses of residues of Globigerina Ooze show, as might be expected, remembering the variability of the deposits, considerable differences in all the substances estimated. It may be held, however, that these two residues, from the point of view of their constitution, present a very close analogy with the Red Clay of greater depths. In short, according to the percentages of water, alumina, and silicic acid, there must exist in the Globigerina Oozes an argillaceous matter coloured by oxides of iron and manganese, and mixed with this clay alkaline and other silicates, as shown by microscopic examination. The composition of this residue is, in fact, similar to a Red Clay. The materials have the same origin in both cases,—the inorganic portion of a Globigerina Ooze being, indeed, analogous to a Red Clay.

This conclusion receives further confirmation from the following analysis (No. 59A) of the portion of the residue soluble in hydrochloric acid, the results of which show the presence of argillaceous and ferruginous matter in these calcareous deposits. The Globigerina Ooze at Station 338 was submitted to the action of boiling hydrochloric acid and a certain quantity of silica, alumina, iron, and manganese was dissolved. After this operation there remained 2·21 grms. of insoluble residue, and the amount dissolved and re-precipitated by ammonia represented 0·0487 grm. of silica, 0·0404 grm. of alumina, and 0·0917 grm. of peroxide of iron.

SiO_2	26·94	per cent.
Al_2O_3	22·34	„
Fe_2O_3	50·72	„
	100·00	

The atomic relations of the silica and alumina are here those in which these two bodies are met with in clay. The part soluble in hydrochloric acid consists thus of clay, in addition to carbonates, sulphates, and phosphates, with ferric hydrate and a small quantity of manganese. In this analysis it is evident that the percentage of iron is very high, which is due to the fact that the hydrate of iron is proportionally more easily attacked by hydrochloric acid than clay properly so called.

The loss on ignition cannot be entirely attributed to water; a part must be referred to organic matters and carbonic acid, and a determination was made with the object of estimating the quality of this organic matter in the Globigerina Ooze from Station 224, 1850 fathoms, the analysis of the residue of which is given above.

(No. 58) 0·9905 grm. of the substance dried at 100° C. lost on ignition 0·0537 grm. = 5·42 per cent.

0·9588 grm. of the substance dried at 100° C. lost on ignition 0·0558 grm. = 5·82 per cent.

(I.) 0·4413 grm. of substance dried at 100° C., burnt with oxide of copper, gave 0·0453 grm. of carbonic acid, corresponding to 0·01235 grm. of carbon.

(II.) 0·9012 grm. of substance dried at 100° C., mixed with oxide of copper and burnt in a current of carbonic acid (barometer, 743·95 mm., mean temperature, 22°·5 C.) gave 6·4 cubic centimetres of nitrogen = 0·0753 grm.

The percentage composition of this organic substance is thus:—

C	2·80 per cent.
N	0·785 ,,

The proportion of carbon and nitrogen in this organic substance is 53·48 : 15, which is the proportion of these two elements in albumen.

To conclude then, it may be said that the foregoing analyses confirm the macroscopic and microscopic observations in showing a Globigerina Ooze to be a deposit formed essentially of the remains of calcareous organisms, while the portion insoluble in dilute acid consists of matters similar to those met with in a Red Clay, and having the same origin.

From the state of our knowledge up to the present time it appears that Globigerina Ooze is one of the most widely distributed of the marine deposits, the area which it covers being estimated at about 49,520,000 square miles, inferior only to that of the Red Clay. It attains its maximum development in the Atlantic Ocean, occupying by far the larger portion of the sea-floor of this ocean, and stretching from within the Arctic Circle to the Southern Ocean as far as 60° S. latitude. The total area of Globigerina Ooze in the Atlantic from north to south is estimated at about 22,500,000 square miles.

In the Indian Ocean, Globigerina Ooze is estimated to occupy about 12,220,000 square miles, covering nearly the whole of the western portion of the basin, extending into the Arabian Sea and Bay of Bengal in the north and into the Southern Ocean in the south.

In the Pacific Ocean, the area covered by Globigerina Ooze is estimated at about 14,800,000 square miles. In the western basin of the Pacific it extends from the Southern Ocean, in about 55° S. latitude, along the shores of New Zealand and Australia, in a very irregular and broken manner, to the eastern shores of Japan in the north; there is a detached area in the Central Pacific around the Society Islands, a smaller area extending north-west from the Sandwich Islands, and numerous small detached patches around the coral island groups. In the south-eastern part of the Pacific, Globigerina Ooze extends westwards from off the Chilian coast of South America, encircling an extensive area of Red Clay, and joins the area of the western basin south-east of New Zealand, so that it may be said to extend almost uninterruptedly from the shores of Japan to the south-west coast of South America.

An examination of the bathymetrical contour lines on Chart 1 shows that the Globigerina Oozes occupy all the medium depths of the ocean removed from continents and islands, and is especially developed in those regions where the surface of the sea is occupied by warm currents, the only development of the deposit in the Arctic regions being in the track of the northern extension of Gulf Stream waters, where in the Norwegian Sea this deposit is estimated to cover about 193,000 square miles, the greater part of which is within the Arctic Circle. It will also be noticed that the deposit is found at greater depths in tropical regions than in more northern or southern latitudes.

Pteropod Ooze.

This name was employed by Mr. Murray during the cruise of the Challenger to designate those deep-sea deposits in which a very large part of the calcareous organisms consists of the dead shells of Pteropods and Heteropods, along with the shells of other pelagic and larval Molluscs. One of the most remarkable facts discovered by the Challenger is, that though the remains of these pelagic Molluscs are abundant everywhere in the surface waters of the tropical and subtropical regions of the ocean, yet their dead shells are wholly absent from the deposits in all the deeper waters. A few traces of them may be met with occasionally in depths as great as 2000 fathoms, but it is only in lesser depths that they make up any appreciable part of a Globigerina Ooze, or are so abundant as to justify the distinctive name of Pteropod Ooze. As in the warmer regions the appearance of Pteropod and Heteropod shells in a deposit is associated with a depth limit and other oceanic phenomena of great interest, it seemed desirable to emphasise their occurrence in this way. A Pteropod Ooze is then distinguished from a Globigerina Ooze, with which it has so many points of resemblance, by the presence of these shells.

The following is a list of the Pteropod and Heteropod shells that may be found in a Pteropod Ooze:—

PTEROPODA.[1]

Limacina inflata (d'Orbigny).
,, *triacantha* (Fischer).
,, *helicina* (Phipps).
,, *antarctica*, Woodward.
,, *helicoides*, Jeffreys.
,, *lesueuri* (d'Orbigny).
,, *australis* (Eydoux and Souleyet).
,, *retroversa* (Fleming).
,, *trochiformis* (d'Orbigny).
,, *bulimoides* (d'Orbigny).
Peraclis reticulata (d'Orbigny).
,, *bispinosa*, Pelseneer.
Clio (*Creseis*) *virgula* (Rang).
,, (,,) *conica* (Eschscholtz).
,, (,,) *acicula* (Rang).
,, (,,) *chierchiæ* (Boas).
,, (*Hyalocylix*) *striata* (Rang).
,, (*Styliola*) *subula* (Quoy and Gaimard).
Clio andreæ (Boas).
,, *polita* (Craven, MS.).
,, *balantium* (Rang).
,, *chaptali* (Souleyet).
,, *australis* (d'Orbigny).
,, *sulcata* (Pfeffer).
,, *pyramidata*, Linné.
,, *cuspidata* (Bosc).
Cuvierina columnella (Rang).
Cavolinia trispinosa (Lesueur).
,, *quadridentata* (Lesueur).
,, *longirostris* (Lesueur).
,, *globulosa* (Rang).
,, *gibbosa* (Rang).
,, *tridentata* (Forskål).
,, *uncinata* (Rang).
,, *inflexa* (Lesueur).

HETEROPODA.[2]

Carinaria cristata (Linné).
,, *fragilis*, St. Vincent.
,, *lamarckii*, Peron and Lesueur.
,, *depressa*, Rang.
,, *australis*, Quoy and Gaimard.
,, *galea*, Benson.
,, *cithara*, Benson.
,, *punctata*, d'Orbigny.
,, *gaudichaudii*, Eydoux and Souleyet.
,, *atlantica*, Adams and Reeve.
,, *cornucopia*, Gould.
Atlanta peronii, Lesueur.
,, *turriculata*, d'Orbigny.
,, *lesueurii*, Eydoux and Souleyet.
,, *involuta*, Eydoux and Souleyet.
,, *inflata*, Eydoux and Souleyet.
Atlanta inclinata, Eydoux and Souleyet.
,, *helicinoides*, Eydoux and Souleyet.
,, *gibbosa*, Eydoux and Souleyet.
,, *gaudichaudii*, Eydoux and Souleyet.
,, *fusca*, Eydoux and Souleyet.
,, *depressa*, Eydoux and Souleyet.
,, *rosea*, Eydoux and Souleyet.
,, *quoyana*, Eydoux and Souleyet.
,, *mediterranea*, Costa.
,, *violacea*, Gould.
,, *tessellata*, Gould.
,, *primitia*, Gould.
,, *cunicula*, Gould.
,, *souleyeti*, Smith.
Oxygyrus keraudrenii (Lesueur).
,, *rangii*, Eydoux and Souleyet.

In addition to the shells of the species in the above lists, there are a number of other shells not usually met with in the deeper Globigerina Oozes, which may be recognised as

[1] Pelseneer, Report on the Pteropoda, *Zool. Chall. Exp.*, pt. lxv.
[2] Smith, Report on the Heteropoda, *Zool. Chall. Exp.*, pt. lxxii.

contributing to the formation of a Pteropod Ooze, viz., the shells of *Ianthina*, larval Gasteropods, and the remains of some of the more delicate shells of pelagic Foraminifera, *Candeina nitida*, for instance. In one or two soundings of less than 1500 fathoms far removed from land, the Pteropod, Heteropod, and other delicate shells here referred to, appear to make up fully 30 per cent. of the deposit. In all deposits near continents and islands, where tropical oceanic waters occupy the surface, they are more or less abundant, though not unfrequently their presence is completely masked by the large quantities of other matters making up the deposits. In consequence of this it arises that a Pteropod Ooze formed in shallow water far from land differs very widely from one formed near to a continental shore or around an oceanic island. In oceanic regions the deposit approaches in constitution to a Globigerina Ooze, being, however, more friable and granular, and less homogeneous and uniform, from the presence of these larger shells, but the mineral particles are the same as in a Globigerina Ooze from the same region. Near the coast line the Pteropod deposits resemble the terrigenous deposits in the large number of shore materials and organisms which enter into their composition, the mineral particles being to a great extent the same as in Blue Muds, Green Muds, and Volcanic Muds, or fragments from coral reefs and calcareous organisms from shallow water may make up a large part of the deposit.

In the Tables of Chapter II. 13 samples of Pteropod Ooze are described. These range in depth from 390 fathoms at Station 24 to 1525 fathoms at Station 3, the average being 1044 fathoms.

2	are from depths	less than	500	fathoms.
3	„	from	500 to 1000	„
7	„	„	1000 „ 1500	„
1	„	over	1500	„

The carbonate of lime ranges from 52·22 per cent. in 900 fathoms to 98·47 per cent. in 1240 fathoms, and averages 79·25 per cent. In these samples it is estimated that the carbonate of lime derived from pelagic Foraminifera averages 47·15 per cent. of the whole deposit, that from the bottom-living Foraminifera 3·15 per cent., and from the other organisms, including the Pteropods, Heteropods, and Coccoliths and Rhabdoliths, 28·95 per cent.

Globigerinidæ, *Pulvinulina*, Pteropods, and Coccoliths are present in all cases (13), Miliolidæ, Rotalidæ, Echinoderm fragments, and Rhabdoliths (12), Textularidæ, otoliths of fish, Gasteropods, Heteropods, and Ostracodes (11), Lagenidæ and Lamellibranchs (10), Polyzoa (8), *Dentalium* and Coral fragments (4), Nummulinidæ and Coccospheres (3), and Cirripeds, Alcyonarian spicules, and Cephalopod beaks each in one case.

The residue left on removal of the carbonate of lime is red or brown in the majority of cases, while the deposit itself is white or dirty white in most instances. The average percentage of the residue is 20·75, being complementary to the quantity of carbonate of lime present.

The remains of siliceous organisms in these samples range from 1 per cent. in 6 cases to 20 per cent. in 1525 fathoms, and the average is 2·89 per cent. They consist of Sponge spicules, Radiolaria, Diatoms, casts of Foraminifera, and arenaceous Foraminifera.

The mineral particles are all angular, and range from less than 1 to 10 per cent., the average being 2·85 per cent. In size they vary from 0·06 to 0·10 mm. in diameter, the average being 0·08 mm. These mineral particles consist of magnetite and augite in 11 instances, felspar and hornblende (8), sanidine, volcanic glass, and lapilli (6), plagioclase and mica (5), pumice (4), manganese (3), quartz (2), and olivine, altered mineral particles, and chloritic scales (1).

The fine washings range from a trace in 1240 fathoms to 41·78 per cent. in 900 fathoms, the average being 15·01 per cent.

The average composition of the Challenger samples of Pteropod Ooze is as follows:—

Carbonate of lime,	Pelagic Foraminifera,	47·15	
	Bottom-living Foraminifera,	3·15	
	Other organisms,	28·95	
			79·25
Residue,	Siliceous organisms,	2·89	
	Minerals,	2·85	
	Fine Washings,	15·01	
			20·75
			100·00

By comparing this with the table showing the average composition of Globigerina Ooze on page 218, it will be observed that Pteropod Ooze differs from Globigerina Ooze in the residue being less abundant and, chiefly, in the relatively large percentage of calcareous organisms other than Foraminifera.

The Challenger dredges and trawls brought up pieces of pumice in 4 instances from these deposits, and manganese nodules and organisms coated with manganese in 3 cases, as well as a large number of deep-sea animals.

The following three analyses of samples of Pteropod Ooze are from Station 22, 1420 fathoms, Station 23, 450 fathoms, and Station 24, 390 fathoms.

				Portion soluble in HCl.									Portion insoluble in HCl.	
Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	Ca_32PO_4	$MgCO_3$	Total.		
22	1420	60	3·80	4·14	4·42		...	80·69	0·41	2·41	0·68	92·75	Al_2O_3,Fe_2O_3,SiO_2, . . .	3·45
23	450	61	4·00	2·60	1·80	3·00	...	84·27	1·00	g.tr.	1·28	93·95	Al_2O_3,Fe_2O_3,SiO_2, . . .	2·05
24	390	62	2·00	3·65	0·80	3·06	...	82·66	0·73	2·44	0·76	94·10	Al_2O_3,Fe_2O_3,SiO_2, ...	3·90

In No. 62 the finer parts had been washed away.

These analyses represent the composition of the three deposits as almost identical. In the first place, they are specially characterised by the high percentage of carbonate of lime, much higher than the average percentage in a Globigerina Ooze, which in this case must be attributed to the presence of Pteropod, Heteropod, and other delicate and larger shells, which are absent or rare in the last-named deposit. Having regard to the small quantities of alumina, silica, and iron, there can be but little argillaceous and ferruginous matters present, and the loss on ignition can most probably be referred to the organic matter associated with the calcareous shells. There is nothing special to remark regarding the sulphate and phosphate of lime, and carbonate of magnesia. These have, it is evident, the same origin as in the case of the Globigerina Oozes; it may be noted, however, that the magnesia does not augment with the proportionally great increase of carbonate of lime.[1]

As the soluble portion rises to a mean of more than 93 per cent. of the whole deposit, few anhydrous minerals could be expected in the insoluble portion, and indeed no quantitative analysis has been attempted of the 3 per cent. of which it is made up.

With reference to the Pteropod Ooze, it may be here stated that with the view of determining whether or not these shells contained mineral matters other than carbonate of lime, an analysis was made of a number of the shells of *Cavolinia* taken at the surface of the sea and still containing the animal. After having removed with all possible care the whole of the animal matter, these shells were analysed, and we were able to detect, in addition to the carbonate of lime, only traces of iron and of organic matter.

From all the foregoing considerations, then, we arrive at the conclusion that a Pteropod Ooze differs from a Globigerina Ooze only in the larger percentage of carbonate of lime, and it has already been pointed out that this is due to the greater abundance of the more delicate shells of pelagic organisms.

Pteropod Ooze was found by the Challenger Expedition only in the Atlantic Ocean. It was met with in its most typical form on the central ridges of the Atlantic, where the depths did not exceed 1400 fathoms; in these regions it is estimated to cover about 400,000 square miles of the sea-floor. Had the Challenger been fortunate enough to discover similar ridges far from land in the tropical and subtropical regions of the Pacific, they would in all probability have been found to be covered by Pteropod Ooze. In nearly all cases these shells are very numerous in the shallower depths near tropical lands, but usually they are not in sufficient abundance to give a distinctive character to the deposit, being masked by the large quantity of other more rapidly accumulating materials either of an organic or inorganic nature. In some exceptional cases, however, as off coral reefs and oceanic islands, they are sufficiently abundant to allow of the deposit being called a Pteropod Ooze, for instance, off the Antilles and the Azores in the Atlantic, and off some of

[1] See pp. 200, 201.

the Fiji and other islands of the Pacific. Indeed many inter-tropical islands are apparently surrounded, between depths of 400 and 1400 fathoms, by deposits which might in most cases be called Pteropod Oozes. In northern temperate and polar regions this deposit could not occur, as the shells do not live in the surface waters of these regions in sufficient abundance.

II. *Terrigenous Deposits.*

At the outset of this chapter it was pointed out that all marine deposits might be divided into two great groups, viz., Pelagic and Terrigenous (see pp. 185 and 186). It was likewise stated that the terrigenous deposits were for the most part made up of materials immediately derived from the great land masses, which had been subject, in a greater or less degree, to the mechanical effects of erosion. A very large part of the terrigenous deposits does not, however, fall to be considered in detail in this work, which is limited to a description of deep-sea deposits, or, according to our definition of the term, to those deposits forming in the ocean beyond a depth of 100 fathoms. The terrigenous deposits of the littoral and shallow-water zones surrounding the land are primarily of the same nature as those forming in the deep-sea zone. In consequence, however, of the different physical conditions prevailing in these three zones, the deposits are more diverse, heterogeneous, local, and coarser in the shallower zones than in the deeper one, for the deposits become more and more uniform, homogeneous, fine grained, and widely distributed as the deep water of the ocean basins is approached.

It is well known that fresh water carries a much larger amount of sediment in suspension than salt water, and that wherever a mixture of these waters takes place along the borders of the continents almost the whole of the sediment falls rapidly to the bottom, thus contributing a great mass of material to the terrigenous deposits in process of formation.[1] Murray and Irvine[2] have shown that a considerable quantity of clayey matter can be held in suspension in sea-water, the amount being greater in waters of a low, than in waters of a high, temperature, and they point out that Radiolarians and Diatoms probably obtain their silica from this source. This does not, however, in any way lessen the importance of the fact that the great bulk of detrital matters borne from the land to the ocean is deposited in somewhat close proximity to the coasts. The combined effect of rivers, winds, waves, currents, and tides on the materials of the land and shallow-water areas, is to transport all the fine particles out to depths in which they may fall to the bottom in comparatively still water, and where they may accumulate in the form of various kinds of muds. We have seen that while the depth at which these muds form in enclosed seas

[1] Th. Scheerer, *Pogg. Ann*, Bd. lxxxii. p. 419, 1851; Fr. Schulze, *Ibid.*, Bd. cxxix. p. 368, 1866; Sidell in Abbot and Humphreys' Report on the Mississippi, App. A. No. 2, 1876; Hilgard, *Amer. Journ. Sci.*, ser. iii. vol. xvii. p. 205, 1879; Brewer, "On the Subsidence of Particles in Liquids," *Mem. Nat. Acad. Sci.*, Washington, vol. ii. p. 165, 1883.

[2] "Silica and Siliceous Organisms in Modern Seas," *Proc. Roy. Soc. Edin.*, 1891; see also Chapter VI.

or estuaries may be only a few fathoms, yet along all the continental shores facing the great ocean basins the average depth of the mud-line may be taken at 100 fathoms.

It is then with deposits formed chiefly of the fine detrital matters beyond the 100-fathom line, which are termed deep-sea terrigenous deposits, that we have especially to deal in this place. They are laid down on what may be called the continental slope, or that area of the earth's surface extending from the 100-fathom line down to the depressed level of the ocean basins at an average depth of two and a half miles. At their lower limit they pass gradually into the pelagic deposits without any sharp line of demarcation, and at their upper limit they are continuous with the shallow-water deposits of the continental shelf.

The terrigenous deposits as a whole are estimated to cover an area of 28,662,500 square miles of the ocean's floor, as follows :—

Terrigenous	deep-sea deposits	(laid down on the continental slope beyond 100 fathoms),	18,600,000 sq. m.
,,	shallow-water ,,	(laid down on the continental shelf within 100 fathoms),.	10,000,000 ,,
,,	littoral ,,	(laid down between tide marks), ...	62,500 ,,

Blue Mud.

This name has been adopted for the deposits most frequently met with in the deeper waters surrounding continental land, and in all enclosed or partially enclosed seas more or less cut off from free communication with the open ocean. The materials of which the Blue Muds are principally composed are derived from the disintegration of continental land, and are very complex in character. When collected this deposit is blue or slate coloured, with an upper red or brown coloured layer, which had been in immediate contact with the water. The blue colour is due to organic matter and sulphide of iron in a fine state of division, and these muds have, as a rule, when taken from the sounding tube or dredge, a smell of sulphuretted hydrogen. The red or brown colour of the thin watery upper layer is evidently due to the presence of ferric oxide or ferric hydrate, but as the deposit accumulates this oxide is transformed into sulphide and ferrous oxide in the presence of organic matter in the underlying layers. When dried the deposit becomes grey or brown, owing to the oxidation of the sulphide of iron. Sometimes the samples are homogeneous, at other times the aspect is heterogeneous, owing to the presence of large fragments of rocks and shells and small fragments of calcareous organisms. When wet the deposit may be plastic, and behave like a true clay, but as a rule these muds may be described rather as earthy than as clayey. They may contain from only a trace to 35 per cent. of carbonate of lime.

Among the Challenger deposits described in the Tables of Chapter II. there are 58 examples of Blue Mud. These range from 125 to 2800 fathoms, the average depth being 1411 fathoms.

12	are from depths	less than	500	fathoms.
6	„	from	500 to 1000	„
15	„	„	1000 „ 1500	„
6	„	„	1500 „ 2000	„
20	„	„	2000 „ 2500	„
9	„	over	2500	„

27 of these examples are called blue-grey in colour, and 18 grey.

The carbonate of lime ranges from the merest trace in 2650 fathoms and lesser depths to 34·34 per cent. in 500 fathoms, the average being 12·48 per cent. This would seem to indicate a gradual decrease in the quantity of carbonate of lime with increase of depth, as in the case of purely pelagic deposits, but arranging the percentages in groups of 500 fathoms, it will be seen that there is a marked departure from this rule, as might indeed be expected, considering the varied origin of these coast deposits and the varying amount of river detritus and organic remains in different situations.

Under 500	fathoms,	. .	10·61 average per cent. $CaCO_3$.
From 500 to 1000	„	. .	10·85 „
„ 1000 „ 1500	„	. .	18·94 „
„ 1500 „ 2000	„	. .	9·41 „
„ 2000 „ 2500	„	. .	10·86 „
Over 2500	„	. .	10·53 „

Of the organisms which yield the carbonate of lime in these Blue Muds the pelagic Foraminifera make up on an average 7·52 per cent., the bottom-living Foraminifera 1·75 per cent., and other carbonate of lime remains 3·21 per cent. In some cases the pelagic Foraminifera make up as much as 25 per cent. of the whole deposit, while in others no trace of them can be detected. The bottom-living Foraminifera may make up 10 per cent., and, again, the other calcareous remains 16 per cent. of the deposit. The shells of pelagic species, which make up so large a part of a Globigerina Ooze, are not abundant nor universally distributed in the Blue Muds, the remains of shallow-water or bottom-living organisms predominating in many cases. The organisms most frequently mentioned are the shells of Globigerinidæ, Rotalidæ, Lagenidæ, Miliolidæ, Textularidæ, Nummulinidæ, Lamellibranchs, Gasteropods, Ostracodes, Echinoderm fragments, Coccoliths, and Rhabdoliths.

The residue left after treating the deposits with dilute hydrochloric acid is chiefly brown or grey; in 19 cases it was a shade of brown, in 15 a shade of grey, in 7 it was green, and in 5 it was blue. In 9 cases there was no carbonate of lime or only traces, and consequently no residue apart from the deposit itself. The mean percentage of residue is 87·52, and the range with respect to depth is the reverse of that given for the carbonate of lime.

With reference to the siliceous organisms in the Blue Muds, these are estimated in the Tables as ranging from 1 per cent. in several instances to 15 per cent. in two cases, the average for the whole being 3·27 per cent. These organic remains consist of the frustules of Diatoms, Radiolarians, Sponge spicules, arenaceous Foraminifera, and casts of the carbonate of lime organisms in glauconite or some allied silicate.

The mineral particles are mostly derived from the adjacent lands, and consist largely of the fragments and minerals of the various rocks forming the continents. The size of the mineral and rock particles varies much with the position; they are as a rule larger near the shore, and smaller as the deep sea is approached, except in those regions affected by floating ice. More than half of the deposit is in many cases made up of the mineral particles, consisting largely of rounded grains of quartz.

In the Challenger samples the mineral particles are stated to be angular in 32 cases, rounded in 3 cases, and in 21 cases to be angular and rounded. The size varies from 0·06 to 0·30 mm. in diameter, and the average diameter is 0·115 mm. The percentage is very variable, ranging from 1 per cent. in several cases to 75 per cent. in one instance, the mean percentage being 22·48.

It may be noticed here that quartz particles, which are relatively rare, not discernible, or absent in typical pelagic deposits, are the most abundant among the mineral particles of these terrigenous deposits, which are further characterised by the presence of particles of older crystalline or schisto-crystalline rocks, quartzite, sandstones, limestones. Among the minerals we observe, besides quartz, orthoclase and plagioclase, green hornblende, augite, white and black mica, epidote, chloritic scales, zircon, tourmaline, &c. Glauconite cannot be considered characteristic of Blue Muds, but is to be found in nearly all of them, though in limited quantity compared with what is met with in those other terrigenous deposits called Green Muds.

The fine washings range from 16·11 per cent. to 97·00 per cent., the average being 61·77 per cent. The fine washings in the Blue Muds are probably always less abundant than in the Red Clays and Radiolarian Oozes.

The following table is arranged to show the average percentage of the minerals and fine washings, as also the average size of the mineral particles, for successive groups of 500 fathoms:—

	Minerals.	Size.	Fine Washings.
Under 500 fathoms, . .	29·08	0·137 mm.	53·22
500 to 1000 „ . .	30·18	0·102 „	56·48
1000 „ 1500 „ . .	19·77	0·118 „	58·29
1500 „ 2000 „ . .	23·33	0·115 „	62·25
2000 „ 2500 „ . .	18·00	0·119 „	66·23
Over 2500 „ . .	16·89	0·087 „	69·46

It will be noticed that the fine washings increase with the depth, while the abundance of mineral particles and their mean diameter are irregular, though on the whole they diminish in size and abundance with greater depth and greater distance from land, where the sea is not affected by floating ice. It must be noticed also that in the neighbourhood of some continental shores, where there are many volcanic rocks, the deposits are made up to a great extent of the disintegrated parts of these rocks, and thus cannot be distinguished from the Volcanic Muds formed around volcanic islands.[1]

The following table shows the average composition of the Challenger samples of Blue Mud, and it will be seen that, compared with the similar table for Red Clay, the percentage of minerals is much higher and the fine washings less abundant :—

Carbonate of lime,	Pelagic Foraminifera,	7·52	
	Bottom-living Foraminifera,	1·75	
	Other organisms,	3·21	
			12·48
Residue,	Siliceous organisms,	3·27	
	Minerals,	22·48	
	Fine washings,	61·77	
			87·52
			100·00

The following are analyses of two samples of Blue Mud, one from the Pacific, the other from the Atlantic :—

				Portion soluble in HCl.									Portion insoluble in HCl.					
Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	Ca_32PO_4	$MgCO_3$	Total.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
213	2050	63	4·92	23·52	7·75	7·50	g. tr.	1·75	0·58	tr.	1·14	42·24	30·84	7·33	3·73	1·63	0·31	52·84
323	1900	64	5·60	28·20	5·50	5·61	...	2·94	0·42	1·39	0·76	44·82	36·00	8·05	2·77	2·51	0·25	49·58

No. 63 is of material obtained from the trawl, No. 64 from tow-net at trawl.

These two analyses show a striking difference when compared with those of pelagic deposits. The quantity of insoluble residue is much greater than the average in deposits from similar depths further removed from land, for it will be seen that it makes up in these two cases about one-half of the deposits. This indicates a higher percentage of mineral particles not decomposable by hydrochloric acid, and may be attributed to the presence of the minerals and rocks from continental lands, in which quartz plays the most important part, thus being in accord with what we have just said as to the origin of this deposit. In the portion soluble in acid we have the hydrated silicate of alumina and ferric oxide, but in these two analyses the percentages of these substances are less than

[1] See Pl. XI. fig. 2 ; Pl. XXVII. fig. 4.

the average found in a Red Clay. The excess of silica must, as in the other deposits, be attributed to the presence of siliceous organisms. The carbonate of lime is due, as in pelagic deposits, to the shells of calcareous organisms; the presence of carbonate of magnesia and sulphate and phosphate of lime is to be interpreted in the same manner as in the case of these substances in the pelagic deposits.[1] In the insoluble portion the excess of silica must be attributed to quartz, but besides there are present anhydrous silicates, which microscopic examination showed to be monoclinic and triclinic felspars, mica, augite, magnetite, hornblende, and the debris of pumice.

An additional analysis of a sample of the Blue Mud from Station 323, in 1900 fathoms, gave the following results:—

Station.	Depth in Fathoms.	No.	SiO_2	Al_2O_3	Fe_2O_3	Phosphoric and Sulphuric Acids.	CaO	MgO	K_2O	Na_2O	Loss on Ignition.	Total.
323	1900	65	59·54	19·42	7·15	traces.	1·68	1·93	1·35	2·68	6·24	99·99

If this analysis be compared with the preceding one from the same station, some differences will be perceived, the total amount of silica in analysis No. 64 being 64·20 per cent., and in No. 65, 59·54 per cent.; alumina, 13·55 per cent. and 19·42 per cent. Although the general result may lead in the two cases to the same interpretation as to the essential mineralogical composition of the deposit, these divergences show how much different samples of the deposit may vary even from the same dredging, and how difficult it is to pronounce upon the mineral nature of a deposit solely by chemical analysis. The variations in the composition of the deposit from the same trawling or dredging may arise from some portions being from deeper layers than others, or from differences of depth and position when the instrument was being dragged over several miles. The mode of collection and preservation, by separating the finer and coarser parts of the same sample, may also give rise to differences in the analyses. This remark may be applied to all the deposits, as already stated, but particularly to the terrigenous deposits which, according to the conditions of formation, are seldom so homogeneous as the pelagic deposits.

The Blue Muds surround nearly all coasts and fill nearly all enclosed seas, like the Mediterranean, and even the Arctic Ocean; of all the terrigenous deposits they occupy by far the largest area of the earth's surface, being estimated to cover about 14,500,000 square miles, of which the Arctic Ocean would contain about four millions of square miles, the Pacific three millions, the Atlantic two millions, the Indian one and a half millions, the Southern one and a half millions, and the Antarctic about two and a half millions of square miles. The geographical position of these muds is represented on Chart 1.

[1] See pp. 200, 201.

Red Mud.

Along the Brazilian coast of South America the terrigenous deposits off shore are different from the deposits found in similar positions along other continents, in that they are all of a red-brown or brick-red colour, in place of blue or green coloured, as is usually the case. The red colour of the deposits appears to be produced by the large quantity of ochreous matter carried into the ocean by the Amazon, Orinoco, and other South American rivers, and distributed by oceanic currents along these coasts. Although organic matters are probably as abundant in these as in the deposits along other coasts, still they do not seem to be sufficient to reduce the whole of the peroxide of iron to the state of protoxide, nor does sulphide of iron accumulate here as in the case of the Blue Muds, in both of which respects these Red Muds resemble the Red Clays of the abysmal regions. It is a remarkable fact that we do not find in these red deposits a trace of the green coloured glauconitic casts of Foraminifera and other calcareous organisms, nor any of the glauconite grains which usually accompany these casts in other terrigenous deposits. There are a few spicules of siliceous Sponges, but frustules of Diatoms and the remains of Radiolarians are exceedingly rare, or wholly absent. As regards the calcareous organisms, and mineral particles other than glauconite, they do not appear to differ from those present in the Blue or Green Muds.

Of these Red Muds 10 samples are described in the Tables of Chapter II. These are from depths varying from 120 to 1200 fathoms, the average depth being 623 fathoms.

3	are from	less than	500	fathoms.
5	,,	between	500 and 1000	,,
2	,,	over	1000	,,

In colour they are all red-brown. The carbonate of lime in these samples ranges from 5·75 to 60·79 per cent., the average being 32·28 per cent. The amount of carbonate of lime in the different samples is more in relation to the nearness or distance from the mouths of rivers than to the depth from which the samples were taken. The carbonate of lime derived from the shells of pelagic Foraminifera ranges from 3 to 30 per cent., the average being 13·44 per cent.; that derived from bottom-living Foraminifera ranges from 1 to 8 per cent., and averages 3·33 per cent.; that from other organisms ranges from 1·75 to 40·75 per cent., the average being 15·51 per cent.

The residue is in all cases reddish brown or yellow; it ranges from 39·21 to 94·25 per cent. of the whole deposit, the average being 67·72 per cent. Siliceous organisms are relatively very rare, and in no case are they estimated to make up more than 1 per cent. of the whole deposit; they consist almost exclusively of Sponge spicules and a few arenaceous Foraminifera. With some doubtful exceptions, Diatoms were not observed during the examination of these deposits.

The mineral particles range from 10 to 25 per cent., the average being 21·11 per cent. The particles are rounded and angular; in size they vary from 0·07 to 0·30 mm. in diameter, the average being 0·15 mm. Quartz is the most abundant mineral, and the other minerals are similar to those found in the other terrigenous deposits along continental shores.

The fine washings range from 28·21 to 68·25 per cent., the average being 45·61 per cent.

By arranging the amount of minerals, their size, and the fine washings according to depth, it is seen that the mineral particles are larger and the amount of fine washings less in the shallower depths.

	Minerals.	Size.	Fine Washings.
Under 500 fathoms, .	20 per cent.	0·30 mm.	33·37 per cent.
500–1000 „ .	20 „	0·126 „	49·04 „
Over 1000 „ .	25 „	0·075 „	49·24 „

The following table shows the average composition of the Challenger samples of Red Mud:—

Carbonate of lime,	Pelagic Foraminifera, ...	13·44	
	Bottom-living Foraminifera, . . .	3·33	
	Other organisms, ...	15·51	
			32·28
Residue, . .	Siliceous organisms, ...	1·00	
	Minerals, ...	21·11	
	Fine washings, ...	45·61	
			67·72
			100·00

The following analysis was made to determine the chemical composition of a Red Mud, from Station 120, 675 fathoms:—

Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	CO_2	Cl.	Total.
120	675	54	6·02	31·66	9·21	4·52	25·68	2·07	1·63	1·33	0·27	17·13	2·46	101·98

In combining the carbonic acid with the oxide of calcium indicated by the analysis we obtain 38·93 per cent. of carbonate of calcium, with an excess of oxide of calcium, which may come from the silicates containing lime, or from the phosphate and sulphate of lime. There must be, according to the analysis, a relatively large quantity of argillaceous matter and hydrated peroxide of iron in the deposit, and free silica in the form of quartz or hydrated silica from organic remains. The presence of alkalies indicates that alkaline silicates are among the minerals, as indeed was shown by microscopic analysis, but a good deal of the percentage of alkalies must be referred to the presence of sea-salts retained in the deposits, as is shown by the following experiment.

In speaking of the analyses of Red Clay and Globigerina Ooze, it was pointed out that, in their examination, the sea-salts that might be retained in the deposits should be taken into account. In order to arrive at an approximate notion on this point, the following determinations were made with a specimen of the Red Mud from Station 120, 675 fathoms, of which we have just given the analysis. The substance was washed with warm and cold distilled water till the water no longer gave the reaction of chlorine. It was afterwards pulverised and treated with hydrofluoric and sulphuric acids. 1·4088 grms. of substance dried at 100° C. gave 0·0496 grm. of chloride of sodium and potassium, and 0·1013 grm. of chloroplatinate of potassium, which corresponds to 0·0195 grm. of oxide of potassium and 0·0099 grm. of oxide of sodium—

[No. 55.]	Na_2O	0·70 per cent.
	K_2O	1·38 „

In comparing this analysis with that given above, so far as regards the alkalies, it will be seen that there is about 1 per cent. more oxide of sodium in the unwashed than in the washed sample, which is doubtless due to the presence of chloride of sodium.

The Red Muds probably occupy along the Brazilian coast about 100,000 square miles of the sea-bed. Similar red deposits are formed in the Yellow Sea off the Chinese coast near the mouth of the Yang-tse-kiang.

Green Muds and Sands.

In their composition, origin, and distribution these deposits resemble in many respects the Blue and Red Muds. Their chief characteristic is the presence in them of a greater or less abundance of glauconitic grains and glauconitic casts of the calcareous organisms. There is also in these muds, mixed with glauconite, a greenish amorphous matter, which in part at least appears to be of an organic nature, for it blackens on being heated on platinum foil, leaving an ash coloured by oxide of iron. These muds and sands are almost always developed along bold and exposed coasts, where no very large rivers pour their detrital matters into the sea.

The collections of the "Tuscarora" indicate that in depths of 100 to 400 fathoms, off the coast of California, there are black sands which, if the specimens be in the state in which they were collected, are almost wholly composed of particles of dark green glauconite. The average diameter of the grains is about 0·6 mm., and mixed with them are a few Foraminifera and mineral particles of the same dimensions. It is rare, however, to find pure glauconitic sands like these, for the deposits contain, as a rule, many remains of calcareous organisms, mineral particles from the continental rocks, and a considerable quantity of clayey matter. This fine clayey or detrital matter appears always to be less abundant than in a characteristic Blue Mud. These Green Muds and Sands do not occur in very deep water; deposits which may be classed under this head are usually met with between the depths of 100 and 900 fathoms. It is true that glauconite is found in both lesser and greater depths than these, but not in sufficient abundance to constitute a Green Mud or Sand. Along coasts where Green Muds are laid down pelagic conditions appear to approach much nearer to the shores than where the Blue Muds prevail; to such an extent is this the case, that were it not for the presence of glauconite and the nature of the mineral particles, many of the Green Muds might equally well be called Globigerina Oozes.

Whenever there is a large quantity of ferric hydrate in a terrigenous deposit, as off the Brazilian shores, or whenever the deposit is chiefly made up of river detritus that bears evidence of having accumulated at a rapid rate, glauconitic matter is either absent or only developed to a very small extent, and, as has already been pointed out, it is rare or absent in pelagic deposits. On the other hand, when there is a large number of the fragments of ancient rocks that have apparently been for a long time exposed to the action of sea-water, and have consequently undergone much alteration, then glauconitic grains and glauconitic casts of the calcareous organisms are usually abundant; phosphatic concretions are also found in the same positions, and there is always evidence of other organic matters. These conditions are as a rule met with along high and bold coasts removed from the embouchures of large rivers, as has already been stated.

Green Muds.—In the Tables of Chapter II. there are described 22 samples of Green Mud. The depths range from 100 to 1270 fathoms, the average being 513 fathoms.

13	are from less than		500	fathoms.
6	,,	depths between	500 and 1000	,,
3	,,	over	1000	,,

In the majority of cases the colour is green, or a tinge of green; two samples are described as of a grey colour.

The carbonate of lime ranges from a trace in several cases to 56·18 per cent., the average being 25·52 per cent. In depths under 500 fathoms the mean percentage is 23·92, from 500 to 1000 fathoms it is 25·77, and in depths over 1000 fathoms, 32·73, so that there is an increase of carbonate of lime with increasing depth and distance from the shore. The carbonate of lime derived from the shells of pelagic Foraminifera ranges from 1 to 35 per cent., the average being 14·59 per cent.; that derived from bottom-living Foraminifera ranges from 1 to 15 per cent., the average being 2·94 per cent.; that derived from the remains of other organisms ranges from 1 to 31·18 per cent., and averages 7·99 per cent.

The residue of the Green Muds, after the removal of the carbonate of lime, ranges from 43·82 to 100 per cent., the average being 74·48 per cent., and is of a distinct green colour.

The siliceous organisms range from 1 to 50 per cent., the average being 13·67 per cent., and consist of the remains of Diatoms, Radiolaria, Sponge spicules, arenaceous Foraminifera, and the glauconitic casts of the calcareous organisms.[1]

The mineral particles range from 1 to 80 per cent. of the whole deposit, the average being 27·11 per cent. With the exception of the glauconite grains they are mostly angular, varying in diameter from 0·06 to 0·20 mm., the average being 0·13 mm. Quartz, monoclinic and triclinic felspars, magnetite, hornblende, and augite are the most abundant, but the presence in these Green Muds of tourmaline, zircon, and garnet is very characteristic, and we may say the same of the fragments of continental rocks which are also very frequent.[2] It may be noticed that in the Green Sands there are frequently nodules and smaller concretions of phosphate of calcium.[3]

The fine washings vary from 9·69 to 84·05 per cent., the average being 33·70 per cent.

The following table gives the average percentage of minerals and fine washings and the average size of the minerals allocated to depth :—

	Minerals.	Size.	Fine Washings.
Under 500 fathoms, . .	29·60 per. cent.	0·145 mm.	24·17 per cent.
From 500 to 1000 fathoms, .	26·16 ,,	0·126 ,,	44·89 ,,
Over 1000 fathoms, . .	17·50 ,,	0·100 ,,	47·76 ,,

It will be seen that the percentage of minerals and the size decrease with increase of depth, while the percentage of fine washings increases.

In the dredge pumice was obtained in two cases, pebbles in one, and hardened pieces of the bottom in one case.

The following shows the average composition of the Challenger samples of Green Mud :—

Carbonate of lime,	Pelagic Foraminifera, ...	14·59	
	Bottom-living Foraminifera, ...	2·94	
	Other organisms, ...	7·99	
			25·52
Residue, . .	Siliceous organisms, ...	13·67[4]	
	Minerals, ...	27·11	
	Fine washings, ...	33·70	
			74·48
			100·00

[1] See Pl. XXV. [2] See Pl. XXVI. [3] See Pl. XX. fig. 1.

[4] The larger number of siliceous organisms compared with these in Blue and Red Muds (see pp. 232 and 235) is due to the glauconitic casts of the Foraminifera.

Green Sands.—In addition to the deposits called Green Muds in the Tables of Chapter II., there are 7 samples which have been called Green Sands. These differ from the Green Muds chiefly in being more granular in appearance, owing to the relatively small quantity of amorphous matter present in them. They are found usually in shallower water than the muds, and in positions where the particles are occasionally at least set in motion by the action of waves and currents. All these samples are from depths less than 900 fathoms, the average depth being 449 fathoms. The average percentage of carbonate of lime in these Green Sands is 49·78;—21·00 per cent. of this derived from pelagic Foraminifera, 15 per cent. from bottom-living Foraminifera, and 13·78 per cent. from the remains of other calcareous organisms—being thus much higher than in the Green Muds.

The residue is greenish in colour, and makes up 50·22 per cent. of the whole deposit. The siliceous organisms average 8 per cent., due to the presence of glauconitic casts of calcareous organisms, while the mineral particles average 30 per cent., and the fine washings 12·22 per cent. The average size of the mineral particles is 0·2 mm., somewhat larger than in the Green Muds.

The following shows the average composition of the Challenger samples of Green Sand:—

Carbonate of lime,	Pelagic Foraminifera,	21·00	
	Bottom-living Foraminifera,	15·00	
	Other organisms,	13·78	
			49·78
Residue,	Siliceous organisms,	8·00	
	Minerals,	30·00	
	Fine washings,	12·22	
			50·22
			100·00

The following analyses are of two of the best examples of a Green Sand and a Green Mud met with during the Expedition, the one being from Station 164B, in 410 fathoms, off the coast of Australia, the other from Station 141 in 98 fathoms, off the Cape of Good Hope:—

				Portion soluble in HCl.								Portion insoluble in HCl.					
Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$CaSO_4$	Ca_32PO_4	$MgCO_3$	Total.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
141	98	66	9·10	8·35	2·30	4·70	49·46	1·07	tr.	2·02	67·90	21·35	0·95	0·35	0·22	0·13	23·00
164B	410	67	3·30	9·28	2·50	12·30	46·36	0·58	0·70	0·57	72·29	21·99	1·58	0·42	0·30	0·12	24·41

No. 67 is of material from the dredge.

In the first place, there is to be noted the relatively high percentage of carbonate of lime, much higher than what is usually met with in a Blue Mud, this being due, as has just been pointed out, to the presence of pelagic shells, which here approach nearer to the coasts than where blue mud deposits prevail. The insoluble portion, it will be seen from the analyses, must be almost exclusively made up of grains of quartz, since the alumina, the iron, the lime, and magnesia do not form more than a small fraction of this insoluble residue. The high percentage of insoluble silica shows that the mineral particles come from continental rocks, and not, as in the case of typical pelagic formations, from the disintegration of volcanic products. The felspar fragments indicated by the microscopical examination are also derived from ancient crystalline rocks, in which potash is a dominant base, and which doubtless furnish by their alteration one of the necessary elements in the constitution of glauconite, so characteristic of these Green Muds. We will refer to this fact in the chapter on the mineralogical composition and mode of formation of glauconite.

The Challenger met with Green Muds and Sands off the coast of Portugal, off the east coast of North America, off the Cape of Good Hope, off the coasts of Australia, Japan, and South America. By other expeditions they have been discovered off the Californian coast of America, off the eastern coast of Africa, and in many other regions. The Green Muds and Sands would appear to form an interrupted band along many continental shores at the upper edge of the continental slope, and the estimated area occupied by these deposits is about 1,000,000 square miles of the sea-bottom, including those occurring in the shallow-water zone in depths less than 100 fathoms.

Volcanic Muds and Sands.

Around oceanic islands of volcanic origin the deposits consist in a large measure of the rocks and minerals arising from the disintegration of the volcanic rocks of the islands. Near shore, within the region of wave action, these are largely sands, composed of volcanic material and the fragments of calcareous organisms, the mean diameter of which may be from 0·5 mm. to several millimetres according to situation. In deeper water, further from the islands, the mineral particles become less abundant and smaller, while pelagic organisms, such as *Globigerina* shells, Coccoliths and Rhabdoliths, and Pteropod shells, increase in number, so that the deposit assumes the character of a mud in which there is a considerable quantity of clayey and calcareous matter. They are light grey, brown, or black in colour, and have an earthy rather than a clayey character. These deposits may be found along any coast where volcanic rocks prevail, but they are characteristically developed around the volcanic islands of the great ocean basins. In general appearance and composition they present great variety, depending on position, depth, and the organic remains that take part in their formation. In some regions they pass insensibly into Blue and Green Muds, in others into Coral Muds and Sands, or with increasing depth into Globigerina, Pteropod, and Diatom Oozes or Red Clays—their chief characteristic being the relative abundance of volcanic materials.

Volcanic Muds.—There are 38 examples of Volcanic Muds among the Challenger soundings and dredgings, described in the Tables of Chapter II. In depth these range from 260 to 2800 fathoms, the average depth being 1033 fathoms. Of these—

9	are under	500				fathoms.
13	,,	from	500	to	1000	,,
7	,,	,,	1000	,,	1500	,,
3	,,	,,	1500	,,	2000	,,
2	,,	,,	2000	,,	2500	,,
4	,,	over	2500			,,

The colour of these deposits was in the majority of cases brown or grey. In depths between 2000 and 2800 fathoms there was only a trace of carbonate of lime, but in one sample from 260 fathoms there was 56·59 per cent., the average percentage in these Volcanic Muds being 20·49. Arranged in groups of 500 fathoms, the mean percentages of carbonate of lime are as follows:—

In less than 500	fathoms,	. .	24·69 average per cent. $CaCO_3$.
From 500 to 1000	,,	. .	26·04 ,, ,,
,, 1000 ,, 1500	,,	. .	20·34 ,, ,,
,, 1500 ,, 2000	,,	. .	31·30 ,, ,,
,, 2000 ,, 2500	,,	. .	trace.
Over 2500	,,	. .	trace.

The carbonate of lime derived from pelagic Foraminifera is in some cases as high as 35 per cent., the average being 10·50 per cent.; that from bottom-living Foraminifera ranges as high as 10 per cent., the average being 2·82 per cent.; that from the remains of other organisms ranges to 21·59 per cent., and averages 7·17 per cent.

The amount of residue varies from 43·41 to nearly 100 per cent., averaging 79·51 per cent., and is usually brown or black. The siliceous organisms range from 1 to 5 per cent., the average being 1·82 per cent., and consist of Radiolaria, Sponge spicules, Diatoms, and arenaceous Foraminifera. True glauconitic casts or characteristic glauconitic grains have not been observed in typical Volcanic Muds.

The mineral particles make up from 5 to 75 per cent. of the whole deposit, the average being 40·82 per cent. The particles are nearly always angular, and have a mean diameter of 0·11 mm., the range being from 0·06 to 0·20 mm. Quartz is mentioned only once and glauconite twice, but, as above stated, typical glauconite grains may be said to be absent.

The fine washings vary from 15·37 to 60·70 per cent., the average being 36·87 per cent.

The following table shows the average percentages of minerals and fine washings and the average size of the mineral particles, arranged in groups of 500 fathoms, and it will be observed that there is no definite relation between the size and abundance of either of these and the depth :—

	Minerals.	Size.	Fine Washings.
Under 500 fathoms,	42·00 per cent.	0·126 mm.	31·51 per cent.
From 500 to 1000 „	27·22 „	0·09 „	45·07 „
„ 1000 „ 1500 „	55·00 „	0·11 „	23·49 „
„ 1500 „ 2000 „	28·33 „	0·09 „	38·70 „
„ 2000 „ 2500 „	45·00 „	0·20 „	52·00 „
Over 2500 „	57·00 „	0·125 „	40·00 „

The following table shows the average composition of the Challenger samples of Volcanic Mud :—

Carbonate of lime,	Pelagic Foraminifera,	10·50	
	Bottom-living Foraminifera,	2·82	
	Other organisms,	7·17	
			20·49
Residue,	Siliceous organisms,	1·82	
	Minerals,	40·82	
	Fine washings,	36·87	
			79·51
			100·00

Volcanic Sands.—Within depths of 500 fathoms there are in the Tables of Chapter II. 7 samples which are called Volcanic Sands. These sands are found in positions where the particles making up the deposit are set in motion by the action of waves and currents, so that the finer materials are carried away into deeper or stiller water. It thus arises that these sands differ from the Volcanic Muds chiefly in the absence of the fine clayey and calcareous matter so abundant in the muds. The seven samples above referred to range from 100 to 420 fathoms, the average depth being 243 fathoms. The percentage of carbonate of lime in these samples ranges from 6·93 to 71·65, the average being 28·79. Of this carbonate of lime the proportion due to the presence of the shells of pelagic Foraminifera is estimated to range from 2 to 50 per cent., the average being 13 per cent.; that derived from the shells of bottom-living Foraminifera ranges from 1 to 5 per cent., and averages 3·80 per cent.; that due to the presence of other organisms varies from 2·93 to 16·65 per cent., the average being 11·99.

The residue of these sands is black or brown in colour, and makes up from 28·35 to 93·07 per cent. of the whole of the deposit, the average being 71·21 per cent.

The siliceous organisms range from 1 to 3 per cent., averaging 1·40 per cent.

The mineral particles consist of angular and rounded particles with a mean diameter of 0·34 mm. They make up from 25 to 80 per cent. of these sands, the average percentage being 60.

The fine washings vary from 2·35 to 18·86 per cent., the average being 9·81 per cent.

The following table gives the average percentage composition of the Challenger samples of Volcanic Sand, and comparison with the similar table given for the Volcanic Muds shows the difference to consist chiefly in the larger number of mineral particles and the less abundance of the fine washings.

Carbonate of lime,	Pelagic Foraminifera,	13·00	
	Bottom-living Foraminifera,	3·80	
	Other organisms,	11·99	
			28·79
Residue,	Siliceous organisms,	1·40	
	Minerals,	60·00	
	Fine washings,	9·81	
			71·21
			100·00

The mineral fragments in these muds and sands are variable as to their nature, being determined by the mineralogical composition and structure of the volcanic rocks or volcanoes in the neighbourhood of which they are formed. The most characteristic are sanidine, plagioclases, augite, hornblende, rhombic pyroxenes, olivine, and magnetite. Among the lapilli the most frequent are those belonging to the basaltic and andesitic series of rocks, especially those belonging to the vitreous varieties, and they are often decomposed into palagonitic matter. The pumice fragments usually present may, from the manner in which pumice floats, be derived from distant sources, and from the lands in the immediate neighbourhood of the deposit. Generally the fragments of minerals enumerated above are more or less enveloped by vitreous matter frequently altered by hydration. These points will be dealt with in greater detail when describing specially the rocks and minerals of marine deposits.

The following table gives the analyses of three Volcanic Muds :—

				Portion soluble in HCl.									Portion insoluble in HCl.					
Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	Ca_32PO_4	$MgCO_3$	Total.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
VIIn.	640	68	4·94	10·76	5·91	7·02	...	35·68	1·05	0·52	2·04	62·98	19·17	4·30	5·38	2·58	0·65	32·08
VIIr.	1750	69	6·30	11·71	5·71	7·14	...	41·43	1·15	g. tr.	1·43	68·57	15·84	3·71	3·43	1·43	0·72	25·13
VIII.	620	70	6·22	16·22	5·00	11·69	tr.	32·22	0·27	l. tr.	0·83	66·23	17·90	4·22	3·77	1·44	0·22	27·55

The soluble portion may be considered as formed of hydrated silica, argillaceous matters, ferruginous materials, and especially of carbonate of calcium derived from the debris of organisms, as in the case of the other deposits previously described. The result most clearly brought out from an examination of these analyses is that obtained from a consideration of the insoluble materials. Taking into account the percentages of the various bases, and remembering the silicates present in these Volcanic Muds, it is very easily seen that the insoluble silica must be combined with the alumina, ferric oxide, lime, magnesia, and alkalies, but as the alkalies have not been estimated, it is impossible to carry these deductions further. However, the analyses support the conclusions arrived at from the microscopic examination of these sediments, which shows the existence of a large quantity of silicates of recent volcanic origin, and that quartz, if present, plays but a very subordinate part.

The Volcanic Muds and Sands are found around all the oceanic volcanic islands and off those coasts where volcanic rocks occur; they are estimated to cover an area of about 750,000 square miles, in which is included the area of the islands themselves.

Coral Muds and Sands.

Just as around volcanic islands the deposits are principally made up of the debris from volcanic rocks, so off coral islands and coral reefs the deposits are chiefly made up of the fragments of organisms living in the shallow waters and on the reefs, such as calcareous Algæ, Corals, Molluscs, Polyzoa, Annelids, Echinoderms, and Foraminifera. These fragments form a coarse sand or gravel in the shallower waters, but beyond the limits of wave action there is a fine mud consisting principally of triturated particles of calcareous matter. With greater depth and increasing distance from the land, Pteropod and Heteropod shells, as well as pelagic Foraminifera, make up more and more of the deposit, till the Coral Muds and Sands pass finally into a Pteropod Ooze or Globigerina Ooze, in which reef fragments can with difficulty be recognised. The pelagic organisms are, then, with difficulty detected in the deposits close to the reefs, and reef fragments are rare in the deeper deposits at a considerable distance from the shallow water around coral reefs or islands. This transition in the character of the deposits from the reef-edge to the deeper water of the open sea, is illustrated in the figures on Plates XIII. and XIV., where the deposits at various depths around the island of Bermuda and off the Fiji and Friendly Islands are figured.

Coral Muds.—There are 16 Coral Muds described in the Tables of Chapter II., ranging in depth from 140 to 1820 fathoms, the average being 740 fathoms.

9	are from depths	under	500	fathoms.
1	,, ,,	of	500 to 1000	,,
3	,, ,,	,,	1000 ,, 1500	,,
3	,, ,,	over	1500	,,

In colour the muds are of various shades of white, due to the large amount of carbonate of lime, which ranges from 77·38 per cent. in 1500 fathoms to 89·68 per cent. in 380 fathoms, the average being 85·53 per cent. The following shows the average percentage of carbonate of lime at various depths, arranged in groups of 500 fathoms, and it will be observed that there is little or no relation to depth :—

Under 500	fathoms,	.	87·34 mean per cent. $CaCO_3$
From 500 to 1000	„	.	89·36 „
„ 1000 „ 1500	„	.	84·59 „
Over 1500	„	.	82·78 „

The carbonate of lime derived from pelagic Foraminifera ranges from 10 to 56 per cent., and averages 31·27 per cent.; that derived from bottom-living Foraminifera ranges from 2 to 40 per cent., the average being 14·64 per cent.; that derived from other organisms varies from 26·31 to 59·68 per cent., and the mean percentage is 39·62.

The residue is always of a brown or reddish colour, and varies from 10·32 to 22·62 per cent., the average being 14·47 per cent. This residue consists of clayey matter, oxides of iron, and mineral particles, generally of volcanic origin, together with a few siliceous organisms.

Siliceous organisms do not make up more than 1 or 2 per cent. of the whole deposit, the average in the above samples being 1·36 per cent. Sponge spicules are always present, and Diatoms and Radiolaria can generally be recognised during the examination of a sample.

The mineral particles are estimated in each of the above samples to make up 1 per cent.; they are always angular, and have an average diameter of 0·07 mm.

The fine washings vary from 8·32 to 20·62 per cent., the average being 12·11 per cent.

Arranged in groups of 500 fathoms, the following table shows the estimated average amount of fine washings and minerals, and the mean diameter of the latter; it will be noticed that no relation to depth is indicated except the greater abundance of fine washings in deep water :—

		Minerals.	Size.	Fine Washings.
Under 500	fathoms, .	1 per cent.	0·065 mm.	9·96 per cent.
From 500 to 1000	„ .	1 „	0·060 „	8·64 „
„ 1000 „ 1500	„ .	1 „	0·077 „	13·41 „
Over 1500	„ .	1 „	0·067 „	14·88 „

The following shows the average composition of the Challenger samples of Coral Mud :—

Carbonate of lime,	Pelagic Foraminifera,	31·27	
	Bottom-living Foraminifera,	14·64	
	Other organisms,	39·62	
			85·53
Residue,	Siliceous organisms,	1·36	
	Minerals,	1·00	
	Fine washings,	12·11	
			14·47
			100·00

Coral Sands.—In addition to the Coral Muds, there are 5 samples that are called Coral Sands in the Tables of Chapter II. These scarcely differ from the Coral Muds in composition except in the fact that the more finely divided calcareous matter is less abundant than in the Coral Muds, and the fragments of calcareous organisms are on the whole larger. These sands are indeed met with in positions where we have reason to believe that the particles composing the deposit are frequently set in motion by the action of waves or currents, being found in depths of less than 300 fathoms, the average depth of the above samples being 176 fathoms. Their colour is white or dirty white.

The average percentage of carbonate of lime in the samples is 86·84. The carbonate of lime derived from pelagic Foraminifera averages 36·25 per cent., from bottom-living Foraminifera 20 per cent., and from the remains of other organisms 30·59 per cent.

The siliceous organisms and mineral particles are more abundant than in the Coral Muds, but on the other hand the proportion of fine washings in the residue is much less.

The following shows the average composition of the Challenger samples of Coral Sand:—

Carbonate of lime,	Pelagic Foraminifera,	36·25	
	Bottom-living Foraminifera,	20·00	
	Other organisms,	30·59	
			86·84
Residue,	Siliceous organisms,	5·00	
	Minerals,	3·75	
	Fine washings,	4·41	
			13·16
			100·00

The following analysis of a Coral Sand from Station 172, 18 fathoms, off Tongatabu, shows the usual composition:—

Station.	Depth in Fathoms.	No.	CaO	MgO	Al_2O_3	Fe_2O_3	P_2O_5	CO_2	Organic Substance.	Mn	Alkalies.	SiO_2	Total.
172	18	71	50·27	3·00	1·42			42·28	2·78	tr.	tr.	tr.	99·75

This analysis shows that the chemical composition corresponds in a general manner with what has been said of the nature of this deposit from a macroscopic and microscopic examination. The carbonic acid must be combined with the lime and magnesia. The low percentage of iron and alumina, and the traces of silica and other substances, show that there can be very few mineral particles in this Coral Sand.

Coral Muds and Sands cover a large area in all coral reef regions, estimated at about 2,700,000 square miles, including those from shallow water and also the area of the islands and of the lagoons and lagoon-channels. The coral reef region of the Pacific is by far the most extensive, and there Coral Muds and Sands attain their maximum development, being estimated to occupy about 1,500,000 square miles; in the Atlantic they cover about 800,000 square miles, and in the Indian Ocean about 400,000 square miles.

c. Geographical and Bathymetrical Distribution of Marine Deposits.

The distribution in space and depth of the various types of marine deposits in the different oceans has been pointed out in detail in the foregoing descriptions. On Chart 1 this distribution is represented by means of colours, while the depth is on the chart indicated by cross-shading. In laying down the limits and extent of each type of deposit all the information available at the present time has been made use of. It may be admitted that the distribution of the various types of deposits as thus exhibited is to a large extent hypothetical, owing to the fact that there are large stretches in some oceans in which there are as yet no soundings; especially is this the case in the Eastern and Northern Pacific and in the great Southern Ocean to the south of the latitude of 50° S. When the depth of the ocean is known, and the composition of several samples from different depths has been ascertained, the nature of the deposits over the whole area can be indicated with a large degree of certainty.[1] Should future investigations make known any great differences in the depths from those shown on the chart, it may be taken for granted that the nature and composition of the deposits will be different from what is represented on this chart.

It may be urged, however, that our knowledge as to the depth of the ocean has in late years become very extensive, and that we have a large number of soundings in all the great oceans and inland seas. It is not likely that any great alteration will be made by future researches in the average depth of the ocean, although the position of the contour lines may undergo very considerable alterations, and volcanic cones rising high above the general depressed level of the sea-bed will certainly be discovered in many regions. It is indeed remarkable how little the position of the contour lines shown in the Challenger charts have been shifted by recent lines of soundings across the Atlantic, Indian, and Pacific Oceans.[2]

[1] See pp. 30–32.

[2] Murray, "On some recent Deep-Sea Observations in the Indian Ocean," *Scot. Geogr. Mag.*, vol. iii. pp. 553–561, 1887; "On Marine Deposits in the Indian, Southern, and Antarctic Oceans," *Scot. Geogr. Mag.*, vol. v. pp. 405–436, 1889; Buchanan, "The Exploration of the Gulf of Guinea," *Scot. Geogr. Mag.*, vol. iv. pp. 177 and 233, 1888.

Many thousands of samples of terrigenous deposits have been examined from the shallower depths of nearly all oceans and enclosed seas. Of pelagic deposits more than 2000 samples from depths exceeding 1000 fathoms—over 1600 from the Atlantic, 300 from the Indian Ocean, and 400 from the Pacific—have passed through our hands. Even when the sample of a deposit has not been examined, the information furnished by marine surveyors and telegraph engineers is often sufficient to make known the type of deposit in the locality. The chart showing the distribution of the deposits, together with the following table, giving the approximate areas occupied by each type of deposit, have been constructed from a great number of reliable data, so that the broad outlines of distribution here presented are not likely to be much modified by future discoveries.

The total area of the surface of the globe has been estimated at 196,940,700 square miles, of which dry land occupies about 53,681,400 square miles, and the waters of the ocean 143,259,300 square miles.[1] In the following table the approximate extent of the areas of the sea-floor occupied by each type of marine deposit is given, together with the mean depth.

Table showing the Mean Depth and the Estimated Area Covered by Marine Deposits on the Floor of the Ocean.

		Mean Depth in Fathoms.	Area in Square Miles.
Littoral Deposits (between tide-marks),		...	62,500
Shallow-water Deposits (from low-water mark to 100 fathoms),		...	10,000,000
Terrigenous Deposits (in deep and shallow water close to land),	Coral Mud,	740	2,556,800[2]
	Coral Sand,	176	
	Volcanic Mud,	1033	600,000[2]
	Volcanic Sand,	243	
	Green Mud,	513	850,000[2]
	Green Sand,	449	
	Red Mud,	623	100,000
	Blue Mud,	1411	14,500,000
Pelagic Deposits (in deep water removed from land),	Pteropod Ooze,	1044	400,000
	Globigerina Ooze,	1996	49,520,000
	Diatom Ooze,	1477	10,880,000
	Radiolarian Ooze,	2894	2,290,000
	Red Clay,	2730	51,500,000

[1] Murray, "On the Height of the Land and the Depth of the Ocean," *Scot. Geogr. Mag.*, vol. iv. pp. 1–41, 1888; vol. vi. p. 265, 1890.

[2] These areas differ from those given in the descriptions, in which are included deposits from the shallow-water zone.

CHAPTER IV.

MATERIALS OF ORGANIC ORIGIN IN DEEP-SEA DEPOSITS.

The dead shells and skeletons, or other hard parts of marine organisms might, in the strict sense of the term, be regarded as belonging to the mineral kingdom. By their structure, as well as by their origin, these organic remains are, however, differentiated from mineral substances properly so called. Their organic nature is at once recognised by the most casual observer, and so abundant are the remains of some species on the floor of the ocean, that their names have been employed to designate certain types of deep-sea deposits, such as Globigerina, Pteropod, Radiolarian, and Diatom Oozes. We therefore devote this chapter to a consideration of the organic substances which take part in the formation of modern marine deposits.

a. Marine Fauna and Flora in General.

Before discussing the materials of organic origin in deep-sea deposits, it is desirable to glance at the light cast by recent investigations on the abundance and distribution of living plants and animals in the ocean, and thereafter to indicate the changes wrought by their functional activity, and by the decomposition of their dead bodies, in ocean waters and in deep-sea deposits.

It would appear to have been definitely established by the researches of the last fifty years that life in some of its many forms is universally distributed throughout the ocean. There do not seem to be any barren regions, where life is altogether absent, as was supposed by the older naturalists. It has long been well known that along all coasts the shallow waters teem with marine plants and animals, some of them living on or attached to the bottom, while others swim freely about in the surface and intermediate waters. The researches of the Americans along the eastern coast of North America, of the Norwegians off the coast of Norway, and of the British in the North Atlantic, had also, previous to the Challenger Expedition, revealed the existence of an abundant fauna in deep water.

The Challenger's dredging and trawling operations have shown that, not only in shallower water near coasts, but even in all the greater depths of all oceans, animal life is exceedingly abundant. A trawling in a depth of over a mile (1000 fathoms, Station 78) yielded two hundred specimens of animals, belonging to seventy-nine species and fifty-five genera. From a depth of about two miles (1600 fathoms, Station 147) a single haul of the trawl procured over two hundred specimens of deep-sea animals, belonging to eighty-four species and seventy-five genera. A trawling in a depth of about three miles (2600 fathoms, Station 160) yielded over fifty specimens, belonging to twenty-seven species and twenty-five genera. These are but a few, and not the most striking, of the examples that might be cited. From the contents of their stomachs it was evident that the great majority of these lived on, or in the immediate neighbourhood of, the bottom. Even in depths of four miles, fishes and animals belonging to all the chief invertebrate groups have been procured, and in the sample of ooze from nearly five and a quarter miles (4475 fathoms) there was evidence that living creatures could exist at that depth. In the deeper waters far removed from the coasts the genera and species are almost all new to science, while at similar depths near continents the species and genera are both more numerous, and include many more forms identical with, or closely allied to, shallow-water species. These results have been confirmed by subsequent investigations in special regions by French, German, Italian, Norwegian, and British expeditions.

Haeckel has introduced the useful term "Benthos" to designate all those animals and plants living fixed to, or creeping over, the bottom of the ocean, and in accordance with the classification given on pages 185 and 186 we would propose that the Benthos be divided into neritic Benthos and deep-sea Benthos. The neritic Benthos may be subdivided into littoral Benthos and shallow-water Benthos. The deep-sea Benthos may again be subdivided into bathybial Benthos for those animals living on deep-sea terrigenous deposits, and abyssal Benthos for those living on pelagic deposits.

Not only is life everywhere distributed over the floor of the ocean, but experiments appear to show that it is present everywhere throughout the whole body of oceanic waters at all depths from the surface to the bottom, most abundant at and near the bottom and at and near the surface, while much more sparingly represented in the waters of intermediate depths. In the spring of 1891, Alexander Agassiz conducted experiments with closing tow-nets from the U.S.S. "Albatross," off the Pacific coast of America. At intermediate depths greater than 200 fathoms he did not procure any animals in the open ocean, but a few specimens were obtained from these intermediate waters in the Gulf of California.[1] As all the surface animals must after death fall towards the bottom, we should expect to capture such specimens, at least sparingly, in tow-nets dragged at intermediate depths, and such captures seemed to be clearly indicated in the Challenger

[1] *Bull. Mus. Comp. Zoöl.*, vol. xxi. pp. 185-200, June 1891.

experiments. The researches of the Challenger in this direction have been confirmed and extended by those of Chun, Hensen, Haeckel, and other naturalists.[1] The researches carried out on board H.M.SS. "Triton" and "Knight Errant" in the Faroe Channel, and by the yacht "Medusa" in the deep lochs of the west of Scotland, conclusively show that some animals which, in their larval condition, are captured in the surface and subsurface waters, are found in the adult condition at the bottom in depths of 100 to 400 fathoms. It was also found that at definite depths in the intermediate waters different species were captured on the same day, but at different depths on the following day, thus showing an oscillation of the great floating banks of animals or Algæ.[2] When the tow-nets could be dragged within a few feet of the deposit without touching the ground, immense hauls of Crustaceans, largely Copepods and Schizopods were always obtained.

Haeckel has extended the connotation of the term "Plankton"[3] to include all animals living in the waters of the ocean, in contradistinction to Benthos—those living on the bottom of the sea. Murray[4] has shown that the organisms living in mid-ocean in the great oceanic currents are quite different from those in the surface waters near land, and Haeckel proposes to designate the former oceanic Plankton, and the latter neritic[5] Plankton. We would suggest that the term oceanic Plankton be subdivided into pelagic Plankton for the animals living in the waters from the surface to 100 fathoms, zonary Plankton for those living in the intermediate zones between 100 fathoms from the surface and 100 fathoms from the bottom, bathybial Plankton for those living within 100 fathoms from the bottom in the transitional area covered by deep-sea terrigenous deposits, and abyssal Plankton for those living within 100 fathoms from the bottom over pelagic deposits.

While, however, life is universally present on the ocean's bed and throughout the mass of oceanic waters, it by no means follows that it is uniformly distributed either over the first or throughout the second. It is well known that in shallow waters certain species are found on some banks or in some deep muddy pits, while they are absent in other localities under apparently, at the present time, similar physical conditions. The productiveness or fertility of certain stretches of the sea-bottom in shallow water would appear to be due to some unknown antecedent conditions. It is the same in the deep sea, for otherwise it seems impossible to account for the almost constant success of the

[1] Chun, "Die pelagische Thierwelt in grösseren Meerestiefen und ihre Beziehungen zu der Oberflächen-Fauna," Bibliotheca Zoologica, Heft i., 1888; "Die pelagische Thierwelt in grössen Tiefen," *Verhandl. d. Gesellsch. Deutsch. Naturf. u. Aerzte*, Bremen, 1890; Hensen, "Einige Ergebnisse der Plankton-Expedition der Humboldt-Stiftung," *Sitzb. d. Berliner Akad. d. Wiss*, 1890, pp. 243–253; Haeckel, Plankton-Studien, Jena, 1890.

[2] Tizard and Murray, "Exploration of the Faroe Channel, during the summer of 1880, in H.M.'s hired ship Knight Errant," *Proc. Roy. Soc. Edin.*, vol. xi. pp. 638–677, 1882; Murray, "On the Effects of Winds on the Distribution of Temperature in the Sea- and Fresh-water Lochs of the West of Scotland," *Scot. Geogr. Mag.*, vol. iv. pp. 345–365, 1888.

[3] First introduced by Hensen in 1887, *loc. cit.*

[4] "The Great Ocean Basins," *Nature*, vol. xxxii. pp. 581 and 611, 1885.

[5] Νηρίτης, son of Nereus.

trawlings in some spots and the comparatively unsuccessful results in others at the same depth and with apparently similar surroundings. From the results of deep-sea dredgings and trawlings, up to the present time, there seems no doubt that life is on the whole more abundant at the bottom near continental shores than at similar depths towards the centres of the ocean basins.

The operations with tow-nets in surface, subsurface, and intermediate waters lead to nearly identical conclusions with reference to the pelagic fauna and flora, or Plankton, as those with reference to the fauna or flora on the deposits, or Benthos. Sometimes the captures in the tow-nets may be very insignificant, while, at a little greater or less depth, or at a different time of the day, the same nets may yield an abundant harvest. Many of the species occur at times in floating banks of vast extent, and at other times only a few specimens may be taken at the same locality. On the whole, the Planktonic species are more numerous in tropical waters, while in polar waters, although the species are less numerous, the individuals of the species have often an enormous development. The Challenger observations appear to indicate clearly that in warm oceanic currents the abundance of life is greater than in the regions of the Sargasso Seas. The pelagic fauna and flora are, again, different and probably more abundant along coasts affected by river water than in purely oceanic regions. Ascending currents of water from the deeper regions near land are sometimes heavily laden with marine organisms whose usual habitat is in deep water about the level of the mud-line surrounding the continental and other coasts.

Owing to this unequal distribution of organisms in ocean water and on the floor of the ocean, it is not possible to arrive at any satisfactory approximation of the total number of living organisms or the total amount of organic matter in the sea, but it is evident that these must, on the lowest estimate, be enormous. Assuming that the lime-secreting organisms were as abundant throughout the whole region as in the path followed by his tow-nets, Mr. Murray[1] has estimated that at least sixteen tons of carbonate of lime, in the form of shells of living organisms, were present in a mass of tropical oceanic water one square mile in extent by 100 fathoms in depth. Hensen has even made a praiseworthy attempt to count the number of individuals of each species in certain tow-net gatherings, and from these data to estimate the total numbers of each species as well as the amount of organic matter in the whole ocean.[2] All these calculations are interesting and valuable for the time and place of the experiments, but unreliable or insufficient when used as a basis for any wide general conclusions or deductions. When considering the amount of organic matter in the ocean, it must be remembered that a large

[1] *Proc. Roy. Soc. Edin.*, vol x. p. 508. In some ten litres of water from the Red Sea, Murray and Irvine recently found suspended carbonate of lime (shells of organisms) equivalent to 51 tons in a mass of ocean water one square mile by 100 fathoms in depth.

[2] Hensen, "Ueber die Bestimmung des Planktons, oder die im Meere treibenden Materials an Pflanzen und Thieren," Bericht d. Comm. z. wiss. Unters. der deutschen Meere in Kiel, 1887.

amount of such material is annually borne to the ocean by rivers from the dry land or washed from the coast line into deep water. The Challenger dredgings near land furnished abundant proof of this in the presence of leaves, fruits, and branches of trees, with occasional fragments of land shells and other organic substances. Alexander Agassiz dredged a great abundance of decaying vegetable matter from deep water in the tropics, off the Pacific coast of America.[1]

b. Albuminoid and other Organic Matters in Deep-Sea Deposits.

In nearly all deep-sea deposits traces of albuminoid organic matters can be detected by chemical analysis. Organic material can be observed after fragments of bones or shells have been removed by dilute acid, when there often remain small flocculent masses —sometimes taking the form of the calcareous shells—which, heated on a platinum plate, burn, leaving a black cinder. In shallower water, for instance in some Green Muds, there is a greenish matter which likewise burns and appears to be of vegetable origin. The presence of sulphides and sulphuretted hydrogen in all harbour muds, muddy bays near land, and, indeed, in nearly all the terrigenous deposits, such as the Blue Muds, is a sure indication that soluble and insoluble albuminoid and other organic matters are distributed throughout these muds and are in process of decomposition. Probably sulphides are present in all deep-sea deposits, but they are most abundant in muds near land where there is rapid accumulation, and where a large quantity of organic matter is borne down from the continents. In the Red Clays and the other truly pelagic deposits, the quantity of organic matter is much less, and, owing to the slow accumulation, the sulphides are probably oxidised as soon as formed, and never make up any considerable portion of the deposit.

The food of the deep-sea animals living on the floor of the ocean consists of the dead bodies of oceanic plants and animals that have fallen to the bottom from the surface and intermediate waters. The stomachs of Echinoderms, Annelids, and other organisms were always found to be completely filled with the surface layers of the ooze, mud, or clay of the region from which they were dredged, and there can be no doubt that the nutriment contained therein was sufficient for the necessities of life.[2] Even the Crustaceans dredged from areas where fine mud commences to settle on the bottom, about or beyond the 100-fathom line, appear to live largely on the minute particles of organic origin which there settle on the bottom along with the argillaceous matters. A very large proportion of marine deposits must in this way be passed through the intestines of marine animals, and in this sense, though not in the sense suggested by Thomson and

[1] *Bull. Mus. Comp. Zoöl.*, vol. xxi. p. 197.

[2] Murray, "Marine Deposits of the Indian, Southern, and Antarctic Oceans," *Scot. Geogr. Mag.*, vol. v. p. 425, 1889.

Huxley,[1] deep-sea clays and muds might be said to be of organic origin. In the Globigerina limestones of Malta the tracks of Echinoderms and Annelids, which had eaten their way through the deposits, may now be seen in the solid rocks.[2] In examining the samples of Blue Muds, and especially those near the mouths of rivers, many oval-shaped bodies, about 0·5 mm. in length, were observed. These were described by some observers as Foraminifera. Mr. Murray, after numerous observations, came to the conclusion that they were mostly the excreta of Echinoderms, principally of Holothurians.[3] When these pellets are voided by the animal they are covered by a slimy substance; many of them may indeed be united in a chain. In some deposits this dung is exceedingly abundant, but as a rule it is impossible to recognise these oval bodies in any of the organic oozes, and in the Red Clays only some doubtful examples have been met with. They appear to fall asunder when the deposit is granular, like a Globigerina Ooze, or when long exposed without being covered up, as in the case of the Red Clays.

It is abundantly evident, then, that much organic matter is mixed with the marine deposits, especially with the surface layers. In the Blue Muds the decomposition of this matter in the deeper layers leads to the reduction of the oxides in the red upper layer and to the formation of sulphides, which give a blue colour to the deposit, but in the Red Clays and Red Muds the quantity of organic matter is insufficient to completely effect this change, and the deposit as a whole remains of a red colour.[4]

The changes connected with the decomposition of albuminoid matter in marine deposits must also be associated, at least in their initiatory stages, with the formation of glauconite in the chambers of Foraminifera and other calcareous organisms, and the production of glauconitic grains in Green and Blue Muds along continental shores. In like manner the formation of phosphatic grains and nodules may be connected with changes brought about by the decomposition of organic substances in terrigenous deposits.

c. Changes Produced by Organisms in the Constitution of Sea-Water and Deep-Sea Deposits.

When we remember the large number of marine organisms in the ocean, and the organic materials carried into the sea from the land, it is evident that the functional activity of these organisms,—together with the nitrogenous organic matter arising

[1] See p. 190. [2] Murray, *Scot. Geogr. Mag.*, vol. vi. pp. 449–488, 1890.

[3] See under Additional Observations, pp. 101, 103.

[4] J. Y. Buchanan says:—"The mud below the surface layer, in localities where ground life is abundant, remains blue, being protected by the oxidation of what is above it" ("Sulphur in Marine Muds," *Proc. Roy. Soc. Edin.*, vol. xvii. p. 37, 1890). This does not appear to be the correct interpretation, for Blue Muds, accumulating by additions at the surface, must all pass through the stage of the red upper or surface layer. The blue colour of the deeper layers must be due to a subsequent change from the reduction of the higher oxides in the red upper layer, and the formation of sulphide of iron through the decomposition of the organic matter present in the deeper parts of the deposit.

from the decomposition of their waste products and dead bodies,—cannot but work continual and extensive changes in the internal constitution of the sea-water salts and of the materials in suspension in sea-water or lying on the floor of the ocean, the intensity of these changes varying with the temperature, the amount of sunlight, and other conditions.

Carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus may fairly be regarded as entering into the composition of the tissues and fluids of all marine organisms; in addition, carbonate of lime, silica, and other substances entering into the composition of the hard parts may be regarded as essential to the life of numerous species of animals and plants.[1] When marine organisms cease to live the resolution of their complex compounds at once begins. The carbon and hydrogen pass off mainly as carbonic acid and water, the nitrogen forms ammonia, and the sulphur and phosphorus give rise to volatile sulphuretted and phosphuretted compounds; in short, decay takes place accompanied by all its well-known phenomena.[2] The skeletal structures of the organisms become altered at the same time, and, passing into solution, may ultimately be wholly reduced, in the presence of sea-water, into their ultimate inorganic components. At the bottom in great depths the process of decay might be an exceedingly slow one were the only available oxygen that which is present in solution in the sea. There is evidence, however, of some remarkable chemical reactions which it is desirable here to indicate.

The analyses of sea-water inform us that earthy and alkaline sulphates make up a very large part of the total sea-water salts. When these are exposed to the action of carbon, or of organic matter, which, of course, contains carbon, the sulphates are reduced and sulphides formed; the carbon unites with the oxygen, formerly combined with the metal and metalloid, to form carbonic acid.[3] Thus for every molecule of sulphate decomposed in this way one molecule of sulphide and two molecules of carbonic acid are formed. As, practically, all the carbon of marine organisms must thus ultimately be resolved into carbonic acid, the quantity of that acid produced in this way must be enormous, and cannot but exert a great solvent action not only on the dead calcareous structures, but also on the minerals in the muds on the floor of the ocean. Were these reactions to end at this stage the bottom of the sea would soon become so poisoned by sulphides as to be unfit to support either animal or vegetable life. As soon, however, as the sulphides are produced, the carbonic acid, which is formed at the same time, decomposes the sulphides, forming earthy and alkaline carbonates,

[1] Pouchet and Chabry, "De la production des larves monstrueuses d'Oursin, par privation de chaux," *Comptes Rendus*, tom. cviii. pp. 196–198, 1889; "L'eau de mer artificielle comme agent tératogénique," *Journal de l'Anatomie*, 1889, pp. 298–307.

[2] These changes are not, of course, due to simple oxidation, but are brought about in a large measure by the influence of organisms familiarly named Bacteria, it being now generally accepted as a fact that all putrefactive changes are brought about or initiated by these minute organisms.

[3] Murray and Irvine, *Proc. Roy. Soc. Edin.*, vol. xvii. p. 93.

sulphuretted hydrogen being given off; the latter passing into the circumambient water is oxidised into sulphuric acid, which in turn decomposes the carbonate of lime dissolved in the sea-water or existing in the form of calcareous shells, sulphate of lime being finally formed. The nitrogenous or albuminoid matters present in animal tissues and fluids break up ultimately, by a series of complex reactions, into ammonia and nitrogen; the former is either liberated, or, combining with the carbonic acid, passes into solution as carbonate of ammonia, or becomes oxidised into nitrates. Further, the sulphur and phosphorus are given off in combination with hydrogen, becoming finally oxidised into sulphuric and phosphoric acids, which, decomposing the alkaline and earthy carbonates present in sea-water, give rise to sulphates and phosphates.

Murray and Irvine have shown by direct analyses that the ammoniacal salts, formed as indicated by the above reactions, are everywhere present in the ocean, due to the decomposition of albuminoid matter, ammonia being always one of the products. This change is accelerated by a high and retarded by a low temperature, consequently tropical or warm water contains much more ammonia than is found in the waters of temperate zones.[1] The carbonate of ammonia, arising from the decomposition of animal products in presence of sulphate of lime in the ocean or in the bodies of animals, becomes converted into carbonate of lime and sulphate of ammonia. The whole of the lime salts in the sea may be thus available for the coral- and shell-builders.[2] The much more rapid decomposition of the nitrogenous organic matter in the tropics may probably explain the greater development of coral reefs, and generally of all lime-secreting organisms, in tropical than in colder seas.

The low temperature at the bottom of the ocean and possibly also the pressure retard putrefaction, but it is evidently incorrect to state that putrefaction does not exist in great depths,[3] for everywhere there are signs to the contrary. This opinion has apparently been founded on some interesting but inconclusive experiments made by Regnard with fresh water,[4] where the absence of sulphates excludes the supply of oxygen, which in sea-water, as has been shown, is the great factor in oxidizing organic remains.

From the reactions referred to above some idea may be formed of the nature and extent of the changes that are continually going on in the ocean, and they are referred to in this place in order to indicate the circumstances which must be taken into consideration when treating of the presence or absence, the quantity, condition, and distribution of organic remains and other materials in deep-sea deposits.

[1] Murray and Irvine, *Proc. Roy. Soc. Edin.*, vol. xvii. p. 89.

[2] Murray and Irvine, *loc. cit.*, p. 90.

[3] Pelseneer, "Exploration des Mers profondes," Gand, 1890.

[4] Regnard, "Influence des hautes pressions sur la putréfaction," *Rev. Scientif.*, tom. xliii. p. 284, 1889.

d. CALCAREOUS ORGANIC REMAINS IN DEEP-SEA DEPOSITS.

Calcareous Algæ.—Species of Algæ which secrete carbonate of lime are abundant in the shallow waters of the ocean. In the tropical regions especially there are large and massive species of *Lithothamnion*, *Lithophyllum*, *Halimeda*, and other genera that make up a large part of some coral reefs and of the surrounding Coral Sands and Muds. Two hundred fathoms is probably the extreme limit at which any of these organisms live in the ocean, but the broken-down fragments of calcareous Algæ have been found in depths of over 2000 fathoms in the neighbourhood of coral reefs. In the Tables of Chapter II. they are noted in all the Coral Muds and Sands, in six different samples of Globigerina Ooze, and in very many samples of Volcanic Muds and Sands.

Coccospheres and Rhabdospheres.—The precise nature of these minute organisms was for a long time obscure, but they are now regarded, and no doubt rightly, as pelagic Algæ. There is considerable difference in the size and form of both the Coccospheres and Rhabdospheres; three of the principal forms are represented in the annexed woodcuts. The interior of the spheres is filled with transparent albuminoid matter, in which no nucleus was detected by the Challenger naturalists. When the calcareous rods and discs are removed by dilute acid, small gelatinous spheres remain behind, on the outer surface of which the Coccoliths and Rhabdoliths were implanted or embedded. Rhabdospheres are especially developed in equatorial and tropical regions, and are rarely met with in regions where the temperature of the surface water falls below 65° F. Coccospheres, while abundant in tropical waters, are found further north and south than the Rhabdospheres; they are present even where the temperature on the surface is as low as 45° F., indeed, Coccospheres attain their greatest development in temperate regions. These organisms are absent or rare in coast waters affected by rivers; they especially flourish in the pelagic currents of the open ocean, and therefore belong to the pelagic Plankton. In Arctic and Antarctic waters Coccospheres and Rhabdospheres are replaced by similar minute Algæ, which do not, however, secrete rods and discs of carbonate of lime on their outer surfaces.[1] Coccospheres and Rhabdospheres are, then, nearly everywhere present in the surface waters of the tropical and temperate regions

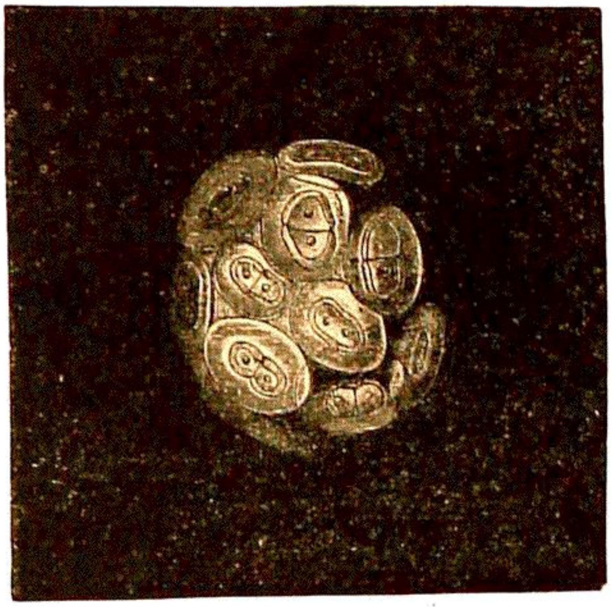


FIG. 19.—A Coccosphere. From the surface ($\frac{1000}{1}$).

[1] Narr. Chall. Exp., vol. i. pp. 436, 938, 939.

of the open ocean; they are usually found entangled in the gelatinous matter of the Radiolarians, Diatoms, and Foraminifera, and are seldom absent from the stomachs of *Salpæ*, Pteropods, and other pelagic animals.

Rhabdoliths and Coccoliths—the broken-down parts of Rhabdospheres and Cocco-

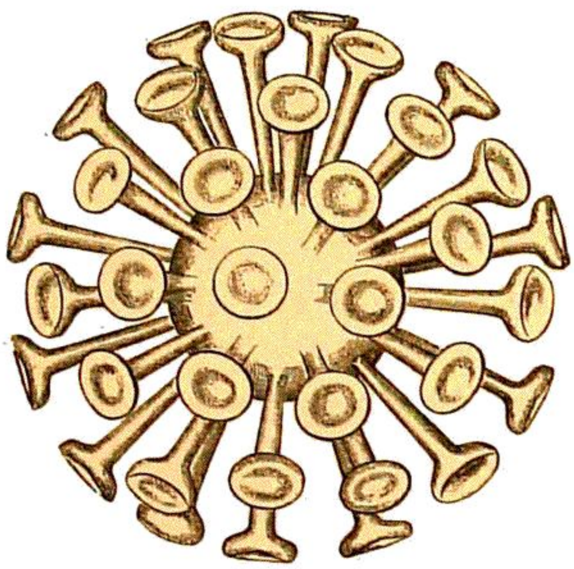


FIG. 20.—A Rhabdosphere. From the surface ($\frac{2000}{1}$).

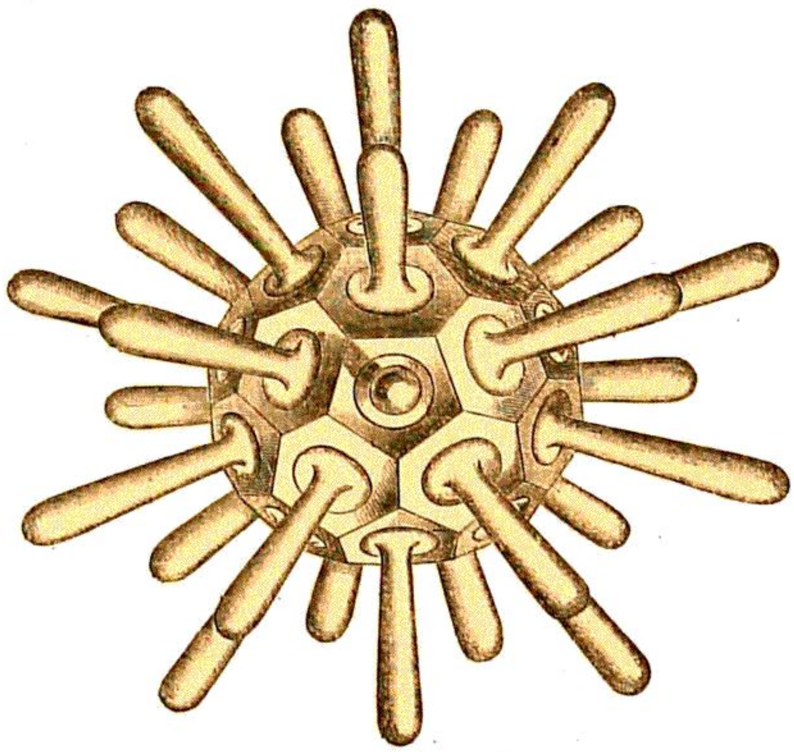


FIG. 21.—A Rhabdosphere. From the surface ($\frac{800}{1}$).

spheres—play a most important part in all deep-sea deposits, with the exception of those laid down in polar and subpolar regions. In terrigenous deposits they are much less abundant than in pelagic deposits; in some Blue Muds and other terrigenous deposits they are either rare or absent, while in all Globigerina and Pteropod Oozes they make up a large portion of the carbonate of lime in the deposit. Perfect Rhabdospheres are never found in the deposits; they are very easily broken up into Rhabdoliths, which are at times very abundant. Coccospheres are found in considerable numbers in deposits from the temperate regions in all moderate depths, but they are rare in the deposits from tropical regions, where the spheres, from not being so compact, break up more readily into Coccoliths (Cyatholiths), and they are generally, like other calcareous remains, absent from Red Clays and Radiolarian Oozes.

The general appearance of these minute fragments under the microscope, when the finer parts of a Globigerina Ooze are examined, is represented on Plate XI., fig. 3, showing Rhabdoliths and Coccoliths from Station 338, lat. 21° 15′ S., in 1990 fathoms, fig. 4 Coccospheres and Coccoliths from Station 166, lat. 38° 50′ S., in 275 fathoms.

Foraminifera.—Of all the organic remains met with in marine deposits by far the most frequent are the shells of Foraminifera; it may be safely said that these organisms or their fragments are present in every average sample of marine mud, clay, ooze, or sand. For our immediate purpose the Foraminifera of marine deposits may be divided into two great groups according to their mode of life, one comprising all those bottom-living species which habitually live on or move about on the floor of the ocean, belonging

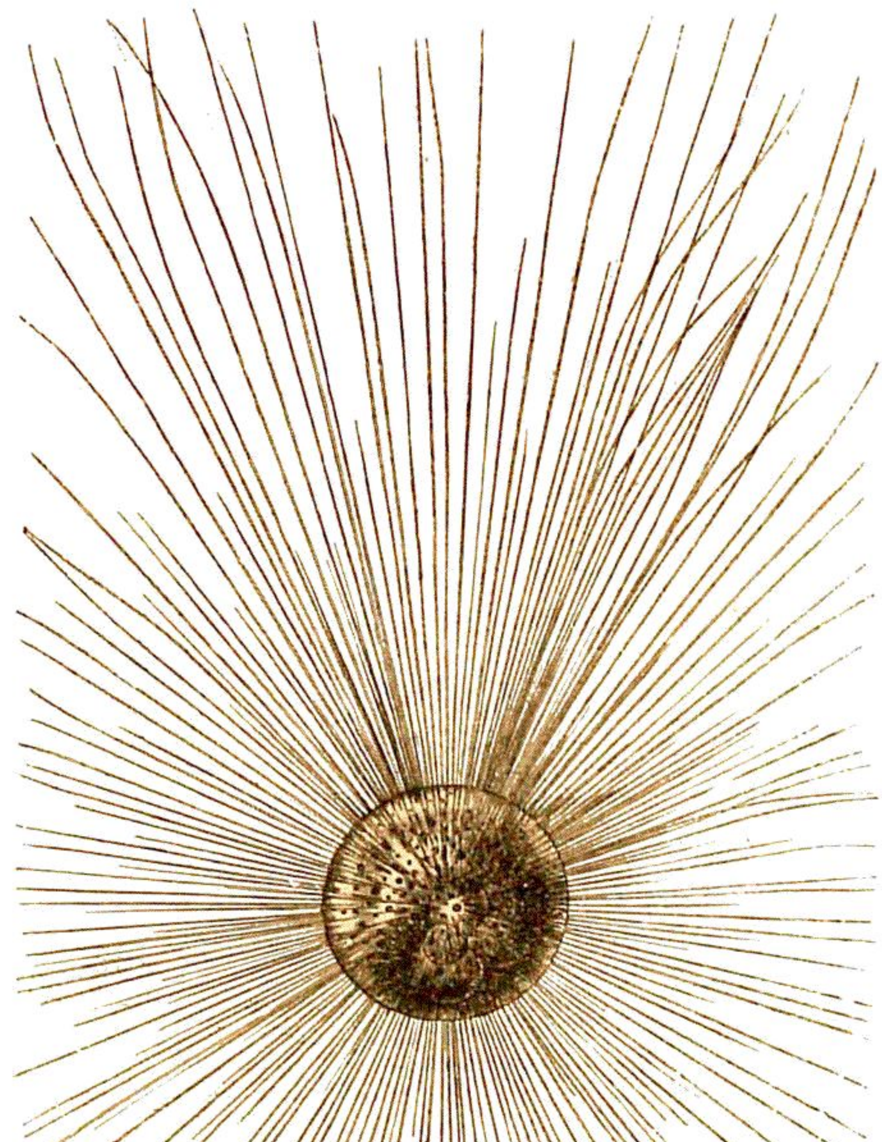


FIG. 22.—*Orbulina universa*, d'Orbigny. From the surface ($\frac{40}{1}$).

to the Benthos, and the other comprising all those pelagic species which habitually live in the surface and subsurface waters of the open ocean, therefore belonging to the pelagic Plankton.[1]

The Challenger observations have clearly established that many species belonging to

[1] These two groups of pelagic and bottom-living Foraminifera are distinguished in the Tables of Chapter II. under the heading "Foraminifera" by different estimated percentages for each group (see p. 26).

the genera *Globigerina*, *Pulvinulina*, *Sphæroidina*, and *Pullenia*, have a pelagic mode of life, which were aforetime believed under all circumstances to inhabit the oozes at the bottom of the sea. All the pelagic or oceanic species, a list of which is given on page 214, have calcareous shells; they especially flourish in the pure currents of the open

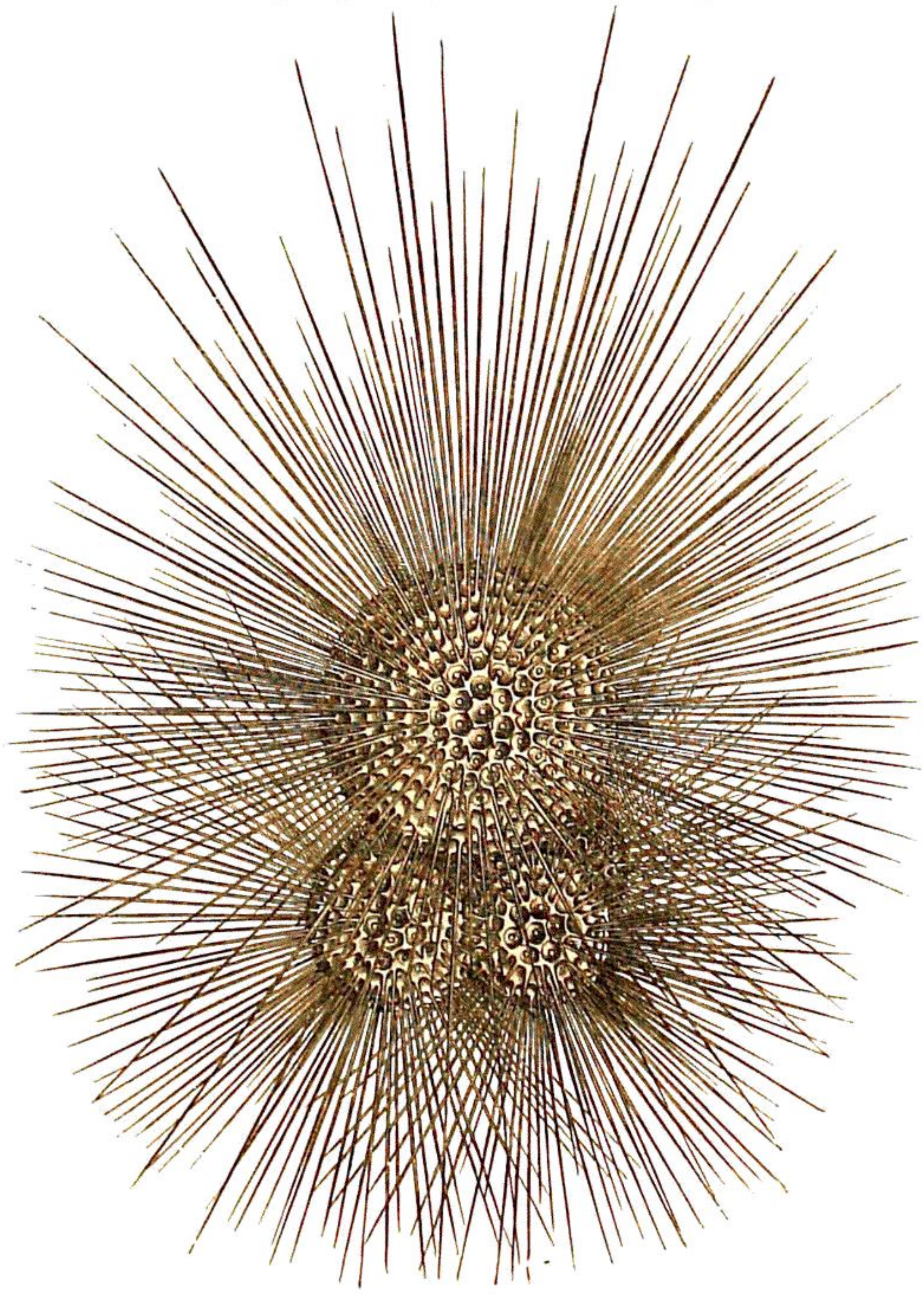


FIG. 23.—*Globigerina bulloides*, d'Orbigny. From the surface.

ocean, and they are but rarely taken in the tow-nets in bays or estuaries or along coasts that are much affected by river water. The annexed woodcuts show four characteristic surface specimens of *Orbulina*, *Globigerina*, and *Hastigerina*. Nearly all the species are confined to tropical and subtropical waters; they gradually disappear from the surface-nets as the polar regions are approached, the dwarfed forms *Globigerina pachyderma* and *Globigerina dutertrei* being the only species met with in Arctic and Antarctic waters. The distribution of these pelagic Foraminifera shells in deep-sea deposits corresponds with their distribution at the surface of the sea, with certain exceptions as to depth, to be referred to immediately. This coincidence, between the distribution of the living organisms at the surface of the sea and of their dead shells in deep-sea deposits, is of itself sufficient to demonstrate that these Foraminifera live only in the surface and subsurface waters.

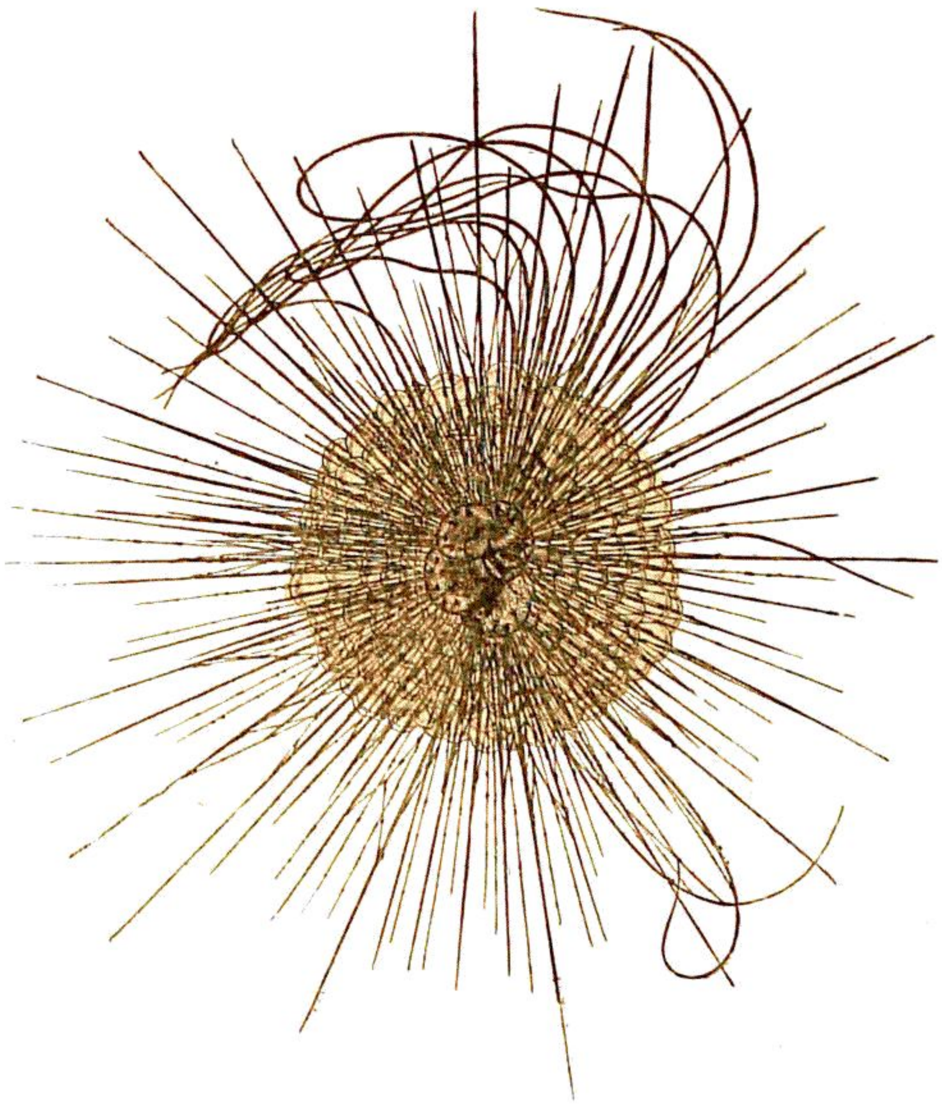


FIG. 24.—*Hastigerina pelagica*, d'Orbigny. From the surface (4⁰).

Did they live on the bottom for a portion of their lives (Meroplanktonic), then the distribution of their shells would resemble that of the shells of other animals belonging to the Benthos. But we have seen that their distribution resembles in every way that of pelagic organisms, and these Foraminifera must therefore, for this as well as for many other reasons, be regarded as Holoplanktonic. In the calcareous oozes from tropical regions the shells of all the species inhabiting the surface waters are observed in enormous abundance, but these same species are never met with in deposits from polar regions, thus showing that these pelagic shells are not drifted to any great distance from their normal habitat by oceanic currents; in this way it is possible after a careful examination of the species present in a Globigerina Ooze to tell approximately the latitude from which the deposit was collected.[1]

The pelagic Foraminifera are especially characteristic of all deep-sea deposits from average or moderate depths, or from 200 to 3000 fathoms, in some equatorial regions. Near shore and in polar regions their presence is masked by the abundance of other materials, so that if present they do not as a rule make up a large part of the deposit, but in all moderate depths in the open sea, far from land, they, on the other hand, form

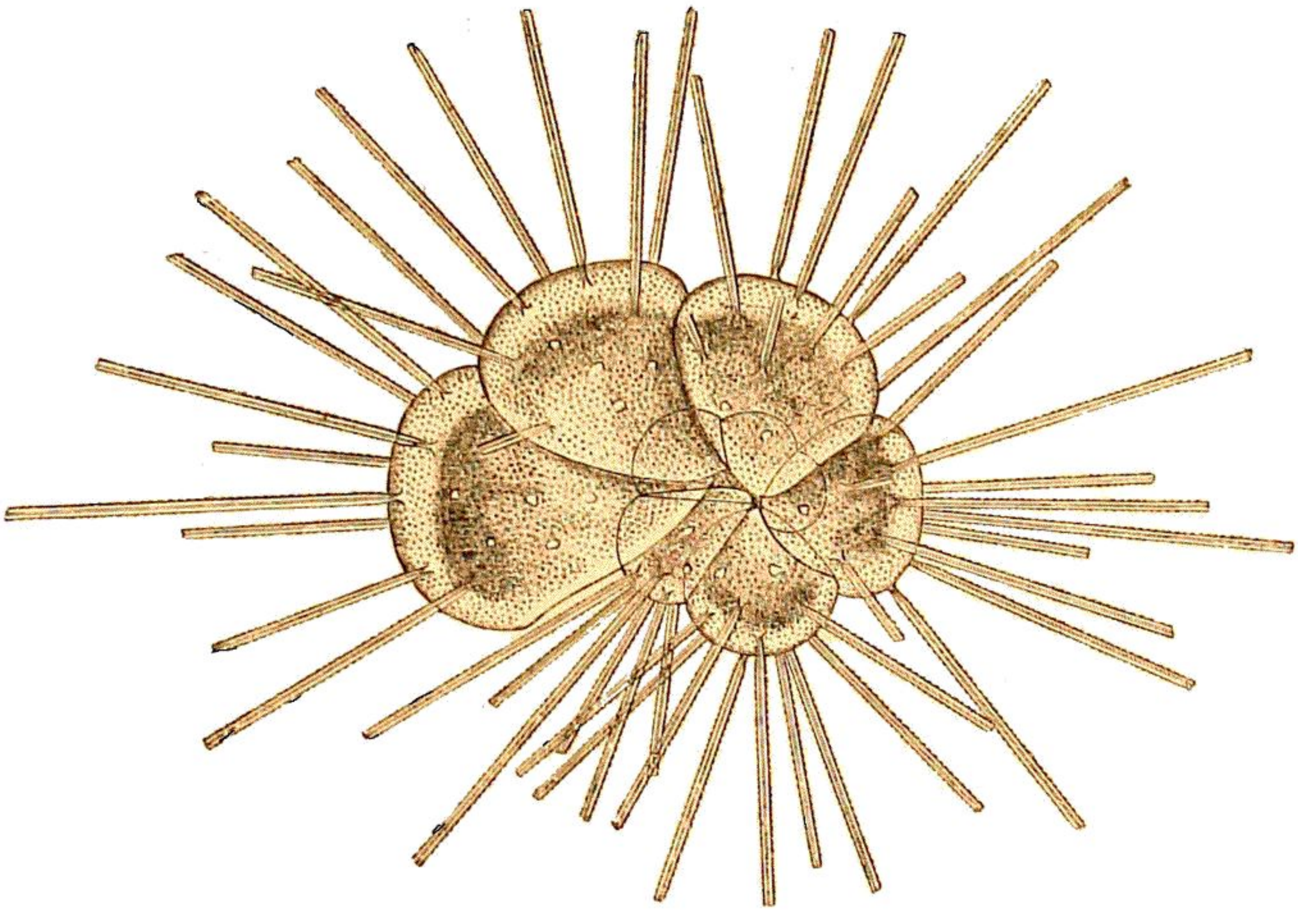


FIG. 25.—*Hastigerina pelagica*, d'Orbigny. From the surface ($\frac{50}{1}$).

the major part of the deposits, or at all events of the carbonate of lime that is present. In all the greatest depths of the ocean in the tropics, and in the lesser depths of the ocean in extra-tropical regions, the shells of these pelagic Foraminifera are either not present in the deposits, or are met with only in a fragmentary condition; like the Coccospheres, Rhabdospheres, Pteropods, and calcareous shells of other pelagic organisms, they have been wholly dissolved either in falling through the water or shortly after having reached the bottom.[2]

[1] See p. 31.

[2] See Murray, *Proc. Roy. Soc.*, vol. xxiv. p. 535, 1876; *Proc. Roy. Soc. Edin.*, vol. x. p. 509, 1880; Royal Institution Lecture, London, March 16, 1888, p. 7; Narr. Chall. Exp., vol. i. pp. 923, 4; Murray and Irvine, *Proc. Roy. Soc. Edin.*, vol. xvii. p. 83, 1889.

There are not more than twenty or twenty-two species of pelagic Foraminifera, yet so numerous are the individuals of the species that they usually make up over 90 per cent. of the carbonate of lime present in the calcareous oozes of the abysmal regions of the ocean. The individuals belonging to even a dozen of these species far outnumber the individuals belonging to all the other known genera and species of Foraminifera. This is true not only with regard to their abundance and great importance in the now-forming deep-sea deposits, but also to their great development in Tertiary and other geological formations.[1]

The bottom-living Foraminifera—those belonging to the Benthos—are more abundant in the shallow-water, than in the deep-sea, deposits, and occasionally a single species may occur in such abundance in shallow depths in some regions as to make up the greater part of a deposit, as, for instance, *Amphistegina* at the Cape Verdes, *Orbitolites* at the Fiji Islands, and *Heterostegina* at Amboina,[2] but the extent of such deposits is very limited when compared with a Globigerina Ooze, or any other deep-sea deposit. Whenever bottom-living species of Foraminifera are, compared with pelagic species, abundant in a deposit, they indicate comparatively shallow water and proximity to land. The species of Foraminifera that live on the bottom in deep water are habitually under very uniform conditions,[3] and consequently their shells do not vary in size and thickness with change of latitude like those of the pelagic species, the animals of which are subject to great changes of temperature and salinity in the surface waters.

Many of the arenaceous Foraminifera form their tests of minute calcareous shells of Globigerinidæ or their fragments, together with other calcareous fragments in the sands, muds, clays, or oozes at the bottom, and many instances are given of the wonderful power of selection possessed by certain species. The tests of *Pilulina* and *Technitella* are constructed of masses of Sponge spicules felted together, and the same is the case with *Marsipella*, in which the spicules are laid together side by side and strongly cemented. *Psammosphæra*, *Storthosphæra*, *Pelosina*, *Pilulina*, and *Technitella* are distinguished from each other primarily by the kind of material they individually select for the construction of the test. In the Lituolidæ there is a certain amount of selective power, the nature of the foreign material depending more or less on the character of the sea-bottom; for instance, in pure Globigerina Ooze the dead shells of the smaller Foraminifera are used, and in the tropics the calcareous debris of coral reefs, while the tests of Radiolaria and the frustules of Diatoms are sometimes employed in considerable numbers. The preference for Sponge spicules, broken or entire, also exists among the Lituolidæ.

[1] See Murray, "The Maltese Islands, with Special Reference to their Geological Structure," *Scot. Geogr. Mag.*, vol. vi. pp. 449–488, 1890.

[2] See pp. 63, 89, and 97, Chapter II.

[3] The following are a few of the cosmopolitan species which extend into deep water:—*Biloculina ringens*, *Miliolina seminulum*, *Rotalia soldanii*, *Truncatulina lobatula*, *Nonionina umbilicatula*, *Nodosaria farcimen*, *Cassidulina crassa*, *Cristellaria rotulata*, *Lagena globosa*, *Lagena lævis*, *Lagena sulcata*, &c.

The casts of Foraminifera in glauconite and other silicates are especially abundant in some terrigenous deposits, and will be specially referred to when discussing the chemical deposits in Chapter VI.

Sponge Spicules.—The spicules of calcareous Sponges (Calcarea) are occasionally met with in the deposits, but they are rare and only locally present.[1]

Corals.—All the groups of the Cœlenterata which secrete carbonate of lime contribute to the formation of marine deposits. In the neighbourhood of coral reefs the remains of Madreporaria and Hydrocorallinæ may frequently make up the principal part of Coral Sands and Muds, and their fragments may be carried into the surrounding deep water. Certain species of Stylasteridæ, *Flabellum*, &c., are inhabitants of deep water, and may be detected in deposits of all depths, but they never form a large part of a deep-sea formation.[2]

Alcyonarian Spicules.—These spicules are very frequently observed when examining the deposits from shallow water, and occasionally are present in considerable abundance in Globigerina or Pteropod Oozes. When they are locally abundant in deep water, as at Station 182,[3] it would seem as if some specimens of Alcyonaria had lived at the spot where the sounding was taken.[4]

Annelida.—The calcareous tubes of the Serpulidæ in some coral reef regions, as for instance at Bermuda, form very massive structures,[5] and these tubes with their broken-down fragments can be recognised in nearly all marine deposits down to depths of 300 fathoms. A few species live in very deep water, and fragments of their tubes are sometimes observed in the Red Clays, Globigerina Oozes, and in other kinds of pelagic deposits.[6]

Crustacea.—When we remember the enormous numbers of Crustacea inhabiting all parts of the ocean, it is somewhat remarkable that their remains are so rarely met with in marine deposits. Chitin, which enters largely into the composition of the crustacean exoskeleton, is well known to be dissolved only with difficulty in acids or alkalies, and it might be supposed that it would protect the calcareous portions of the skeleton from solution in sea-water. The disappearance of the crustacean exoskeleton in all likelihood arises from its areolar structure, which admits of relatively rapid solution after the death of the animal, and the putrefaction of its soft parts.

In two or three cases the tip of a claw has been observed in the dredgings from both shallow and deep water, but with these exceptions, the remains of all the higher groups

[1] See Poléjaeff, Report on the Calcarea, Zool. Chall. Exp., pt. 24.

[2] See Moseley, Report on the Corals, Zool. Chall. Exp., pt. 7.

[3] See p. 91, Chapter II.

[4] See Wright and Studer, Report on the Alcyonaria, Zool. Chall. Exp., pts. 64 and 81.

[5] See Murray, *Proc. Roy. Soc. Edin.*, vol. x. p. 512, 1880.

[6] M'Intosh says :—*Serpula philippensis* reaches 1050 fathoms, a *Vermilia* 1450 fathoms, *Placostegus challengeriæ* 2375 fathoms, *Placostegus ornatus* 2900 fathoms, and *Placostegus benthalianus* the still greater depth of 3125 fathoms (see M'Intosh, Report on the Annelida, Zool. Chall. Exp., pt. 34, p. 508).

of the order are quite absent. The valves of *Scalpellum*, *Balanus*, etc., are frequently met with, but never in any abundance. The most constant remains are the valves of certain species of Ostracoda which secrete thick calcareous shells. These animals evidently lived on the bottom where their shells are found, and, although limited in numbers, extend to the most profound depths. It is seldom that any specimen of a

FIG. 26.—*Krithe producta*, Brady.

FIG. 27.—*Cythere dictyon*, Brady.

calcareous ooze from the deep sea is examined without several of the valves of these organisms being observed. *Krithe producta* and three species of *Cythere* are almost universally present in deep-sea deposits.[1]

Echinodermata.—Representatives of the various orders of Echinoderms are widespread over the sea-bottom at all depths, and one would expect to find their remains somewhat abundant in the deposits now forming in the ocean; like the Crustacea, however, the areolar nature of the shells seems to determine the removal of the hard parts in solution shortly after the death of the animal. It is seldom that a large sample of Globigerina Ooze or Pteropod Ooze can be examined without some fragments of Echini spines being observed, but it is the exception to meet with any other remains in the deep-sea deposits. In Coral Muds and Sands and other deposits near land, fragments of the shells and spines of Echini, Starfish, and Ophiurids are frequently present, and in moderate depths fragments of Crinoids have been noticed.[2]

Polyzoa.—There are many species of Polyzoa or Bryozoa which secrete carbonate of lime, and in some localities the fragments of these compound organisms make up a large part, if not the greater part, of the deposits, as, for instance, in 110 to 150 fathoms off Tristan da Cunha, and in 50 to 300 fathoms off Marion and Prince Edward Islands. In both shallow and deep water fragments of Polyzoa are nearly always to be observed, but in the pelagic deposits they make up but an insignificant part of the carbonate of lime present.[3]

[1] See Hoek, Report on the Cirripedia, Zool. Chall. Exp., pt. 25; Brady, Report on the Ostracoda, Zool. Chall. Exp., pt. 3.

[2] See Agassiz, Report on the Echinoidea, Zool. Chall. Exp., pt. 9; Sladen, Report on the Asteroidea, Zool. Chall. Exp., pt. 51; Lyman, Report on the Ophiuroidea, Zool. Chall. Exp., pt. 14; Carpenter, Report on the Crinoidea, Zool. Chall. Exp., pts. 32 and 60.

[3] See Busk, Report on the Polyzoa, Zool. Chall. Exp., pts. 30 and 50; Waters, Zool. Chall. Exp., pt. 79.

Brachiopoda.—These organisms are found living even in the greatest depths of the ocean; occasionally they are dredged in large numbers in depths down to 300 fathoms, but in deep water it is only rarely that their remains can be detected in the deposits.[1]

Pteropoda and Heteropoda.—A large number of these pelagic Molluscs secrete carbonate of lime shells, and this is especially the case in tropical waters. In polar regions the place of the shelled species is taken, with the exception of one or two small species of *Limacina*, by shell-less species. The shells of the tropical species make up a large part of some tropical and subtropical deposits from moderate depths, in which there is a relatively small quantity of land debris. Like the pelagic Foraminifera, these pelagic Mollusca attain their greatest development in the warm oceanic currents, and diminish both in the number of species and the size and mass of the shells as the colder currents of the polar regions are approached. Like the pelagic Foraminifera, also, the distribution of the living animals at the surface corresponds with the distribution of their dead shells over the sea-bed, with certain limits as to depth. The dead shells are not universally distributed over the floor of the ocean, for in all the deposits from the greater depths of the ocean they are absent, or only rare fragments are met with, and as a general rule they disappear from deep-sea deposits with increasing depth in the same way as the shells of pelagic Foraminifera, the more delicate and fragile ones being found only in the lesser depths. In the deposits of polar regions these shells are very rarely, if ever, observed in the deposits, and certainly never make up any sensible part of the carbonate of lime in the muds or oozes. A list of the species, whose shells may constitute a large part of a Pteropod Ooze, is given on page 224.[2]

The Pteropoda and Heteropoda live in the surface and subsurface waters of the ocean, are Holoplanktonic, and belong exclusively to the pelagic Plankton. It has never been suggested that they lived exclusively, or for any portion of their lives, at the bottom of the sea, as was long maintained with reference to the pelagic Foraminifera. It is interesting then to point out that the shells of these pelagic Molluscs follow the same order with respect to distribution in depth as the shells of pelagic Foraminifera. They are abundant, and the shells of all species appear to be represented, in the shallower deposits, but with increasing depth the more delicate shells first disappear, and then the thicker and more massive ones. In depths of 2300 fathoms they are wholly removed from the deposits, or only an occasional fragment is encountered. In the surface waters, however, the living animals are quite as abundant over the region where the shells are absent, as over the region where they are present, on the bottom. In whatever way we may account for the removal of the Pteropod shells from the deeper deposits of the ocean, the same reasoning is evidently applicable to the removal of the shells of pelagic Foramini-

[1] See Davidson, Report on the Brachiopoda, Zool. Chall. Exp., pt. 1.

[2] See Pelseneer, Report on the Pteropoda, Zool. Chall. Exp., pt. 65; Smith, Report on the Heteropoda, Zool. Chall. Exp., pt. 72.

fera. Some of the more delicate Foraminiferous shells, like *Candeina*, disappear at the same depths as the Pteropod shells, but the denser shells of *Sphæroidina* and *Pulvinulina* persist to greater depths. In all cases the greater the surface of shell exposed to the action of sea-water in proportion to its total mass the sooner does the shell appear to be dissolved. In Molluscan shells the conchioline may for a time protect the calcareous structures, but when putrefaction sets in it accelerates solution.

Gasteropoda and Lamellibranchiata.—The pelagic species, *Ianthina rotundata*, having the same habitat and distribution as the Pteropods, may be found associated with these pelagic shells, but it never occurs in any great abundance in deposits. Many larval shells of Gasteropods and Lamellibranchs are also frequently present along with Pteropod shells in the shallower deposits not far removed from coasts. The shells of adult Gasteropods and Lamellibranchs are well known to form extensive beds in many shallow-water areas, and the shells of these Molluscs make up a considerable proportion of the carbonate of lime in all deposits near the shores of continents and islands. In nearly all the pelagic deposits the shells of Gasteropods and Lamellibranchs, or their fragments, can be detected when any considerable quantity of the deposit is examined, but they never form more than a small percentage of the carbonate of lime present.[1] On the whole the Gasteropods and Lamellibranchs are poorly represented in the abyssal regions, and their shells are thin and fragile. In this respect alone there is a wide difference between the Pteropod and Globigerina Oozes of recent seas and the white chalk of the Cretaceous period, which was evidently laid down in much shallower water than these organic oozes.

Cephalopoda.—The only fragments of this order that have been observed in deep-sea deposits are the beaks, and these are occasionally found even in a small specimen from the sounding tube; they can nearly always be picked out from the washings when a large quantity of ooze is passed through fine sieves. In some shore dredgings, however, fragments of cuttle-fish bones have been met with.[2]

Fishes.—When we remember the enormous numbers of fishes that inhabit the ocean, the rarity of their remains in nearly all marine deposits is a very striking fact.[3] In only three or four instances were any fish bones, other than otoliths and teeth, observed in the deposits brought up in the dredges and trawls. In 1875 fathoms, off the coast of Japan, two vertebræ were found, and on other occasions a scapula and a vertebra. The otoliths of fish are, however, tolerably abundant in all the calcareous oozes, and are frequently present in Red Clays. That otoliths can resist the solvent action of sea-water better than the other bones probably arises from the dense structure of these bones, and possibly also from the difference in their composition when compared with the other bones of fish, the otoliths being mostly composed of carbonate of lime, while

[1] See Watson, Report on the Gasteropoda, Zool. Chall. Exp., pt. xlii.; Smith, Report on the Lamellibranchiata, Zool. Chall. Exp., pt. xxxv.

[2] See Hoyle, Report on the Cephalopoda, Zool. Chall. Exp., pt. xliv.

[3] See Günther, Report on the Fishes, Zool. Chall. Exp., pts. vi., lvii., and lxxviii.

the other fish bones are largely made up of phosphate of lime associated with much albuminoid matter. The otoliths of a cod gave on analysis :[1]—

Lime (CaO),	53·08
Carbonic Acid (CO_2),	43·85
Magnesia (MgO),	2·71
Phosphoric Acid (P_2O_5),	trace
Alumina (Al_2O_3),	0·22
Silica (SiO_2),	0·33
	100·19

The teeth of fish are rather rare in terrigenous deposits and tolerably abundant in some pelagic deposits; in certain regions of the Central Pacific and in the other oceans in great depths far removed from land, the teeth of sharks were most exceptionally abundant in many of the deeper trawlings and dredgings. These sharks' teeth, it will be observed, are from red clay areas as a rule, it being the exception to find any of the large specimens in the calcareous oozes or terrigenous deposits. In general all that remains is the hard dentine or enamel, the whole of the vaso-dentine having disappeared. In this respect the condition of these teeth differs from that of those belonging to the same species from the Tertiary deposits in Malta, Carolina, Australia, and from one tooth dredged by Agassiz from the existing sea-bed in relatively shallow water off the coast of North America;[2] in all these the vaso-dentine and the base are almost always preserved. In the following list details are given as to the number, size, and condition of the teeth procured by the Challenger Expedition in the trawlings and dredgings in the order of the stations :[3]—

Atlantic Ocean.

Station 16, 2435 fathoms.—Two *Oxyrhina* teeth, the larger 1½ inches (38 mm.) in length; one *Lamna*, about an inch (25·4 mm.) in length.

Station 106, 1850 fathoms.—One *Lamna* tooth, 1½ inches (38 mm.) in length.

Southern Indian Ocean.

Station 160, 2600 fathoms.—Two *Carcharodon* teeth, one broken, over 1½ inches (38 mm.) in length, and three small *Lamna* teeth.

Pacific Ocean.

Station 237, 1875 fathoms.—Two vertebræ and several large otoliths of fish.

Station 241, 2300 fathoms.—One small *Lamna* tooth, a little over half an inch (12·7 mm.) in length.

[1] Made by J. G. Ross.

[2] See Agassiz, *Three Cruises of the "Blake,"* vol. i. p. 276, 1888.

[3] Dr. Albert Günther of the British Museum examined these teeth and was satisfied that the determinations were, as far as possible, correct.

Station 244, 2900 fathoms.—One *Lamna* tooth, $\frac{3}{4}$ inch (19 mm.) in length.

Station 248, 2900 fathoms.—One *Lamna* tooth, about an inch (25·4 mm.) in length, slightly coated with manganese.

Station 252, 2740 fathoms.—One *Carcharodon* tooth, fully $1\frac{3}{4}$ inches (44·4 mm.) in length, imbedded in the centre of a nodule, the layers of manganese around the tooth varying from $\frac{1}{2}$ to $\frac{3}{4}$ inch (12·7 to 19 mm.) in thickness; also four small *Oxyrhina* teeth imbedded in nodules.

Station 256, 2950 fathoms.—Four *Oxyrhina* teeth, the largest $1\frac{1}{2}$ inches (38 mm.) in length, and five *Lamna* teeth; three of the teeth were very deeply imbedded in manganese depositions.

Station 274, 2750 fathoms.—One large *Carcharodon* tooth, fully 2 inches (51 mm.) in length, and broken piece of another large *Carcharodon* tooth, both deeply imbedded in manganese; also nine *Oxyrhina* and five *Lamna* teeth,[1] the largest $1\frac{1}{2}$ inches (38 mm.) in length, some deeply imbedded, along with several fragments of teeth and numerous small teeth of other fish.

Station 276, 2350 fathoms.—Over 250 sharks' teeth and fragments were counted from this station, including four large *Carcharodons*, from 2 to $2\frac{1}{2}$ inches (51 to 64 mm.) in length, and fragments of similar large teeth; fourteen smaller serrated teeth,[2] similar to *Corax* or *Carcharias;* sixty teeth like *Lamna*,[3] of various sizes, the largest $1\frac{1}{2}$ inches (38 mm.) in length; thirty *Oxyrhina* teeth, the largest, *Oxyrhina trigonodon*,[4] $1\frac{1}{2}$ inches (38 mm.) in length; fifteen teeth which may possibly be the central fangs of *Otodus;* and over one hundred small teeth, less than $\frac{1}{2}$ inch (12·7 mm.) in length. The majority were more or less deeply imbedded in manganese. There were also two tabulated teeth of *Tetradon*, and four large otoliths of fish, similar to those of the Tunny.

Station 281, 2385 fathoms.—116 sharks' teeth and fragments were counted from this station, including eleven *Carcharodons*, one, the largest obtained during the cruise, being fully 4 inches (10 cm.) in length, belonging to *Carcharodon megalodon*,[5] the others 2 inches (51 mm.) and less in length;[6] and over one hundred teeth of *Oxyrhina*, *Lamna*, &c., the largest 2 inches (51 mm.) in length.[7] Most of the teeth had a slight coating of manganese, while a few were deeply imbedded.

Station 285, 2375 fathoms.—Over 1500 sharks' teeth and fragments of considerable size were counted from this station, in addition to immense numbers of very small teeth and fragments. There were fifteen nearly perfect *Carcharodons*,[8] the largest $3\frac{1}{4}$ inches (83 mm.) across the base and $2\frac{1}{2}$ inches (64 mm.) in length, and about twenty fragments of similar teeth; twenty small teeth, like *Corax* or *Galeus* or *Hemipristis;*[9] about two hundred perfect *Oxyrhina* and *Lamna* teeth of various sizes,[10] in addition to

[1] See Pl. VI. figs. 8, 16.
[2] See Pl. V. fig. 12.
[3] See Pl. VI. fig. 19.
[4] See Pl. VI. fig 1.
[5] See Pl. V. fig. 1.
[6] See Pl. V. figs. 2–5.
[7] See Pl. V. fig. 13; Pl. VI. figs. 9, 10, 13, 15, 17.
[8] See Pl. V. figs. 6, 7.
[9] See Pl. V. figs. 10, 11.
[10] See Pl. V. figs. 2–7; Pl. VI. figs. 12, 18, 20, 21, 23.

many hundred fragments and teeth of small size. The majority of the teeth were more or less thickly coated with manganese, the smaller ones apparently to a greater extent than the larger ones. The hard dentine of one of the *Carcharodon* teeth was found to contain 33·66 per cent. of phosphoric acid, equal to 73·48 per cent. of tricalcic phosphate, and 2·28 per cent. of fluorine. The inside of the tooth was filled with deposits of manganese, iron, and clayey materials, resembling the manganese nodules in composition, and containing only 0·83 per cent. of phosphoric acid.

Station 286, 2335 fathoms.—Over 350 sharks' teeth and fragments were counted from this station, including about thirty *Carcharodons*,[1] half of them perfect, the largest nearly 3 inches (76 mm.) in length; about two hundred *Oxyrhina* and *Lamna* teeth,[2] the largest of the former 2½ inches (64 mm.), and of the latter 1¾ inches (44·4 mm.), in length; and over one hundred small teeth, *Hemipristis*, &c.[3] All the teeth were more or less deeply imbedded in depositions of manganese. Three of the *Oxyrhina* teeth yielded 32·58 per cent. of phosphoric acid, equivalent to 71·12 per cent. of tricalcic phosphate, while the black material which filled the interior of the teeth yielded only 7·97 per cent. of phosphoric acid, equivalent to 17·39 per cent. of tricalcic phosphate.

Station 289, 2550 fathoms.—One perfect *Oxyrhina* tooth, about 1⅛ inches (28·6 mm.) in length, deeply imbedded, and fragment of a similar tooth.

Station 293, 2025 fathoms.—One *Carcharodon* tooth, about 1¾ inches (44·4 mm.) in length, and one *Oxyrhina* tooth, about 1¼ inches (31·6 mm.) in length, the former with, the latter without, a coating of manganese.

Mammalia.—The remains of Mammalia were exceedingly rare in the great majority of the Challenger's dredgings and trawlings. In all the terrigenous deposits and calcareous oozes they were not observed, but the "Blake" expedition dredged off the coast of North America a few bones, and one or two sharks' teeth belonging to the same species as some of those noted in the foregoing list. Numerous remains of Cetaceans were collected by the Challenger in the same trawlings in which the sharks' teeth were obtained, principally the dense earbones and beaks of Ziphioid whales, but besides these were a few fragments of the other more areolar bones, evidently in the process of being dissolved by the action of the sea-water. A microscopic examination of the nuclei of the manganese nodules revealed the fact that many of these concretions had been formed around bone fragments, the structure of which had almost disappeared. The following list gives the number, condition, and nature of these Mammalian remains in the trawlings and dredgings at the several stations where they were procured :[4]—

[1] Sections of one are given in Pl. X. figs. 4, 4*a*.

[2] See Pl. VI. figs. 14, 22; Pl. X. fig. 5 (section).

[3] See Pl. V. figs. 8, 9.

[4] All these bones were examined and determined by Professor Sir William Turner; see Report on the Cetacea, Zool. Chall. Exp., part iv.

ATLANTIC OCEAN.

Station 131, 2275 fathoms.—A tympanic bulla, 2½ inches (63 mm.) in length, closely corresponding with that of *Ziphius cavirostris*.[1]

SOUTHERN INDIAN OCEAN.

Station 143, 1900 fathoms.—A small indeterminable fragment of bone, about the size of a marble, consisting of cancellated tissue, and coated and impregnated with manganese.

Station 160, 2600 fathoms.—Several tympanic bullæ, three apparently allied to *Mesoplodon*,[2] another belonging to *Delphinus*, and a petrous bone apparently of a *Globiocephalus*; also a nodulated mass of bone, coated and impregnated with manganese, and three small fragments, one a flat bone.

PACIFIC OCEAN.

Station 274, 2750 fathoms.—Tympano-periotic bone of *Globiocephalus*,[3] another of one of the Delphinidæ,[4] another like that of a *Mesoplodon*, and six separate petrous bones and four separate tympanic bullæ belonging to the smaller species of Cetacea; also a small fragment of bone forming the nucleus of a manganese nodule.

Station 276, 2350 fathoms.—Two tympano-periotic bones of *Mesoplodon*, closely resembling *Mesoplodon layardi*,[5] eight separate petrous bones and six tympanic bullæ, one of the latter belonging to *Globiocephalus* and another allied to *Kogia*, the rest apparently those of *Delphinus*.

Station 281, 2385 fathoms.—Six tympanic bones, 1 to 1¼ inches (25 to 32 mm.) in length, and three petrous bones, all belonging to the family of dolphins.

Station 285, 2375 fathoms.—Four tympanic bones, 2·7 to 4·7 inches (7 to 12 cm.) in length, belonging to the genus *Balænoptera*;[6] another closely allied, 3½ inches (9 cm.) in length; twenty-five smaller tympanic bones and eighteen petrous bones, belonging to the genera *Mesoplodon*, *Delphinus*, and *Globiocephalus*; a petro-mastoid bone, 4 inches (10 cm.) in length, probably belonging to one of the Baleen whales; and numerous small fragments of bone thickly coated with manganese.

Station 286, 2335 fathoms.—About ninety tympanic bullæ were recognised, and various fragments coated with and imbedded in manganese, which appeared to be portions of tympanic bones, in addition to forty-two detached petrous bones. A bulla nearly 6 inches (15 cm.) in length, and a fragment of a similar bone, belong probably to *Balænoptera antarctica*;[7] two bullæ, one 3·6 inches (91 mm.) the other 3·4 inches (86 mm.) in length, belong probably to *Balænoptera rostrata*[8] (possibly *Balænoptera huttoni*?); several bullæ, about 3 inches (76 mm.) in length, belong to *Balænoptera*, probably an extinct species.[9] Two bones, 3 inches (76 mm.) in length, probably belong to the

[1] Figured in Zool. Chall. Exp., pt. iv. pl. ii. fig. 10.
[2] See Pl. VIII. fig. 11.
[3] See Pl. VIII. figs. 4, 5.
[4] See Pl. VIII. figs. 12, 13.
[5] See Pl. VII. figs. 6, 7.
[6] See Pl. VII. fig. 1.
[7] See Pl. VII. fig. 2.
[8] See Pl. VII. fig. 3.
[9] Figured in Zool. Chall. Exp., pt. iv. pl. ii. fig. 11.

Balænidæ.[1] Eight bullæ, 2 to 3 inches (64 to 76 mm.) in length, somewhat resemble those of *Ziphius cavirostris*, though without the unciform lobe.[2] About forty specimens, 1·6 to 2·3 inches (41 to 58 mm.) in length, belong to the genus *Mesoplodon;* the two largest, in which the petrous bone was united with the tympanic, could not be determined, but the rest apparently belong to *Mesoplodon layardi*.[3] Twenty-four specimens, 1 to 1·7 inches (25 to 43 mm.) in length, belong apparently to the Delphinidæ; the longest resembles the bulla of *Globiocephalus*,[4] others belong to the genus *Delphinus*, while the smallest are like those of the common porpoise. One specimen belongs to the genus *Kogia*,[5] and other two are closely allied to it.[6]

The larger petrous bones, the longest being 2 inches (51 mm.) in length, probably belong to the genus *Mesoplodon*, the others to the genus *Delphinus*, while two specimens are smaller than those of the common porpoise.[7] There were fourteen specimens consisting of the petrous and a portion of the elongated mastoid element continuous with it, varying in length from 2·5 to 3·6 inches (64 to 91 mm.), belonging apparently to the Baleen whales.[8]

There were also numerous fragments of other bones, including a beak of a Ziphioid whale,[9] measuring over 8 inches (20 cm.) in length, and three smaller fragments of beaks of Ziphioids; numerous flat fragments, portions of the brain case,[10] and one or two probably bits of the shaft of a rib. An irregular mass of spongy bone 8 × 4 × 3 inches (20 × 10 × 8 cm.), not nearly so much impregnated with manganese as the rest, and two smaller fragments,[11] one 5 × 5 inches (13 × 13 cm.), are apparently portions of the expanded wings of superior maxillæ. Nearly two hundred small fragments, forming the nuclei of manganese nodules, exhibited evidence of bone structure.

A portion of the spongy mass of whale's bone was completely analysed by Professor Dittmar, F.R.S.,[12] with the following results :—

Moisture,	3·06
Combined water,	3·66
Phosphoric acid,	27·49
Carbonic acid,	4·14
Fluorine, 0·71 = ($F_2 - O$),	0·41
Lime,	39·00
Magnesia,	2·01
Ferrous oxide,	1·04
Ferric oxide,	4·83
Binoxide of manganese,	1·61
Alumina,	2·70
Silica and substances insoluble in hydrochloric acid,	9·08
Alkalies and loss,	0·97
	100·00

[1] See Pl. VII. figs. 4, 5. [2] Figured in Zool. Chall. Exp., pt. iv. pl. ii. fig. 12. [3] See Pl. VIII. figs. 1, 2.
[4] See Pl. VIII. fig. 6. [5] See Pl. VIII. fig. 7; also figured in Zool. Chall. Exp., pt. iv. pl. ii. fig. 13.
[6] Figured in Zool. Chall. Exp., pt. iv. pl. ii. fig. 14. [7] See Pl. VIII. figs. 8, 9, 14. [8] See Pl. VIII. fig. 3.
[9] See Pl. X. fig. 1. [10] See Pl. X. fig. 2. [11] See Pl. X. fig. 3. [12] See Appendix III.

The insoluble residue consisted apparently of amorphous silica. The part soluble in hydrochloric acid seemed to be a mixture of—

Phosphate of lime,	60·0	per cent. of the whole substance.
Carbonate of lime,	9·4	„ „
Fluoride of calcium,	1·4	„ „
Binoxide of manganese,	1·6	„ „
Ferric oxide,	4·8	„ „

and minor constituents.

A portion of a flat whale's bone, much impregnated with manganese, was submitted to analysis. A small portion in the centre, comparatively uncoloured by the manganese, was used for the following determinations:—

Moisture,	2·87	per cent.
Phosphoric acid,	29·13	„
Fluorine,	1·44	„
Lime,	36·05	„
Substances insoluble in hydrochloric acid,	2·91	„

There was an appreciable quantity of manganese present, and also a trace of cobalt. The outer manganiferous portion was completely analysed, with the following results:—

Portion insoluble in hydrochloric acid,	5·76	
Total water,	9·77	
Manganous oxide,	20·22	
Loose oxygen,	3·49	
Ferric oxide,	6·54	
Alumina,	1·66	
Lime,	19·71	
Magnesia,	7·42	
Potash,	0·55	
Soda,	1·12	
Phosphoric acid,	18·59	= 40·90 per cent. tricalcic phosphate.
Carbonic acid,	3·87	
Traces of copper, chlorine, fluorine, and loss,	1·30	
	100·00	

The manganese is probably present mostly as hydrated binoxide, and partly as protoxides.

Another portion of a flat whale's bone, in which the manganese was pretty well diffused throughout, was used for the following determinations:—

Moisture,	5·49	per cent.
Combined water,	6·88	„
Phosphoric acid,	13·05	„
Fluorine,	0·65	„

One-half of an earbone of *Balæna* (?) was analysed, and for that purpose the manganese filling the cavity of the bone was scraped out and analysed separately. The white siliceous-looking core gave the following results:—

Insoluble in acid,	0·06	
Moisture,	2·21	
Combined water,	2·22	
Phosphates of iron and alumina,	0·42	
Phosphoric acid,	34·13	= 74·5 per cent. tricalcic phosphate.
Carbonic acid,	6·61	
Fluorine, 1·4 = (F_2 − O),	0·81	
Sulphuric acid,	0·81	
Chlorine,	trace	
Lime,	49·85	
Magnesia,	0·77	
Alkalies and loss,	2·11	
	100·00	

The contents of the cavity gave on analysis the following results:—

Insoluble in acid,	13·66
Total water,	27·00
Manganous oxide,	27·13
Loose oxygen,	3·13
Ferric oxide,	8·34
Lime,	4·34
Magnesia,	4·03
Alumina,	6·54
Silica,	1·31
Phosphoric acid,	2·39
Potash,	1·07
Soda,	2·39
Nickel and copper,	traces
	101·33

The insoluble residue was apparently all amorphous silica. The soluble portion apparently consists of hydrated sesquioxides of manganese and iron and decomposible silicates.

The inner, almost uncoloured, portion of an earbone of *Balænoptera* was used for the following determinations:—

Moisture,	1·60 per cent.	
Combined water,	1·34 ,,	
Phosphoric acid,	31·21 ,,	= 68·13 per cent. tricalcic phosphate.
Fluorine,	1·89 ,,	

The inner portion of the large *Ziphius* beak gave the following results :—

Moisture,	1·14 per cent.	
Combined water,	2·78 „	
Carbonic acid,	6·81 „	
Phosphoric acid,	33·30 „	=72·69 per cent. tricalcic phosphate.
Fluorine,	1·65 „	

Station 289, 2550 fathoms.—Three large tympanic bones, 3 to 4 inches (8 to 10 cm.) in length, apparently belonging to the genus *Balænoptera*, and two nodules with bony nuclei.

The inner portion of an earbone of *Balænoptera* was used for the following determinations :—

Moisture,	1·61 per cent.	
Phosphoric acid,	32·73 „	=71·44 per cent. tricalcic phosphate.
Fluorine,	1·61 „	

Station 293, 2025 fathoms.—One small indeterminable fragment of bone, impregnated with manganese.

Station 299, 2160 fathoms.—One bilobed tympanic bulla, with the petrous bone attached, apparently of a *Globiocephalus*.

On comparing the preceding analyses of these deep-sea bones and teeth[1] with analyses of recent and fossil bones,[2] it is found that as regards the phosphoric acid there is not much divergence, except where there is much manganese in the specimen: in deep-sea bones the percentage varies from 27 to 34, in recent bones 22 to 34, and in fossil bone 33; the same is the case with the lime: in deep-sea bones 36 to 49 per cent., in recent bones 30 to 41 per cent., and in fossil bone 48 per cent.

The most striking difference is in the fluorine, the percentage of which in recent bones is only 0·004 to 0·032 per cent., in fossil bone 1·50 per cent., while in deep-sea bones it varies from 0·65 to 1·89 per cent., and in deep-sea teeth it reaches 2·28 per cent. These deep-sea specimens of bones and teeth thus resemble fossil bones in the large percentage of fluorine they contain. This fluorine might be assumed to be the original fluorine of the bones rendered more abundant by the removal of the lime salts, but more probably it owes its origin to a continuous, though slowly progressing, double decomposition between the phosphate of the bone and the trace of dissolved fluorides in the sea-water.

Some of the bones and teeth were in a much better state of preservation than others; in some the coating of manganese was very thin, and the Haversian canals and lacunæ were but little impregnated by that substance, so that a fractured surface was greyish white; in others, not only were the bones thickly encrusted, but the canals and lacunæ were nearly all infiltrated with the manganese, as will be seen by reference to the illustrations on Plate X., so that the fractured surface was brown or black, and the bones very

[1] See Analyses Nos. 137 to 153, Appendix III. [2] See Analyses Nos. 153A, B, C, D.

brittle. The great majority of the large cancellated bones of the whales appear to have been wholly removed from the deposits through the chemical action of the sea-water.

With respect to the distribution of the earbones and fragments of other Cetacean bones, it will be observed that no specimens were obtained north of the equator either in the Atlantic or Pacific. From terrigenous deposits only one earbone was dredged, viz., at Station 299, 2160 fathoms, over 100 miles from the South American coast, where the deposit was a Blue Mud. These Cetacean bones are also rare in Globigerina Ooze, being obtained in only three instances, viz., one bulla at Station 131, 2275 fathoms, in the South Atlantic (the only Cetacean bone procured in the Atlantic); a fragment at Station 143, 1900 fathoms, 100 miles south-east of the Cape of Good Hope; and another fragment at Station 293, 2025 fathoms, in the South Pacific. With the above exceptions all the bones of Cetaceans procured during the Challenger Expedition were dredged from Red Clays and Radiolarian Oozes, and these are all situated in the Central South Pacific, excepting Station 160, 2600 fathoms, in the Southern Indian Ocean, 500 miles southwest of Australia.

The preservation of the earbones and fragments of beaks of Ziphioid whales is to be accounted for by the great density of these portions of the skeleton, and the consequent small amount of surface presented to the action of sea-water when compared with the cancellated bones. Professor Sir William Turner points out that he could not identify any of the bones as belonging to the great Sperm Whale (*Physeter macrocephalus*), although the track of the Challenger, where these hauls of Cetacean bones were made, was through the part of the Pacific frequented by that huge Cetacean.

The distribution of the sharks' teeth in the deposits is similar to that of the bones of Cetaceans, although they were dredged more frequently. They are most abundant in the red clay areas far removed from land, and especially in those of the Central South Pacific; they were less frequently taken in the organic oozes of the deep sea, and only in one or two instances in the terrigenous deposits surrounding continental or other land. It seems undoubted that many of the teeth of sharks and the bones of the Ziphioid whales belong to Tertiary and extinct species.

In the foregoing paragraphs we have indicated the various kinds of organic structures of a calcareous nature which enter into the composition of marine deposits, and we have to some extent pointed out their bathymetrical and geographical distribution. Those structures, like the bones of fish and marine mammals, or even the exoskeletons of Crustacea, which are very areolar in structure, and contain a large quantity of phosphate of lime associated with much albuminoid matter, appear to be able to resist the solvent action of sea-water only for a relatively short time, so that they disappear from marine deposits much more rapidly than the bones with a denser structure. The otoliths of fish, the hard dentine of sharks' teeth, and the dense earbones and beaks of certain whales, resist for a longer time the solvent action of the sea-water, and may therefore accumulate and be preserved in the deposits. But from what has been said as to the condition of these bones, it cannot be doubted that even the densest specimens would ultimately quite disappear if continually exposed at the bottom of the sea. In deposits where there is a more rapid accumulation, it is not improbable that these bones and teeth would be covered up by detrital matters, before being wholly dissolved, and being thus protected some remnants of them might be preserved in the beds now forming at the bottom of the ocean.

In the case of shells and other skeletal structures, like Corals, Molluscs, Foraminifera, and calcareous Algæ, there is likewise a difference in the extent to which they can resist the destructive effects of exposure to sea-water. Those which have a porous structure, with a large quantity of albuminoid matter in the shell or skeleton, disappear much more rapidly than those compact shells with a close texture, which consequently expose a relatively much smaller surface to the action of the surrounding water. As already indicated, the conchioline, that is, albuminoid matters associated with the calcareous structures, would at first, as shown by Bischoff, protect the calcareous structures; but when putrefaction sets in, the areolar structure and the decomposing organic matters would accelerate the solution of the calcareous shells and skeletons. In all cases, however, calcareous structures of all kinds are slowly removed from the bottom of the ocean on the death of the organisms, unless rapidly covered up by the accumulating deposits, and in this way protected to a certain extent from the solvent action of the sea-water. It is evident from the Challenger investigations that whole classes of animals with hard calcareous shells and skeletons, remains of which one might suppose would be preserved in modern deposits, are not there represented; although they are now living in immense numbers in the surface waters or on the deposits at the bottom, in some regions all trace of them has been removed by solution. A similar removal of calcareous organic structures has undoubtedly taken place in the marine formations of past geological eras.[1]

In the warm waters of the tropical regions of the ocean there is the greatest development of lime-secreting organisms. This is rendered evident not only by the vast organic accumulations known as coral reefs, but by what has been said above as to the number of pelagic species of calcareous Algæ, Foraminifera, and Molluscs, which inhabit the surface and subsurface waters of the tropics, and whose dead remains form organic accumulations at the bottom of the sea far exceeding in extent and importance those of coral reefs. On the other hand, there is a restricted development of these calcareous structures both in the cold waters of the deep sea and in those of the temperate and polar regions; it is observed that in the shells and skeletons of deep-sea animals there is a marked deficiency in carbonate of lime, and the same holds good, in a general sense, with the organisms in polar waters. The probable cause of this distribution has been indicated when treating of the changes produced by organisms in the constitution of sea-water salts.[2]

[1] Murray, "The Maltese Islands, with special reference to their Geological Structure," *Scot. Geogr. Mag.*, vol. vi. p. 482, 1890.

[2] See pp. 254–256.

In tropical and temperate regions there is likewise a much greater accumulation of carbonate of lime remains on the bottom than at like depths towards the polar areas, where the surface waters have a low temperature throughout the year. At the present time, then, it is evident that there is a decided tendency for carbonate of lime deposits to accumulate towards the equatorial regions of the ocean. In the central parts of the equatorial regions of the ocean basins this carbonate of lime is almost exclusively derived from the shells and skeletons of pelagic organisms whose habitat is in the warm surface and subsurface waters. That these pelagic shells should be abundant on the bottom in tropical regions at nearly all moderate depths, and wholly or almost wholly absent from the deposits in all the greater depths, has been regarded as one of the most remarkable facts brought to light by the Challenger investigations. This fact, however, admits of a ready explanation, if it be remembered that all these shells are subject to solution immediately on the death of the organisms, that only a small number of them—the more delicate ones—are wholly removed in falling through a moderate depth of water, while a very large proportion are wholly dissolved in falling through a depth of four or five miles.

Mr. Murray made a large number of experiments during the expedition with the view of ascertaining the rate of fall of pelagic organisms in sea-water. The experiments were conducted in a long glass cylinder, and the rate was found to vary greatly according to the shape of the shell and the albuminoid matter associated with it. According to the results of these experiments it would take from three to six days for the shells to reach a depth of 2500 fathoms. In the deeper layers the rate of fall would probably be much slower than in the surface layers, owing to the shells being less compressible than water.[1] It has also been shown that solution of carbonate of lime shells takes place more rapidly under pressure.[2] In this dissolution of the carbonate of lime shells the reaction referred to on pages 255 and 256 appears to play an important role. Besides it must be remembered that in the greater depths of the ocean, those shells which may reach the bottom are not covered up so rapidly by other shells falling from the surface, as they undoubtedly are in the shallower depths, where large numbers reach the bottom, and there accumulate. The practically motionless water in contact with the large quantity of carbonate of lime in moderate depths would in addition soon become saturated, and consequently be unable to take up more carbonate of lime, for sea-water can only take up a relatively small quantity of carbonate of lime in addition to what it normally contains. The water in contact with the deeper deposits, in which there is but little carbonate of lime, would not become thus saturated. These considerations also explain why the whole of the carbonate of lime shells are removed from the deposits at lesser depths in extra-tropical regions, where there are fewer living calcareous organisms at the surface, than in the tropics beneath the warm oceanic currents, where the surface shells are much more abundant.[3]

[1] Murray and Irvine, *Proc. Roy Soc. Edin.*, vol. xvii. p. 98.

[2] Reid, *Proc. Roy. Soc. Edin.*, vol. xv. pp. 151-157, 1888.

[3] Murray and Irvine, *Proc. Roy. Soc. Edin.*, vol. xvii. p. 97.

The gradual disappearance of the carbonate of lime remains from deep-sea deposits with increasing depth is exhibited in the following table giving the mean percentages of carbonate of lime in 231 samples of organic oozes, Red Clays, and Coral Muds from the Challenger collections, arranged in groups of 500 fathoms :—

14 cases	under 500	fathoms, average per cent. $CaCO_3$,	86·04
7 „	from 500 to 1000	„ „ „ . .	66·86
24 „	„ 1000 to 1500	„ „ „ . .	70·87
42 „	„ 1500 to 2000	„ „ „ . .	69·55
68 „	„ 2000 to 2500	„ „ „ . .	46·73
65 „	„ 2500 to 3000	„ „ „ . .	17·36
8 „	„ 3000 to 3500	„ „ „ . .	0·88
2 „	„ 3500 to 4000	„ „ „ . .	0·00
1 „	over 4000	„ „ „ . .	trace.

The fourteen samples under 500 fathoms are chiefly Coral Muds; in the seven samples from between 500 and 1000 fathoms there are many mineral particles from neighbouring continents and islands. In all the depths beyond 1000 fathoms the carbonate of lime is almost exclusively derived from the shells of pelagic organisms that have fallen to the bottom from the surface waters, and it will be observed that in all the greatest depths of the ocean all of these pelagic calcareous shells have disappeared from the deposits.

Many years ago Sorby[1] called attention to the importance of observing the form in which carbonate of lime is built up in animal structures: whether the shells be composed of aragonite or of calcite. According to him some shells are found to be composed wholly of calcite, while others are composed of aragonite or of layers of calcite and aragonite.[2] The prismatic aragonite is much less stable than calcite, and consequently much more soluble. It has been stated by geologists that in some geological formations the aragonite shells were completely removed from the rock while the calcite shells were preserved. Some observers[3] have attempted to apply the same reasoning to the disappearance of the calcareous shells from the deeper deposits of the oceanic basins, it being held that the aragonite shells, or the aragonite portions of shells, have been removed in solution while the calcite shells, or the calcite portions of shells, are preserved in the deposits. It does not appear to us that any sufficient explanation of the facts to which we have just referred can be found in this direction. It is exceedingly difficult to determine by optical means whether or not any of these pelagic and microscopic shells are aragonite, and it is equally difficult to apply the specific gravity test with accuracy.

[1] Sorby, Presidential Address to the Geological Society, February 1879.

[2] See also F. Leydolt, *Sitzungsb. d. k. Akad. Wiss. Wien*, Bd. xix. pp. 10–32, 1856; G. Rose, *Abhandl. d. k. Akad. Wiss. Berlin*, 1858 (Phys. Kl.), pp. 63–111.

[3] Th. Fuchs, *Sitzb. d. k. Akad. Wiss. Wien*, Bd. lxxvi. pp. 329–334, 1877; *Neues Jahrbuch für Min. etc.*, Jahrg. 1882, Bd. ii. pp. 487–584.

So far as we can judge, these shells appear to be formed of calcite. But whether the shells be calcite or aragonite they all disappear in the greatest depths of the ocean, while only those with very thin or very porous shells are removed from the shallower deposits. Any shells may be preserved in marine deposits if they be rapidly covered up by other shells, or may be removed if long enough exposed to the solvent action of normal sea-water. So far as we have been able to observe, the crystalline form of the carbonate of lime in these shells does not enter into the problem as to the causes of their gradual removal from marine deposits with increasing depth.

If we take the Challenger deposits as representative of those covering the whole floor of the ocean, then the average proportion of carbonate of lime in deep-sea deposits as a whole is about 37 per cent., and of this carbonate of lime it is estimated that fully 90 per cent. is derived from the remains of pelagic organisms that lived in the surface waters, and therefore belonging to the pelagic Plankton.

Coral Muds, Coral Sands, Pteropod and Globigerina Oozes are estimated to cover over 52,000,000 square miles of the sea bottom, and the average percentage of carbonate of lime in these deposits, taking the Challenger samples as a basis, is 76·44.

Beyond the fact that the sounding tube and dredge have occasionally penetrated about 18 inches or two feet into these deposits, there is little, if any, information as to the depth or thickness of these beds, but judging from what has taken place in past geological periods they may undoubtedly have a very great thickness.[1]

The following table exhibits the percentage of carbonate of lime in each of the types of deep-sea deposits according to the analyses of the Challenger samples, together with the average depth of each type of deposit, and the estimated area which each type covers on the sea-floor, the extent of the areas being founded on a consideration of all available information on the subject.

Table showing the Mean Depth, Mean Percentage of Carbonate of Lime, and the Estimated Area of the various Deep-Sea Deposits.

	Mean Depth in Fathoms.	Mean Percentage of $CaCO_3$.	Area, Square Miles.
Red Clay, ...	2730	6·70	51,500,000
Radiolarian Ooze, ...	2894	4·01	2,290,400
Diatom Ooze, ...	1477	22·96	10,880,000
Globigerina Ooze, ...	1996	64·53	49,520,000
Pteropod Ooze, ...	1044	79·26	400,000
Coral Mud, ...	740 }	86·41	2,556,800
Coral Sand, ...	176 }		
Other terrigenous deposits, Blue Mud, &c.	1016	19·20	16,050,000

[1] Murray, *Scot. Geogr. Mag.*, vol. vi. pp. 468–473, 1890.

e. Siliceous Organic Remains.

The organisms whose siliceous remains are met with in deep-sea deposits belong to three groups: the Diatomacea and Radiolaria, both of which have a pelagic habitat, and belong to the neritic and oceanic Plankton, and the siliceous Sponges, which live on the bottom of the sea, and belong exclusively to the Benthos. Diatoms and Radiolaria are as widely spread throughout the waters of the ocean, and their dead siliceous shells and skeletons are as widely distributed over the sea-floor, as the remains of calcareous organisms. Siliceous Sponges are also universally distributed on the sea-bed, and their skeletons contribute to the materials of marine deposits. The remains of these siliceous organisms do not, however, bulk so largely in deep-sea deposits as the calcareous remains, still in some regions they are so abundant as to make up a very large part, if not the principal part, of a deposit, as, for instance, in the case of Diatom and Radiolarian Oozes.

Diatomacea.—These siliceous Algæ are met with everywhere in the surface and sub-surface waters of the ocean. It is rare, one may say impossible, to drag a very fine tow-net through sea-water anywhere without capturing a number of these minute organisms. A considerable number of attached forms are carried from land surfaces into the ocean by rivers, and in all the shallower depths of the sea such attached forms may be procured, but the species that play so large a part in deep-sea deposits are free-swimming and pelagic. These pelagic species can generally be recognised in the tow-net gatherings from the sea-surface, if the net used be of very fine texture; when a coarse net is used they can usually be found in the stomachs of the pelagic animals obtained. At times they occur near the surface in enormous numbers, in great floating banks many miles in extent and several fathoms in depth. When the nets are drawn through these banks they are filled with a brown-coloured slimy and felt-like mass, composed principally of the frustules of Diatoms. In the tropics the banks are found at the very surface at night, and during the day their superior limit may be 10 or 15 fathoms below the surface. Floating banks of Algæ were met with by the Challenger in the Southern and Antarctic Oceans, in the Sulu Sea, in the Arafura Sea, and off the coast of North America, by H.M.S. "Triton" off the Shetland Islands, and in other regions by previous and later observers. The dried surface collections made from one of these banks by the Challenger in 54° south latitude gave on analysis:[1]—

Silica soluble in acid,	1·00
Silica insoluble in acid,	76·00
Alumina,	1·38
Organic matter,	16·75
Water,	4·87
	100·00

[1] Made by W. S. Anderson.

The largest forms hitherto discovered are from tropical or subtropical surface waters, *e.g.*, *Ethmodisci*, Castracane = *Coscinodiscus gazellæ*, Janisch, *Coscinodiscus imperator*, Janisch, *Coscinodiscus praetor*, Grove, *Coscinodiscus nobilis*, Grun., *Coscinodiscus sol*, Wallich. The most delicate species are especially tropical or subtropical, *e.g.*, the peripheral rotate rim of *Coscinodiscus sol*, many *Rhizosoleniæ*, and Chætocerotidæ; this applies equally to the degree of tenuity of the siliceous test as a whole, to the nature of its ornamentation as determined by the difficulty of microscopical resolution, and to the siliceous appendages when present.[1] This great development of Diatoms at the surface of

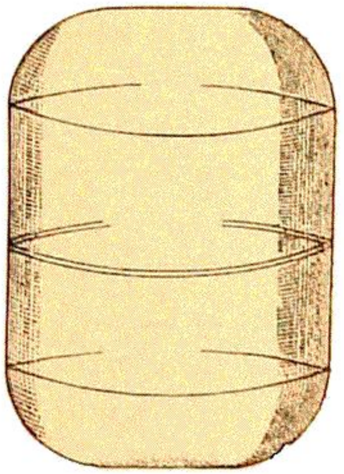


Fig. 28.—Frustule of *Ethmodiscus wyvilleanus*, Castracane ($\frac{40}{1}$).

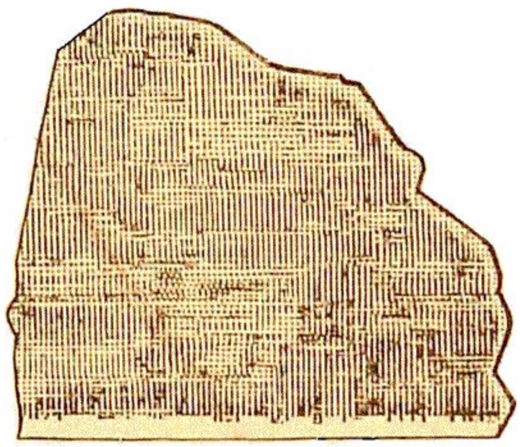


Fig. 29.—Portion of Frustule of *Ethmodiscus* sp. ($\frac{440}{1}$).

the sea takes place especially in brackish water, or in sea-water where the salinity is relatively low, as, for instance, in the Antarctic and Arctic Oceans, and in estuaries or off the mouths of great rivers. In the warm and salter waters of the ocean Diatoms are less abundant, and the frustules as a rule are much thinner than in the colder and less salt waters of the polar regions or in the warm brackish waters off continental shores in the tropics.

In deep-sea deposits the remains of these pelagic Diatoms can generally be detected if a considerable quantity of the deposit be carefully examined. In some Pteropod and Globigerina Oozes and Coral Muds, however, no trace of Diatoms have been observed after the removal of the carbonate of lime from a large sample and a subsequent careful examination of the residue; they are also extremely rare in, or absent from, some of the deep-sea clays. In terrigenous muds, especially when near the mouths of great rivers, they frequently occur in great abundance.

[1] Mr. John Rattray, M.A., F.R.S.E., a diatomist who has examined many of the Challenger deposits, says in an MS. letter to Mr. Murray:—"No dead tests are to be considered absolutely indestructible in time. Delicate Chætocerotidæ are not found in oceanic deposits nor in geological strata. *Coscinodisci* disrupt along lines passing through, and not between, the hexagonal markings; the extremities of a *Rhizosolenia* separate from the more destructible, spirally-ornamented, intermediate, cylindrical areas, and are alone preserved. In any one oceanic deposit, where the degree of solvent power must be the same for all forms, the degree of persistence varies directly as the strength of the siliceous parts, *e.g.*, cingula are less persistent than valves. On comparing the same species from widely-separated areas, the balance of evidence goes to show that more robust forms occur in more polar areas, and more delicate ones in more equatorial areas. The differences observable are slight, but specimens of *Coscinodiscus lentiginosus*, *Coscinodiscus subtilis*, &c., point to their real existence."

In the typical Diatom Ooze from Station 157, 1950 fathoms, about forty-eight species have been recognised, and it is estimated that the recognisable species together with their minute broken parts, make up fully 50 per cent. of the whole deposit; in some specimens of Diatom Ooze this percentage of Diatom remains is still higher. In the case of some deep Red Clays of the tropical Pacific, for instance, Station 229, 2500 fathoms, in lat. 22° N., 36 species of Diatoms have been recognised, but in this deposit it is estimated that the Diatom remains do not make up over 2 per cent. of the whole deposit. In the case of a Blue Mud off the coast of Japan, Station 237, 1875 fathoms, in lat. 34° N., 61 species of Diatoms have been recognised, still it is estimated that here again they do not make up more than 3 or 4 per cent. of the whole deposit. In a Radiolarian Ooze, Station 269, 2550 fathoms, in lat. 5° 54′ N., there have been recognised 51 species of Diatoms, and it is estimated that here their remains make up about 15 per cent. of the whole deposit. It will thus be noted that although Diatom remains may, in a Diatom Ooze, make up fully one-half of the whole deposit, and in a Radiolarian Ooze 15 per cent., in other kinds of deposits they seldom make up over 2 or 3 per cent. It is true that in the fine washings of a deposit a relatively large number of very minute broken-down fragments of Diatoms may be recognised, so that could these be determined with certainty, a larger percentage might be given in many cases to these Diatom remains. It is also to be noted that in tropical regions (*e.g.*, Station 269), where the remains make up only 3 or 4 per cent. of the deposit, the number of species may be greater than in a deposit from high southern latitudes (*e.g.*, Station 157), where the remains make up fully two-thirds of the whole deposit; fourteen species are recorded as common to these two deposits.[1] It seems difficult to account for the absence of Diatom remains in some deposits, except on the supposition of their removal by exposure to the action of sea-water; this subject will be referred to further on.

Radiolaria.—The Radiolaria are quite as widely distributed in oceanic waters as the Diatoms, but while Diatoms are probably more abundant near shore and in brackish waters, the Radiolaria on the other hand flourish in purely oceanic regions. One whole legion—the Acantharia—has a skeleton composed of acanthin, a substance related apparently to chitin,[2] and the representatives of this legion are almost wholly absent from the deposits at the bottom of the sea. The most abundant species in the deposits belong to the legions Nassellaria and Spumellaria. The species belonging to the fourth legion—the Phæodaria—are frequently met with in the deposits, but not so abundantly as might have been expected, this probably arising from the fact that many of the species of the Phæodaria contain a large quantity of organic matter in the composition of their shells, and thus owing to their areolar structure are more easily dissolved than the shells composed of pure silica.[3]

[1] Mr. Comber recognises 48 species and 4 varieties in Station 157, and 44 species and 1 variety in Station 269, and 11 species common to the two Stations.

[2] See Haeckel, Report on the Radiolaria, Zool. Chall. Exp., part xl. p. lxx.

[3] Haeckel, *loc. cit.*, p. lxix.

The species of Radiolaria are most abundant in tropical waters of rather low salinity, especially in the western and central Pacific and eastern Indian Oceans. In the Diatom Ooze at Station 157, in 1950 fathoms, lat. 53° 55′ S., 84 species of Radiolaria have been recognised, while in the Radiolarian Ooze at Station 225, in 4475 fathoms, lat. 11° 24′ N., 338 species have been found, and of these only six species are common to the two stations, two belonging to the order Sphæroidea, three to the Discoidea, and one to the Cyrtoidea. The results of numerous tow-net experiments appear to show that the Phæodaria, and many of the Nassellaria, live in deep water, at a temperature as low as 40° F. In a Radiolarian Ooze the percentage of Radiolaria may be as high as 60 or 70 per cent., and in a Diatom Ooze or Globigerina Ooze, as high as 10 per cent., but generally the percentage is very much less. In terrigenous deposits the Radiolarian remains seldom make up over 2 or 3 per cent. of the whole deposit.

FIG. 30.—*Tuscarora belknapi*, Murray (one of the Phæodaria). North Pacific, 500 fathoms.

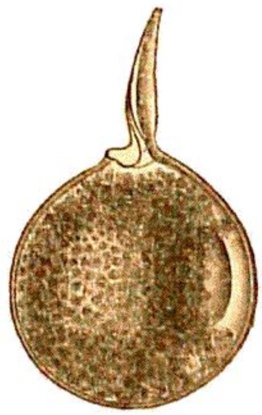


FIG. 31.—*Challengeria naresii*, Murray (one of the Phæodaria). North Pacific, 500 fathoms.

Sponge Spicules.—The spicules of siliceous Sponges are universally distributed in the different kinds of deep-sea deposits, the Hexactinellid spicules prevailing in deep water and the Tetractinellid and Monaxonid spicules in the shallower depths. In some regions siliceous Sponges were dredged in great numbers, for instance, off Kerguelen, in 120 fathoms, over one hundred specimens of *Rossella antarctica* were obtained in one haul of the trawl; at Zebu, Philippines, numerous specimens of *Euplectella* and other Sponges were obtained in 100 fathoms; off the Ki Islands, in 129 fathoms, there were eighteen species of Hexactinellida and a large number of individuals; in the Atlantic near the Cape Verdes there was procured in 1525 fathoms a large specimen of *Poliopogon amadou* (2 × 2 feet), attached to the branches of an Alcyonarian Coral; off the Kermadecs, in 630 fathoms, there was obtained another *Poliopogon* (*Poliopogon gigas*), measuring 3½ × 2 feet, which was but a fragment of what appeared to be an enormous Sponge; in the Faroe Channel a large number of specimens of *Pheronema* (*Holtenia*) were dredged from a depth of 530 fathoms by the "Porcupine." In the deposits from areas like the above, where these siliceous Sponges flourish in large numbers, the spicules are particularly abundant, and make up a large proportion of some specimens of the deposit. With the exception, however, of the samples obtained from among these patches, terrigenous or pelagic deposits do not as a rule contain a large percentage of Sponge spicules, the average proportion in any of the types of deep-sea deposits not exceeding 2 or 3 per cent. of the whole deposit. The silica of these spicules is intimately associated with organic matter, the spicules being composed of alternate layers of opal or hydrated silica and organic substances.[1] The percentage of water in the various analyses of Sponge spicules varies from 7 to 13 per cent.[2] There is abundant evidence to show that these spicules are slowly dissolved in the sea-water after the death of the animal.[3]

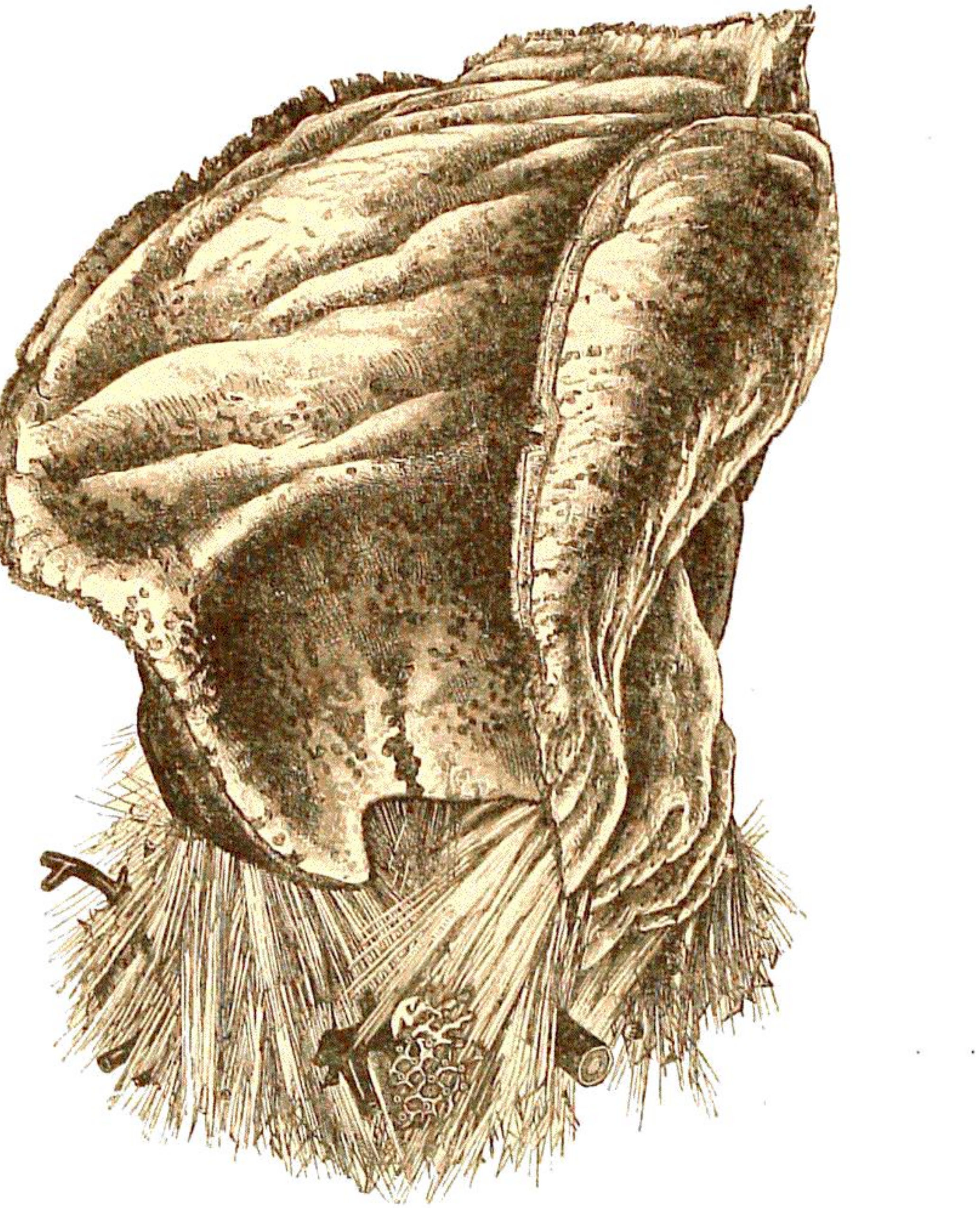


FIG. 32.—*Poliopogon amadou*, Wyville Thomson (½).

In addition to the Diatoms, Radiolarians, and Sponge spicules, there are large numbers of Foraminifera, Annelids, Crustacea, and Molluscs, which form their shells, tubes, and houses of Sponge spicules, Radiolarians, Diatoms, and other materials

[1] See Schulze, Report on the Hexactinellida, Zool. Chall. Exp., pt. liii. ; Ridley and Dendy, Report on the Monaxonida, Zool. Chall. Exp., pt. lix. ; Sollas, Report on the Tetractinellida, Zool. Chall. Exp., pt. lxiii. ; Thoulet, *Comptes Rendus*, tom. xcviii. pp. 1000, 1001.

[2] Sollas, *loc. cit.*, pp. 47 *et seq.*; Thoulet, *loc. cit.*

[3] Schulze, *loc. cit.*, pp. 26, 27.

found in marine deposits, but these do not in any case make up a large percentage of the whole deposit, and being composed of foreign particles need not be specially referred to here. The glauconitic casts of Foraminifera and other calcareous organisms frequently form a considerable part of Green Sands and Muds; these, together with other casts, will be referred to in detail further on.

The greater abundance of siliceous organisms in the surface and subsurface waters of some regions of the ocean than in others leads us to enquire if there may not also be a variation in the quantity of available silica in the waters of different regions. In the analyses of samples of sea-water, silica has always been found whenever specially looked for, and a relatively large number of attempts have been made at a quantitative

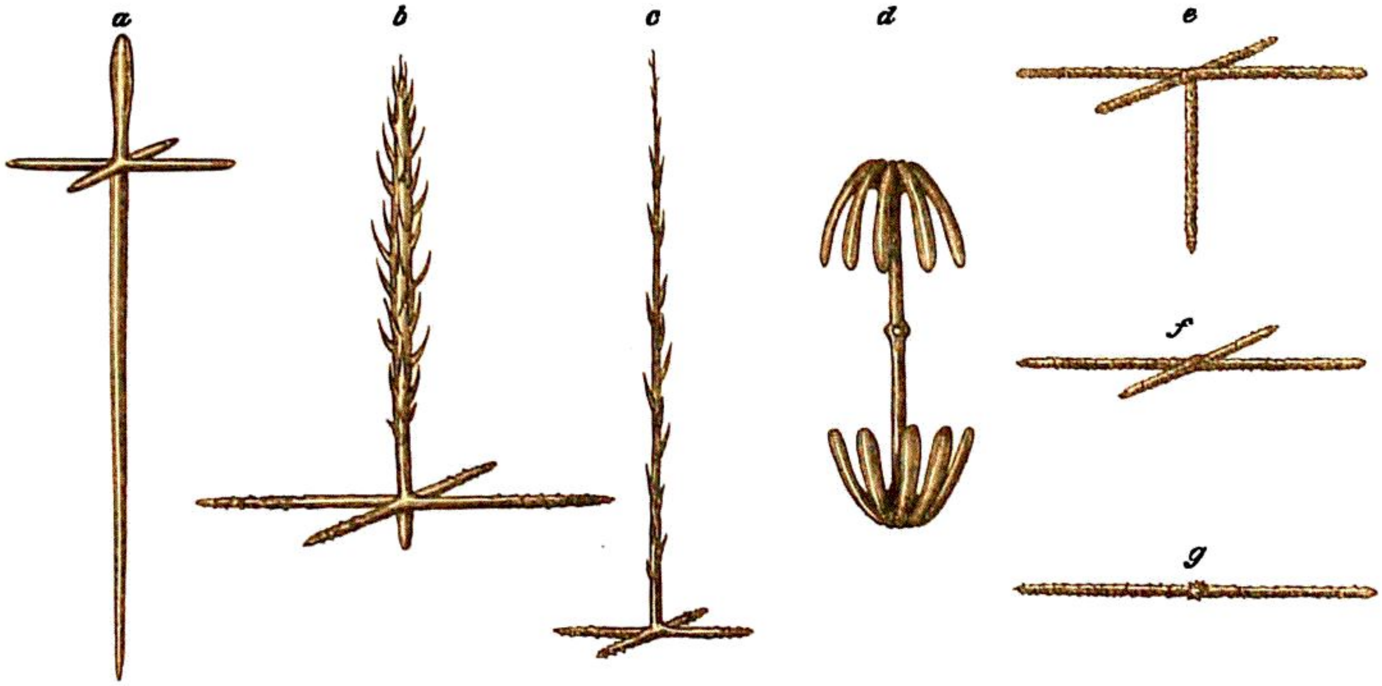


FIG. 33.—Characteristic forms of the dermal spicules of Hexactinellida. *a*, spicule of *Walteria flemmingii*, Schulze; *b*, of *Sympagella nux*, Schmidt; *c*, *d*, of *Hyalonema sieboldi*, Gray; *e*, *f*, *g*, of *Rossella antarctica*, Carter.

determination. When these analyses are examined they can be arranged into a maximum set of determinations, showing 1 part of silica in 9000 to 82,000 parts of sea-water, and a minimum set, showing 1 part of silica in 120,000 to 1,460,000 of sea-water. Murray and Irvine have pointed out that in all probability the maximum results were obtained from unfiltered waters, and the minimum from filtered waters, for sea-water, when carefully filtered, gives an average proportion of 1 part of silica in 250,000 parts of sea-water, and this amount of soluble silica appears to be almost constant in purely oceanic waters, coast waters, and in many river waters. The amount of soluble silica in sea-water is thus so small that it seems almost impossible to admit that this is the exclusive source from which the numerous siliceous organisms in oceanic waters obtain the material to form their shells. The quantity of water that would require to be in contact with, or pass through, each Diatom or other organism to enable it to form its siliceous frustule or skeleton would be enormous. In the case of the carbonate of lime organisms it has been shown that they can obtain the material for their shells from the other salts of lime in solution in sea-water.[1] In the case of the silica, however, the total silica in solution in sea-water can only be present in the one condition, so that an analogous interpretation is impossible. Is there then any other source from which these organisms may derive their silica?

It appears to have been generally accepted by recent writers that all the clayey matter held in suspension in river water is thrown down when the river water enters, and is mixed with the waters of, the ocean, and there is little doubt that this view is in the main correct.[2] It is an undoubted fact that almost all the clay held in suspension in fresh water falls rapidly to the bottom on mixture with sea-water. It appears, however, that this precipitation takes place more rapidly at a high than at a low temperature;[3] for instance, a sample of sea-water with clay in suspension was divided into two portions and allowed to stand for twenty-four hours, the one portion at a temperature of 50° F. and the other at 80° F.; at the end of that time in the former case 0·0188 gramme per litre remained in suspension, and in the latter only 0·0083 gramme per litre. It would also appear that a small quantity of clayey matter may be held in suspension for an indefinite time, even in the saltest and warmest waters of the ocean. A large sample of water (14 litres) from the North Atlantic, lat. 51° 20′ N., long. 31° W., contained 0·0052 gramme per litre, or about 1601 tons of clay in a cubic mile of sea-water. A similar sample from the centre of the Mediterranean gave 0·0066 gramme per litre, or 2031 tons of clay per cubic mile. Another sample from the German Ocean gave nearly identical results as in the water from the Mediterranean. It is true that the soluble silica in a cubic mile of sea-water (17,000 tons) greatly exceeds the quantity of silica in the suspended clay found in the above experiments, but Murray and Irvine suggest that it is not improbable that the clayey matter in suspension contains silica in a more available form than the silica in solution, from the clay being locally abundant in certain layers, in place of being dissolved in 250,000 times its weight of water, as would be the case with silica in solution.

If, then, the pelagic organisms which secrete silica for their frustules, shells, and skeletons, obtain it from the hydrated silicate of alumina or clay held in suspension in sea-water, as well as from the silica in solution in sea-water, we may in this way have some explanation of the fact that these organisms abound in brackish waters and waters of a low salinity and low temperature, where, for the reasons stated above, this finely-

[1] Murray and Irvine, *Proc. Roy. Soc. Edin.*, vol. xvii. p. 91.

[2] See E. W. Hilgard, *Amer. Journ. Sci.*, ser. 3, vol. vi. p. 338, 1873; W. H. Sidell in Humphreys and Abbot's *Report on the Mississippi*, App. A. No. 2, pp. 495 *et seq.*, 1876; J. D. Dana, *Manual of Geology*, 3rd ed., p. 677, 1880.

[3] Murray and Irvine, "On Silica and the Siliceous Remains of Organisms in Modern Seas," *Proc. Roy. Soc. Edin.*, vol. xviii. pp. 229–250, 1891.

divided matter is more abundant than in the warmest and saltest waters of the ocean. In this connection it may be observed that there is a relatively low salinity, as well as low temperature, in the Arctic, the Antarctic, and Southern Oceans; in the western Pacific and eastern Indian Oceans there is also a relatively low salinity, and in both these regions Radiolaria and Diatoms are especially abundant.

In the case of siliceous Sponges, which are rooted for the most part in the oozes and clays, the silica of their skeletons may be derived from the silica in solution in sea-water, or from the colloid silica set free during the decomposition of the felspathic rock fragments and minerals in the deposits.

We have frequently referred to the fact that the remains of Diatoms and Radiolarians cannot be detected in many of the calcareous oozes, although they live in abundance in the surface and subsurface waters of the region. It is most probable that they were at one time present in the deposit and have been removed in solution.[1] That both siliceous and calcareous organisms, when together in the organic oozes, are acted upon by sea-water, is shown by the following experiments:—A portion of mixed Diatom and Globigerina Oozes was placed in a litre of sea-water and some mussel flesh added, so as to obtain as nearly as possible the conditions attending decomposing organic matter on an ocean floor. After a week's exposure, during which time the organic matter had become putrid, the water was carefully filtered from the sediment, and the silicic acid determined in the filtrate. The amount found was equal to 0·025 grm. per litre, or, according to the amount of water, 1 part of silica had been dissolved from the Diatom Ooze in 41,000 parts of sea-water. This action of silicic acid in decomposing carbonate of lime was further proved by exposing 2 grms. of the mixed oozes to boiling water for half an hour, the amount of silicic acid present in a soluble condition after that period amounting to 0·014 grm., or 1 part in 80,000 of water. To check this result, and at the same time to determine whether the decomposing action of silicic acid upon carbonate of lime was continuous, the same sample of the mixed oozes was heated with successive quantities of sea-water, when it was found that each portion of water contained soluble silica.

f. Relative Frequency of Organic Remains in Deep-Sea Deposits.

Detailed statements have been given above of those stations at which the remains of vertebrates have been obtained in the dredgings and trawlings of the Challenger Expedition. The relative frequency of organic fragments observed during the examination of the small samples of the deposits from the sounding tube may now be noted. The frequency of occurrence is in the first instance given for the deep-sea deposits as a whole, and secondly, for the pelagic deposits as a whole. These numbers are solely

[1] See Murray and Irvine, *Proc. Roy. Soc. Edin.*, vol. xviii. p. 249.

derived from the examination of the Challenger samples, but may fairly be taken as an index of the relative frequency of occurrence of these organic fragments in all deep-sea deposits.

There are 348 Challenger deposits fully described in the Tables of Chapter II., and the order of frequency is as follows, the number of times the various organic remains were observed being indicated in brackets :—

Globigerinidæ (306 times), Radiolaria (274), Sponge spicules (271), Rotalidæ (269), Echinoderm fragments (266), pelagic *Pulvinulinæ* (263), Lituolidæ (244), Miliolidæ (241), Coccoliths (235), Lagenidæ (211), Textularidæ (201), Diatoms (181), Rhabdoliths (179), Ostracodes (173), Astrorhizidæ (145), Lamellibranchs (121), Pteropods (119), Nummulinidæ (112), Gasteropods (109), otoliths and bones of fish (102), Polyzoa (91), casts (78), teeth of fish (65), Heteropods (61), *Serpula*, and other worm tubes (53), arenaceous Textularidæ (34), calcareous Algæ (27), Alcyonarian spicules (24), Coral fragments (23), Coccospheres (20), *Dentalium* (19), arenaceous Foraminifera, families not given (15), Brachiopods (8), Cephalopod beaks (8), Cirripedia (7), Chilostomellidæ (1), and Crustacean fragments (1).

There are 215 purely pelagic deposits fully described, and confining our attention to these, viz., the Red Clay, Radiolarian, Diatom, Globigerina, and Pteropod Oozes, the order is somewhat different, as follows :—Radiolaria (197 times), Globigerinidæ (186), *Pulvinulina* (168), Rotalidæ (160), Coccoliths (155), Sponge spicules (155), Echinoderm fragments (153), Lituolidæ (150), Miliolidæ (142), Rhabdoliths (126), Lagenidæ (109), Diatoms (99), Textularidæ (97), Ostracodes (88), Astrorhizidæ (82), teeth of fish (60), Pteropods (51), Nummulinidæ (48), casts (46), otoliths of fish (43), Lamellibranchs (41), Gasteropods (39), Polyzoa (33), Heteropods (22), arenaceous Foraminifera (12), *Serpula*, and other worm tubes (11), Coccospheres (10), arenaceous Textularidæ (10), *Dentalium* (7), Coral fragments (7), calcareous Algæ (6), Alcyonarian spicules (5), Brachiopods (5), Cirripeds (4), and Cephalopod beaks (4).

g. Coral Reefs.

A description of coral reefs and islands, and a discussion of their peculiar features, do not fall within the scope of this work. The subject of coral reefs, and the bearing of deep-sea investigations on the question of their origin, has been dealt with by Mr Murray in several Memoirs.[1] It may, however, be here pointed out that a recent writer,[2] among

[1] Murray, "On the Structure and Origin of Coral Reefs and Islands, *Proc. Roy. Soc. Edin.*, vol. x. pp. 505–518, 1880; "Structure, Origin, and Distribution of Coral Reefs and Islands," Lecture before Roy. Inst. of Gt. Brit., March 16, 1888; "The Great Ocean Basins," *Nature*, vol. xxxii. p. 613, 1885; also Narr. Chall. Exp., vol. i. pp. 781, 782, 1885; Murray and Irvine, "On Coral Reefs and other Carbonate of Lime Formations in Modern Seas," *Proc. Roy. Soc. Edin.*, vol. xvii. pp. 79–109, 1890.

[2] R. Langenbeck, "Die Theorieen über die Enstehung der Koralleninseln und Korallenriffe, &c.," p. 158, Leipzig, 1890.

other forced arguments, urges, as a direct proof of the correctness of the Darwinian theory of coral reefs, that the "Tuscarora" found hard coral rock in great depths at several places in the Pacific (for instance in 2096, 935, and 1390 fathoms). The "Tuscarora" samples have all passed through our hands. We have examined the samples referred to, and in all cases they are Globigerina or Pteropod Oozes, and of course furnish no proof whatever of subsidence. Dr W. B. Carpenter fell into the same error with respect to the "Tuscarora" soundings in a paper published in 1875,[1] where he argues that all the submarine elevations, on which "white coral" (Globigerina Ooze) was reported, must once have been coral reefs at the surface, hence furnishing a proof of Darwin's views as to the formation of coral atolls through subsidence. In these cases the terms applied to the specimens of the deposits by the marine surveyors have led the writers to adopt an erroneous interpretation.

[1] *Proc. Roy. Geogr. Soc.*, vol. xix. p. 511, 1875.

CHAPTER V.

MINERAL SUBSTANCES OF TERRESTRIAL AND EXTRA-TERRESTRIAL ORIGIN IN DEEP-SEA DEPOSITS.

THE materials of organic origin in deep-sea deposits having been considered in the preceding chapter, we shall now turn our attention to the mineral particles, properly so called, which form a more or less considerable part of all marine deposits.

When these mineral particles are regarded from the point of view of their origin, or rather of the source from which they have been immediately derived, they may be divided into three groups:—

1. Mineral particles more immediately derived from the mechanical disintegration of the solid crust of the earth, and distributed by terrestrial forces over the bed of the sea.
2. Mineral particles derived from extra-terrestrial regions, which play but an insignificant part in the mass of marine deposits, but are highly interesting from their origin, nature, and distribution.
3. Mineral particles and substances formed *in situ* at the bottom of the ocean, as a result of chemical interaction with substances in solution in sea-water and materials of organic and inorganic origin undergoing decomposition at the sea-bottom, which may therefore be called chemical products.

These last (No. 3) will be dealt with in detail in Chapter VI., the present chapter being devoted to a consideration of the first two groups.

I. MATERIALS DERIVED DIRECTLY FROM THE SOLID CRUST OF THE EARTH.

If the materials derived directly from the solid crust of the earth, or from the underlying layers, be looked at from a general point of view, they may be divided into two categories, corresponding in a certain way with the two great groups into which we have divided marine deposits, viz., Pelagic Deposits and Terrigenous Deposits. The first of these categories comprises all those rocks and minerals projected in a fragmentary form from subaerial and submarine volcanoes during the present geological period, or during relatively recent periods. The small dimensions and areolar structure of these fragmental volcanic materials admit of their being universally distributed over the floor of the ocean, and from the very fact that they are easily distributed by meteorological and oceanic agencies, they are especially characteristic of pelagic deposits. The second of these categories comprises all the rocks and minerals derived immediately from the disintegration of all continental and other lands by ordinary meteorological agencies, especially from the disintegration of crystalline, schisto-crystalline, and clastic rocks, which form the larger part of the continental masses. These disintegrated materials are carried to the ocean by rivers and by winds, and are distributed to the deep sea by waves, tides, currents, and floating ice, but not so widely as the fragmental volcanic materials of the first category; they are essentially characteristic of those deposits formed near continental shores and islands, which we have called Terrigenous Deposits.[1]

(a.) *Recent Volcanic Products.*

It is merely necessary to cast a glance at the synoptical Tables of Chapter II. to be convinced of the universal distribution of volcanic products in marine deposits. In running the eye down the column indicating the mineral particles, it will be seen that in nearly all the samples of the different types of deposits minerals and rocks occur which we recognise, from the study of terrestrial volcanoes, as having been derived from eruptions of the present or of relatively recent geological periods. It is not the same, however, with those rocks and minerals to which we attribute a continental origin, properly so called, for these last are especially abundant near land, and are almost wholly absent in the central parts of the great ocean basins. The fragmentary volcanic materials, while very often associated with the continental rocks and minerals near shore, are especially abundant in, and characteristic of, deposits far from land. It could not well be otherwise, if the structure, conditions of formation, and mode of ejection of these volcanic materials be borne in mind. Whilst there may be a limit, towards the open sea, to which the minerals and fragments derived from the disintegration of the continental masses can be transported, there is no such limit for the rocks and minerals projected as dust, lapilli, and masses of pumice by terrestrial volcanoes, and though they may have a more restricted distribution, the same is the case with ejectamenta of submarine eruptions.

In this connection it is but necessary to recall the distribution of active and recent volcanoes over the earth's surface to show how favourably the ocean basins are situated for receiving the fragmentary materials projected into the air or the sea during eruptions.

[1] Although we believe that there are no essential differences between the older and recent eruptive rocks, in the sense formerly admitted by petrographers, there is no doubt that each of these two groups, in the generality of the cases under consideration, offers some peculiarities on which rests the subdivision adopted in this and other chapters.

The Pacific is surrounded by a zone of volcanic activity, and scattered over its surface there are many active and recent volcanoes—in fact, two-thirds of the active volcanoes of the world are situated in, or at no great distance from the shores of, this ocean. The Atlantic, Indian, and Southern Oceans also offer numerous centres of volcanic activity, either in the oceanic islands or on the coasts of the adjoining continents. In short, one may say that all the important volcanic vents of the globe are situated in or near to the great oceans or the enclosed seas which penetrate between continental masses of land.

In addition to terrestrial volcanoes, it must be admitted that the bottom of the ocean is frequently the seat of volcanic eruptions. Although the conditions of observation are much less favourable than in the case of terrestrial volcanoes, still the evidences of submarine eruptions are very numerous. In many instances the volcanic eruptions in the open sea have been accompanied by sulphurous emanations, by steam, columns of water, flames, ashes, scoriæ, and pumice, and the formation and disappearance of islands. Santorin and Graham Island in the Mediterranean, some islands in the neighbourhood of the Azores, and in recent years Falcon Island in the South Pacific,[1] are but a few of the instances that might be cited of submarine eruptions. Earthquake waves have, in a great number of instances, been placed in direct relation with submarine eruptions.[2] The recent extensive soundings throughout the great ocean basins have revealed the presence of conical mountains, rising to various heights above the general level of the sea-bed, but not reaching the surface of the waters. These conical mountains must, from their resemblance in form to volcanic islands, and from the volcanic materials that have been dredged in their neighbourhood, be regarded as the results of submarine eruptions in deep water. We know that masses of lava have flowed for weeks from volcanic islands into the ocean, but at the present time there is little knowledge of the spaces covered by lava-flows on the sea-bed itself. However, the study of ancient geological formations has familiarised us with the idea of such lava-beds or tufas intercalated between marine sedimentary layers, and there can be no doubt that the same order of phenomena occurs in our present seas.

It would appear, then, that the fragmentary volcanic materials which we find carpeting the floor of the ocean have been derived from both subaerial and submarine eruptions, and that, both from actual observations and theoretical considerations, the oceans of the present and recent geological periods are especially well situated for receiving the products of these eruptions. It is difficult, however, to distinguish the products of subaerial from the products of submarine eruptions. In certain cases the dimensions and numbers of vitreous lapilli, dredged from great depths far from land, indicate that these fragments came from centres of submarine eruption not far removed from the points where they were dredged. In the case, however, of large fragments of pumice or of tufa made up

[1] See *Nature*, vol. xli. p. 276, 1890.
[2] E. Rudolph "Über submarine Erdbeben und Eruptionen," *Beiträge zur Geophysik*, 1887, pp. 226 *et seq.*

of a fall of volcanic ashes, likewise obtained in the dredges, it is often impossible to say whether they came from a submarine or a subaerial eruption.

Pumice.—On account of its abundance and the wide area of its distribution, pumice merits the first consideration among the volcanic materials of marine deposits. This rock is merely a vesicular variety of a number of lithological species, and the wide distribution of this variety is dependent on its spongy structure. Mr Murray was the first to point out the important role played by pumice in the formation of pelagic deposits and in the origin of the soil of coral atolls,[1] and the same considerations, with further developments, were afterwards dwelt upon in a joint paper by ourselves.[2]

During the Challenger Expedition fragments of pumice were frequently taken in the tow-nets while floating on the surface of the sea, and were often found to be covered with Cirripeds and other marine animals. Long lines of pumice fragments were also observed on coral reefs just above high-water mark. From New Zealand, South America, Japan, and other countries, immense quantities of pumice are carried to the ocean by rivers. The Expedition, however, did not meet with any of those prodigious fields of floating pumice which have many times been recorded by voyagers as being so vast as to impede the progress of their ships,—for instance, after the famous eruption of Krakatoa in 1883,[3] and in the South Pacific in June and July 1878 by Captain Turpey, and by Captain Harrington in March 1879.[4] The pumice sent to us by Captain Turpey was dark-green in colour, and was believed to have been derived from a submarine eruption. The fragments of pumice, which float on the surface in great fields, or in long parallel lines, are carried enormous distances by oceanic currents, and, being rubbed and knocked against each other by the action of the waves, they ultimately assume a rounded appearance, as if they had been rolled like river pebbles. While this rubbing, knocking against each other, and rounding goes on, a very large number of the triturated fragments that are broken away from the outer surfaces fall as minute splinters to the bottom of the sea, contributing largely to the formation of pelagic deposits. The larger and smaller fragments of pumice slowly become waterlogged and sink to the bottom. Mr Murray

[1] Murray, *Proc. Roy. Soc. Edin.*, vol. ix. p. 247.

[2] Murray and Renard, *Proc. Roy. Soc. Edin.*, vol. xii. p. 495. See also Helge Bäckström, "Ueber angeschwemmte Bimsteine und Schlacken der nordeuropäischen Küsten," *Bihang till. K. Svenska Vet. Ak. Handl.*, Bd. xvi. Afd. 11, No. 5.

[3] The Bay of Lampoong, in the Strait of Sunda, was blocked by a vast accumulation of pumice projected in a few hours by the eruption of Krakatoa. This floating barrier of pumice had a length of 30 kilometres, a breadth of 1 kilometre, and a depth of 3 to 4 metres; it was raised about 1 metre above, and plunged 2 metres below, the surface of the water. These numbers indicate that at this point 150,000,000 cubic metres of volcanic matters were thus accumulated. This elastic and moving wall undulated with the flux and reflux of the waves, and the fragments of which it was formed were carried by currents to thousands of miles from the eruption, and scattered finally over the surface, and, as we now know, also over the bottom, of the ocean (*Comptes Rendus*, tom. xc. p. 1101, 1883). See also Charles Meldrum, *Brit. Ass. Report* for 1885, pp. 773–779, 1886; S. M. Rendall, *Nature*, vol. xxx. p. 288, 1884.

[4] Captain Turpey says that in some parts of the sea these pumice stones were in such large numbers that the small boats which the ship drew after it rose out of the water and were drawn along as if on a bed of rocks. Captain Harrington says that many of the patches assumed the appearance of islands, and were large enough to retard the progress of the vessel considerably, their appearance being alarming.

made a series of experiments with pumice stones dredged from the North Pacific sea-bed at a depth of 2900 fathoms. After these fragments, which were about the size of a hen's egg, had been out of the sea for seven years, they were placed in vessels of sea-water and floated lightly. They slowly sank in the water, some reaching the bottom of the vessel in three months, and others taking nine months. Similar experiments were made with the basic variety of pumice collected by Captain Turpey on the surface of the South Pacific, and it took one year and eight months before some of the fragments sank to the bottom of the vessels.

The great majority of the pumice fragments dredged by the Challenger from the sea-bed were more or less rounded, and varied from the size of a man's head or a cricket-ball down to the size of a pea or mustard-seed; many fragments, however, were angular. It is probable that nearly all these fragments of pumice floated a short time after their ejection at the surface of the sea, and then sank to the bottom. From their great abundance near volcanic centres, it is probable that some fragments float only for a very short time. The general appearance of some of the larger fragments of pumice from deep-sea deposits is represented on Plate I. In all the specimens the surface layers have undergone more or less alteration into a soft, brown-coloured, clayey substance; but in the case of the specimens represented in figs. 5 and 6 the structure of the pumice is almost completely lost except in the very centre, while the outer layers are composed of black depositions of the peroxides of iron and manganese—in short, these fragments have been transformed into manganese nodules with pumice nuclei.

There were great numbers of pumice stones in the dredgings around the Azores in the Atlantic, off the Kermadecs in the Pacific, around some of the Philippine Islands, and off the coast of Japan, and in general close to all recent volcanoes. In the North Pacific, hundreds of miles from land, at depths of 2300, 2900, and 2050 fathoms, the trawl and dredge brought up hundreds of these more or less rounded pumice stones. In general they were rather abundant in the Red Clays and Radiolarian Oozes, but less so in the Blue Muds and calcareous oozes, except where these were close to active volcanoes. It may be said, however, that in no case was a large quantity of any pelagic deposit passed through sieves without a number of pumice fragments, of small or large size, being detected, and minute particles can generally be observed when a relatively small sample of the deposit is under examination.

The most numerous specimens, collected floating at the surface or lying on the bottom of the sea, belong to the well-known variety of *liparitic pumice.* They are whitish or greyish, generally with elongated fibres; when little altered they present a silky aspect, but in many instances decomposition has transformed them, even to the very centre, into a friable earthy mass, which can be reduced by the finger nail, when the pumice is wet, to amorphous earthy matter with a muddy consistence. When fragments of this variety are examined under the microscope, they are seen to be composed of a colourless glass, with numerous closed, often elongated, vesicles, and with a few individualised mineralogical elements. This variety is rich in silica, and hence is referred to the lithological types of liparite or trachyte. The minerals which are embedded in the vitreous mass, or project from the weathered surfaces, are sanidine, plagioclases, black mica, augite, and magnetite, and with the microscope many microliths belonging to the same species can be observed. Quartz is very rare; sometimes rhombic pyroxene is present.

A second variety, but less abundant than the liparitic variety, is that known as *andesitic pumice.* In external characters andesitic pumice stones nearly approach the liparitic ones, and might at first sight be confounded with them; they have the same grey colour, are sometimes fibrous, and decompose in the same way. They are especially distinguished by the minerals which they contain, the most important being augite, plagioclases, and magnetite, while microliths of augite and hornblende are sometimes seen in the transparent base. Olivine is absent, and the silica in this andesitic pumice is estimated at 60 per cent. A specimen of this variety, from 2300 fathoms in the North Pacific, was analysed, with the following results:—

Station.	Depth in Fathoms.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	CaO	MgO	K_2O	Na_2O	Total.
241	2300	80	4·95	60·95	15·97	9·08	g.tr.	2·92	1·40	1·61	2·34	99·22

The surface of the fragment analysed was extremely friable—almost earthy. Beneath this decomposed layer the centre was still formed of a whitish mass, having the appearance of a fresh rock, but, as shown by the analysis, especially by the percentage of water, which rises to nearly 5, this central portion had also undergone a profound alteration.

A third variety of pumice met with in deposits is *basaltic* or *basic pumice.* In a large measure we owe our knowledge of the nature of this variety of pumice to the investigations of Cohen[1] on the lavas of the Hawaiian Islands and of Niafou in the Friendly Islands, as well as on some floating pumice collected between New Britain and New Ireland. He has pointed out that volcanic products from several areas of the Pacific far removed from each other have a true basic character, and belong to the basaltic glasses. The pumice stones collected from numerous stations in the Pacific during the voyage of the Challenger have exactly the same characters as those described by Cohen. These are vitreous vesicular rocks of a rather deep colour, yellowish or approaching to bottle-green. The pores affect in general a more rounded or spherical form than those of the preceding varieties of pumice. The vitreous partitions between the vesicles are not very thick, and when the specimens are but little altered they show

[1] E. Cohen, "Ueber Laven von Hawaii und einigen anderen Inseln des grossen Ocean, etc.," *Neues Jahrbuch für Mineralogie, etc.*, Jahrg. 1888, Bd. ii. p. 23.

iridescent colours on the fractures. Under the microscope there can be seen in the dark-green transparent glass the skeletons or sharply-terminated individuals of olivine, augite, and plagioclase; there is little or no magnetite, but sometimes black or opaque concretions. The percentage of silica is on an average about 50, therefore much less than in the acid varieties. The following is an analysis of one of these deep-coloured specimens from a dredging in 1400 fathoms in the South Pacific. After having washed the fragment with oxalic acid, to take away traces of manganese which covered the specimen, and then repeatedly with boiling distilled water, to extract the sea-salts and to detach the mud adhering to it, the following results were obtained:—

Station.	Depth in Fathoms.	No.	H_2O	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO_2	CaO	MgO	K_2O	Na_2O	Total.
184	1400	79	1·70	50·56	0·80	10·30	4·95	7·59	0·14	9·35	9·27	1·24	2·81	98·71

On comparing the above results with those obtained by Cohen they present a perfect analogy, within the limits that may be expected for analyses of rocks of the same family, so that this specimen represents the basaltic lavas of Hawaii in its mineralogical composition, and the same may be said of all the dark-coloured specimens that have been dredged from the sea-bottom in the Pacific, and to a less extent in other oceans.

Minute fragments of the different varieties of pumice noted above can be detected in all marine deposits, and in some areas the greater part of a Red Clay, or of the residue of a calcareous ooze after removal of the carbonate of lime by dilute acid, may be made up of minute fragments and splinters of pumice. These microscopic fragments may be derived from the trituration of floating pumice, or from its disintegration on the sea-bottom, or, again, they may have been ejected as showers of ashes from subaerial or submarine eruptions, and have been widely distributed by aerial or marine currents.

In general, when mineral particles are reduced to infinitesimal dimensions, and are irregularly fractured, they lose their distinctive characters; the crystallographic form and the optic properties are no longer recognisable, but with vitreous pumice fragments the recognition of the particles is still possible when they are even less than 0·005 mm. in diameter. The most reliable diagnostic character of these pumice particles is to be found in their peculiar structure. The enormous numbers of vesicles in the pumice, due to the expansion of the dissolved gases in the original magma, present a special structure and characteristic fracture which can be recognised even in the minutest fragments. This property can easily be tested by pulverising a piece of pumice in an agate mortar, when it will be noticed on examination under the microscope that the minutest particles bear the impress of this vesicular or filamentous structure. The appearance arising from several pores being drawn out so as to be mere streaks, renders the fragment at first sight like a striated felspar, or even like the remains of certain microscopic organisms. In following under the microscope the contours of these vitreous splinters, it will be observed that they are generally terminated by curved lines, and present a riddled appearance, all the sinuosities being curvilinear.[1] They also present in most cases near the vesicles the optical phenomena of tension, analogous to those observed in "Rupert's drops." From the differences in the form of the vesicles, and the nature of the fracture, it is even possible in some cases to determine the variety of pumice from which the minute splinters have been derived.

It must be pointed out that the trituration of floating pumice, and the decomposition of pumice at the bottom, both tend to bring about a more or less complete isolation of the individual minerals which formed an integral part of the pumice rock at the time of its eruption; these volcanic minerals are thus spread over the bed of the sea in the same way as the vitreous splinters of the pumice. It may therefore be very difficult to recognise a difference between volcanic dusts projected as ashes from a crater, and the pulverulent debris derived from the wear and tear of floating pumice at the surface of the ocean and its disintegration in the deposits. In the case of showers of ashes some mechanical processes may, however, produce a sorting of the mineral particles from the areolar vitreous particles, as for instance when these are transported by winds or marine currents. On account of their lightness, the vitreous particles are carried to greater distances than the fragments of crystallised minerals coming from the same eruptions. It follows from this, that at any given point the pumiceous particles may quite well predominate in a marked manner over the minerals. This may explain why in some deposits the vitreous particles appear to mask, by their number, the volcanic minerals with which they are associated.

As examples of the aspect and of the characters which these minute particles of pumice affect in the sediments, we have represented on Pl. XXVI. fig. 4 the residue (mineral particles) of a Blue Mud from the South Pacific, Station 303, 1325 fathoms. Almost the whole field of the figure is here occupied by pumice particles. Two varieties can be distinguished: first, basaltic (designated in our Tables brown vesicular glass), the minute fragments of which are perfectly characterised by their slightly brownish tint, by their less lengthened structure, and by the relatively small number of vesicles. The little pumice fragments of the more acid variety are distinguished by their elongated fibres and pores, their very irregular borders, and their almost colourless tint, which may be said to be more or less greyish. This figure gives a good idea of the characteristic appearances just described; it also shows the predominant part taken by microscopic splinters of pumice among the mineral particles of this deposit. Pl. XXVII. fig. 3 shows the extremely fine mineral particles in a Red Clay from the North Pacific, Station 240, 2900 fathoms. The splinters of pumice figured here belong especially to the acid variety.

[1] A. Penck, "Studien über lockere vulkanische Auswürflinge," *Zeitschr. d. d. geol. Gesellsch.*, 1878, pp. 97–129; J. S. Diller, "Volcanic Sand which fell at Unahalashka, Alaska, Oct. 20, 1883," *Science*, vol. iii. p. 651.

Basic Volcanic Glass.—In many regions of the deep sea the Challenger Expedition collected numerous lapilli and pebble-like fragments of compact volcanic glass, which, although more or less limited and localised in their distribution, appear to be the most important volcanic products in deep-sea deposits after the pumice fragments above described. While these glasses are known only from a few geological formations, and from a few eruptions of recent volcanoes at the surface of the continents, they, on the other hand, appear in abundance and in most typical form among the products of submarine eruptions, as if the deep oceans had been in some way specially favourable to the development of this lithological type. We devote, in consequence, a considerable space to the description and illustration of these glassy particles and the products of their alteration. All the chief varieties found at the different stations are included in these descriptions, and in their structure they pass, on the one hand, into basic pumice, and on the other into basaltic fragments with a vitreous base.

The most characteristic of these lapilli of basic volcanic glass collected by the various trawlings and dredgings vary from the size of a walnut to that of a pea, and minuter fragments descend to the mean dimensions of the mineral particles found in the clays and oozes, when their nature becomes masked from their small size; it is only by following the transitions from the larger particles, upon which the characters are sharply impressed, to the smaller, that it is possible to recognise the minute splinters disseminated in the deposits. In nearly all cases, whatever their size, these fragments have undergone a more or less profound alteration, their primitive vitreous matter being transformed by hydrochemical agencies into a secondary product, which is designated palagonite in all our descriptions. Frequently these fragments form the centres of manganese nodules, and generally they are more or less incrusted by manganese depositions; sometimes they are isolated in the deposits, or associated with other lapilli, volcanic ashes, and free zeolitic crystals. They are most abundant in certain red clay areas of the Pacific, but may be found in all the types of deep-sea deposits. The form of the fragments is generally rounded, elliptical, or flattened, but they are sometimes quite irregular. The larger fragments have, as a rule, a vitreous centre, with external highly-altered zones; the smaller fragments are frequently entirely transformed into palagonite.

When one of the larger fragments is taken from the centre of a manganese nodule, or found in a free state, the external surface is always covered by a resinoid yellowish green or reddish brown coating. When the fragment is broken, the interior is seen to be a true unaltered glass. This vitreous material is compact or scoriaceous, and resembles in some respects acid volcanic glasses, like obsidian, but the fracture is less conchoidal. The rock breaks into little splinters, due to a latent perlitic structure and to microscopic fissures, and a shock often produces a pulverisation of the mass. The fragments are dark green or brown, with a pronounced vitreous aspect and resinoid lustre, and they melt easily before the blow-pipe into a dark glass. Their density ranges between 2·8 and 2·9; the greyish green powder is very magnetic, and always gives the reaction of manganese. There is a marked contrast in the hardness between the vitreous centre, which has a hardness of about 5, and the altered palagonitic envelope, which when dried may have a hardness of about 4; but when freshly taken from the sea this resinoid secondary substance can be cut with a knife like new cheese. The powder of the vitreous glass is attackable by acids, with separation of gelatinous silica, leaving a residue formed principally of minerals which had been enclosed in the vitreous mass. These minerals, however, are rarely visible to the naked eye, and consist of minute yellowish grains of olivine, augite, and some small lamellæ of plagioclase.

When seen by the naked eye, the central vitreous mass is almost always bordered or penetrated by the yellowish brown, resinoid, slightly transparent, palagonite. This secondary substance has not such a brilliant aspect as the glassy interior, sometimes even presenting an earthy aspect; it forms zones around the vitreous nucleus, and each zone is distinguished by a different colour, marking the progressive transformations of the basic glass. The unaltered centre is usually more or less irregular, but presents a form in relation with that of the whole fragment. It is evident that the decomposition has taken place from the periphery towards the centre, and that each stage is marked by the different coloured zones, which may be black-brown, red, red-brown, pale yellow or green, yellowish white, or almost colourless, the uncoloured portions having a soapy aspect. The external zones are in general paler and more delicate than those towards the interior; they are so thin in some cases that they can only be recognised under the microscope. The specimens collected at Station 302, 1450 fathoms, in the South Pacific, present this zonary character due to the decomposition of the basic glass in the greatest perfection, so that they resemble the finely-zoned structure of some agates. In vesicular specimens the progress of this decomposition is not so well shown as in the compact specimens; generally they are entirely transformed into palagonite, and no trace of the original glass has been left.

It has been already stated that these fragments frequently form the nuclei of manganese nodules, and it is interesting to observe that they are very rarely found without a more or less thick coating of manganese, whilst lapilli of felspathic basalt, of augitic or hornblendic andesite, or fragments of ancient rocks like gneiss and granites, are often found in the same deposits without any, or but a very slight, coating of manganese. This might be interpreted by supposing that these basic fragments had lain for a much longer time upon the bottom of the sea than the other fragments, and that the manganese had thus had time to deposit round them in much thicker layers, or it may be held that they are more rapidly altered, and yield in the process the concretionary manganese which covers them. It may even be, we think, that traces of these highly alterable basic glasses have been preserved in consequence of the manganese coatings having held together in position the fragments which, were they free, would crumble and be transformed into argillaceous matter. Some manganese nodules have their nuclei almost entirely composed of little angular fragments of basic glass, most of which are entirely transformed into palagonite. It is barely necessary to observe that this transformation would take place much more rapidly and more completely the smaller the vitreous splinters, so that it is only in those stations where the specimens are large that the traces of the unaltered glass are preserved in consequence of their forming the nuclei of the manganese nodules; the minute splinters distributed throughout the deposit, being entirely converted into palagonite, can only be recognised by the aid of the microscope, after having followed the transitions which these specimens of different sizes undergo in the process of decomposition. These basic vitreous fragments, and the palagonitic particles resulting from their decomposition, are so frequently associated with numerous nodules of peroxide of manganese in deep-sea deposits, as to at once suggest a relation of cause and effect, which is confirmed by the analyses showing the presence of manganese in the unaltered vitreous fragments.

When these fragments of basic glass are examined in thin sections under the microscope, the vitreous part is seen to be perfectly transparent, with more or less deep colours ranging from grey-brown to brown and yellowish brown; it is perfectly isotropic and with a homogeneous structure, but is occasionally traversed by more or less irregular lines of fracture, which indicate vaguely a perlitic structure. These fractures can be seen in Pl. XVII. fig. 3, and the general aspect of the sections is shown in Pl. XVI. figs. 1–4.

The minerals observed in the vitreous base are olivine and plagioclase, often separate, rarely associated; augite is relatively rare, and so also is magnetic iron. In addition to the species distinctly recognisable, there are frequently very large numbers of crystallites, whose accumulation in certain sections of the rock masks or renders opaque the vitreous matter enclosing them. The mineral most frequently met with in these sections is olivine, which is observed in the form of very minute, very regular, and generally almost colourless, crystals. Often their proportions are so very small that, in spite of the thinness of the preparations, they are still entirely encased in the vitreous matter. The faces of these crystals are generally ∞P, $2\breve{P}\infty$, $\infty\breve{P}\infty$, $\infty\bar{P}\infty$. Frequently they have exactly the same form as fayalite. In a certain number of cases they occur as skeletons of crystals. It is possible to follow in thin slides all the transitions between these embryonic forms and the sharply-terminated crystals, the latter almost always containing a rather large number of inclusions of a brownish glass, similar to the surrounding base. Sometimes these inclusions are so large that the crystal forms around it merely a simple border. On Pl. XVI. the various peculiarities presented by olivine in these basic glasses are represented in detail.

After olivine, the mineral most frequently occurring is plagioclase-felspar; it is sometimes found in the form of lamellæ, similar to those observed in eruptive rocks of the basaltic series (see Pl. XVII. fig. 3), but the most characteristic forms, and probably also the most frequent, are extremely thin rhombic tables. As by the disintegration of the palagonite these little crystals of plagioclase are sometimes detached from the matrix and found in a free state in the clay, we have been able to study them in an isolated condition, and to determine with exactitude their form and nature. It may be mentioned in passing that these rhombic tables of felspar play an important role among the minerals present in the deposits of those regions where the basic glasses are abundant. When these tables embedded in the vitreous fragments are examined by means of transparent slides, they are seen to be so thin that the vitreous material still covers them on all sides, and at first sight one might regard their contours as traces of regular fractures of the mass in which they are enclosed; this aspect is represented in Pl. XVII. fig. 2, where near the base of the figure two of these little crystals can be seen in a mass of red altered glass, their contours being almost entirely hidden by the enclosing matrix. In other preparations they are better developed, and on account of their thickness can be readily recognised, as, for instance, in the vitreous altered fragment represented in Pl. XIX. fig. 1. The lapilli here represented is remarkable for the abundance of these rhombic lamellæ, the fundamental vitreous mass being decomposed into palagonite; in certain points the manganese has infiltrated and masked the palagonitic matter by its deep brown tint. On this background the unaltered sections stand out in relief, with the exception of some parts of their surface still covered by a thin vitreous layer or coloured by manganese.

These plagioclase crystals show a colourless transparent mass, in which the following forms may be observed:—The most frequent forms are flat tabular crystals, with the clinopinakoid especially developed. Individuals of the columnar type, elongated in the direction of the edge P/M, are rare. These tabular crystals consist essentially of a combination of the clinopinakoid with P and x, more rarely with P, u, and y, and occasionally x and y appear together. In the first case the crystals have the form of a rhomb, in the second case they are elongated through the predominance of either x or P. The dimensions of those crystals which were examined and measured lie between 0·61 mm. broad and 1 mm. long as maximum, and 0·015 mm. broad and 0·042 mm. long as minimum. The extinction of the plagioclase is negative. Its value was found to vary between 22° and 32° on the clinopinakoid, and between 8° and 16° on the basal plane. The average values of many measurements made on good crystals are as follows:— 24° 12′, 25° 6′, and 29° 6′ on the clinopinakoid; 10° 42′ on the one side, and 10° 18′ on the other side, of the twinning line, as this is shown on the basal plane. Polysynthetic individuals, made up of repeated twins on the albite plan, were very rarely observed. The felspar, in its optical properties, is thus seen to be between labradorite and bytownite. The twin growths are particularly frequent, and interesting on account of the structure of the individuals. In addition to those of the albite type, others were observed in which the edges P/M and P/*k* could be definitely determined as the axes of twinning. The plane of composition was principally either P or M when penetration twins were not observed.

Crystallites are very often observed in these vitreous lapilli although no crystal has as yet been developed, and these elementary crystalline forms occur under various aspects. In certain cases they are merely parallel streaks, traversed by others at right angles, thus forming groups whose dimensions do not exceed 0·05 mm. At other times these fibres are simply parallel, and not crossed by others. In other cases they diverge at the two extremities of the group; the arborescent disposition found among the microliths of certain pechsteins has, however, never been observed. Finally, they may be disposed as little fans, or irregularly interlaced and forming balls; sometimes the vitreous matter has undergone the initial stage of globulitic devitrification. When these crystallites are examined with a very high magnifying power, they are observed to be transparent, with a brownish tint. Around crystals of olivine they generally assume a regular disposition, the crystallites being arranged parallelly and perpendicularly to the crystallographic axis of the mineral. This layer of crystallites is sometimes composed of five or six rows; at other times there are but one or two (see Pl. XVI. fig. 2). In certain of the preparations of these vitreous lapilli the products of crystallitic devitrification are so crowded together that they render the base almost entirely opaque. Around these groups of crystallites the brown glass is observed to be sensibly decolorised, as is often the case when the pigmentary matter of the base is concentrated in crystals or microliths.

Black opaque spots without metallic reflection are often present, being more or less mammillated and elongated (see Pl. XVI. fig. 1). When these spots are along lines of fissure they are almost certainly more or less dendritic infiltrations of manganese (see Pl. XVII. figs. 1–3), but when embedded in the unaltered vitreous material they must be regarded as segregations of the fundamental mass, and, under very high powers, they can often be resolved into groups of crystallites, closely packed the one against the other. This is proved by the examination of the periphery of these black spots, for when the crystallites which constitute the groups can be observed upon the borders, they appear to be individualised. It has just been remarked that manganese is infiltrated into the fissures of these basic glasses; the dissemination of this substance is so great, indeed, that it is sure to be found in all the preparations of rocks dredged from points where these vitreous fragments occur in abundance. It is possible, without the aid of chemical reaction, to recognise the manganese by its microscopic characters. The colour of the altered vitreous parts is red or brownish yellow, and they present the zones of decomposition, together with embedded crystals. The parts invaded by the manganese are brownish, and the transparency is then almost lost, or they may become in places quite opaque. The infiltrations of manganese do not affect polarised light.

In the sections of these basic glasses that have been examined, augite among the basaltic elements plays the least important role. If this mineral be present its form is not sharply defined; its sections are greenish, sometimes violet coloured. Its cleavages are not distinct, and the crystals are small, containing inclusions of the vitreous mass. Magnetite is generally absent.

The various minerals enumerated above are not found together in all the preparations, but it cannot be denied that we find in them the whole series of transitions from these basic glasses to felspathic magma basalts. However, in these vitreous fragments the substance which serves as a base is incomparably better developed than in those basalts, and the crystals disseminated in the glass are very small in comparison with those observed in typical basaltic rocks; besides, the crystallites are as numerous in the basic glasses as in the basaltic rocks. It might be said that when the basic vitreous rock is porous, the crystalline elements are better developed, and that the transition to the basalts or limburgites takes place rather through the types of areolar basic glass than through the types of compact structure.

The progress of the decomposition of the basic glasses into palagonite can be distinctly followed in thin sections under the microscope. The unaltered part, as already stated, is in transmitted light characterised by a great homogeneity of structure; no trace of perlitic scaling can be observed; the colour is clear, brownish or greyish in different specimens. The palagonite, on the contrary, is but little homogeneous; the zonary and perlitic structures are sharply accentuated; the colour is a beautiful red, sometimes remarkably brilliant, and may pass into reddish yellow, yellow, dirty brown, green, and finally to a milky white, in which last case transparency gives place to semi-opacity. This resinoid substance is still further distinguished from the unaltered vitreous matter by optical properties: while the latter is always isotropic, the former presents between crossed nicols the phenomena of chromatic polarisation; the palagonite is coloured brilliant yellow mixed with red; the tints have a wavy disposition, and the layers are seen to be formed by an aggregate of crystalline fibres disposed more or less perpendicularly to the surface of the lapilli in process of decomposition. This fibrous arrangement is also evident by the well-marked traces of the black cross of spherulitic aggregates observed in the palagonitic zones. This secondary substance is seen to line or to infiltrate all the fissures of the vitreous fragment, more or less profoundly according to the degree of alteration; it surrounds all the external borders, and is generally zonary, but the zones are capricious, sometimes imitating those of concretionary minerals, like the zinc blends or certain agates. One of the best examples in this respect is the specimen figured on Pl. XIX. fig. 3, as seen by reflected light. The fragment is enveloped in black-brown opaque manganese, seen on the right, left, and bottom of the figure. Directly in the centre is a fragment of black-grey, homogeneous, unaltered basic glass; around this nucleus are found the various zones of decomposition, taking the form of the elongated internal nucleus. The internal zones are brownish, marked by deeper coloured lines of separation, due to infiltration of manganese; then the palagonite affects a whiter tint, followed by other well-marked zones of a greenish colour. Finally the external zones become more vague, take on a soapy aspect, and become charged with matters containing manganese, but through this brownish mass the ill-defined external limits of the original vitreous fragment can be traced. These various zones are especially well seen under the microscope, but, as we have already pointed out, they can be observed on a macroscopic examination.

When these vitreous fragments in process of decomposition are studied in transmitted light, the stages of the alteration are still more evident. The altered substances are not only seen to penetrate and to modify the vitreous mass, but the decomposition only attacks the easily alterable glass, and does not generally affect the embedded crystals. This is well shown in Pl. XVI. figs. 3 and 4, where the palagonite is seen with its characteristic tint to advance into the glass while leaving the crystals of olivine intact and in place. Pl. XVII. fig. 3 gives a similar example, but here little lamellæ of plagioclase remain as witnesses of the primitive nature of the substance in which they are enveloped. This figure, which represents the nucleus of a manganese nodule, from Station 302, 1450 fathoms, South Pacific, shows the zonary aspect of the brown palagonite formed at the expense of a brownish homogeneous volcanic glass, shown in the lower two-thirds of the figure, this glass being especially rich in small crystals of plagioclase. In the interior it has not undergone alteration, but the fractures are seen to be infiltrated with manganese. In the palagonitic zones the same felspathic lamellæ are observed as in the vitreous portion; at the lower part of the figure a crystal of plagioclase is seen, one-half of which is in the altered and the other half in the unaltered portion of the rock. In this figure the striking contrast between the glass without structure and the concretionary texture of the decomposed portion is well represented.

In certain cases the alteration has reached a much more advanced stage, as represented, for instance, in Pl. XVII. fig. 1. The vitreous matter, which formerly occupied the whole of the space, has been so far decomposed that there now remain only two isolated vitreous fragments, characterised by their greyish tint; all the other portions of the specimen have been transformed into yellowish palagonite. In the same figure manganese is seen to be infiltrated into the fractures, and presents, especially at the upper part of the figure, a dendritic arrangement. It also often happens that the secondary substance has penetrated to the very centre of the vitreous fragment, as represented in Pl. XVII. figs. 2 and 4; in these cases nothing remains of the basic glass, and it is observed that the perlitic structure is sometimes developed in a remarkable manner. No better example of this could be produced than that shown in Pl. XVII. fig. 4, where each of the sinuous and more or less curvilinear fissures preserves its parallelism; the fissures are marked by infiltrations of manganese bringing out very characteristic undulations, which may be aptly compared to a transverse section of mahogany.

When the vitreous matter is areolar, it is evident that the alteration of the glass into palagonite must progress more rapidly than in the case of a more compact glass, and, as might therefore be expected, the primitive vitreous material has almost completely disappeared, and the fractures due to the perlitic structure are so pronounced that the entire fragment must have fallen to pieces were it not held together by the enveloping manganese. Pl. XVIII. fig. 4 shows the decomposition that takes place in some specimens of these basic glasses, and the same thing is well represented on the left hand side of figure 3 on the same plate. In these preparations, which must be made rather thick to prevent the nucleus falling to pieces, the palagonite is divided into little fragments following the sinuous lines of fracture. We often find in the sediments numerous splinters of palagonite with rounded or curved surfaces, along with zeolitic globules formed of the circular microscopic geodes, which probably once filled the circular pores of an original areolar fragment of rock, as shown in Pl. XVIII. fig. 4; Pl. XVII. fig. 2 also offers an excellent example of the same palagonitisation of the mass. Pl. XVIII. fig. 1 represents a still further advanced state of alteration; in this, throughout the fundamental mass of manganese, triangular, elongated, or irregular splinters of altered glass are observed. The sections of these are yellowish, often zonary near the borders; to a primary zone another succeeds of a deeper tint produced by the interposition of a black manganese pigment; then, near the centre, the colour becomes lighter, and often there exists an internal concretionary zone surrounding an empty space. In polarised light these sections of volcanic glass still show traces of a black cross and of chromatic polarisation; they are almost entirely transformed into zeolitic matter. Where the centre has disappeared, it is possible that in polishing the thin sections the hard centre was eliminated from the softer surrounding mass, but we are not disposed to admit this supposition as probable from our examination of specimens in reflected light previous to preparation. The view is rather held that the decomposition has advanced so far that the centre was reduced to an almost earthy mass, and has thus been eliminated, the border composed principally of zeolitic matter alone remaining.

In a subsequent chapter we shall return to the role played by zeolitic substances in these basic glasses, but it may be pointed out here that in the pores of the less compact fragments the colourless zeolites with radiate fibres give the black cross of spherulitic aggregates. These zeolites are arranged in the interior of the vacuoles upon a layer of carbonate of iron, and it is sometimes possible to observe crystals like phillipsite, brevicite, or even chabasite, but in the great number of cases these zeolitic aggregates are finely zonary, or at the same time zonary and fibro-radiate, as may be observed in Pl. XVIII. fig. 4. The part of the pores not filled with zeolites is generally invaded by manganese and the mud of the deposit, filled with microscopic concretions of peroxide of manganese.

After the above description of basic glasses and of palagonite, it is important to show that our determinations are supported in all points by the results of chemical analysis. We give first the analyses of three compact, black, vitreous fragments from Stations 276, 285, and 302, all in the South Pacific. The fragments analysed presented all the characters above indicated for fragments of compact basic glass, in which by means of the lens small crystals of olivine alone could be distinguished.

Station.	Depth in Fathoms.	No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	Total.
276	2350	93	46·76	17·71	1·73	10·92	0·44	11·56	10·37	0·17	1·83	...	101·49
285	2375	82	49·97	11·68	2·45	10·60	traces	11·20	12·84	0·25	1·60	0·33	100·92
302	1450	95	46·84	17·78	1·64	10·79	0·34	11·87	9·24	0·28	2·02	...	100·80

It is evident, after the examination of the above figures, that the determination of these fragments as belonging to the basic glasses is established in an incontestable manner; they must be referred to the lithological family comprising the basalts.

It remains now to indicate the results of the analysis of the palagonitic matter which covered the fragment made use of in Analysis No. 93.

Station.	Depth in Fathoms.	No.	SiO_2	Al_2O_3	Fe_2O_3	Mn_2O_3	CaO	MgO	K_2O	Na_2O	H_2O	Total.
276	2350	94	44·73	16·26	14·57	2·89	1·88	2·23	4·02	4·50	9·56	100·64

In comparing this analysis with that of the anhydrous silicate (Analysis No. 93) from which this palagonitic matter was derived, it may be observed that the latter is produced by the hydration of the former; it contains, in fact, 9·56 per cent. of water. The transformation which has taken place seems to tend to the formation of a zeolitic substance; lime and magnesia are eliminated, the protoxide of iron passes into peroxide, alkalies derived from the action of sea-water enter into combination, the quantity of alumina remaining almost constant.

Palagonitic Tufas.—This name was introduced by Sartorius von Waltershausen to designate certain tufas found in Iceland, Sicily, Galapagos Islands, and other regions, composed principally of fragments of basic volcanic glass, like those described above, along with other volcanic lapilli chiefly belonging to the basic series. These tufas are known to have been deposited under water, and in some cases the materials were probably derived from submarine eruptions.[1] In many regions of the deep sea tufas in every way analogous to these palagonitic tufas were discovered by the Challenger Expedition, associated with extensive depositions of peroxide of manganese, and frequently forming the nuclei of manganese nodules.

[1] See A. Penck, "Ueber Palagonit- und Basalttuffe," *Zeitsch. d. d. geol. Gesellsch.*, 1879, pp. 504–577.

The brecciaform character of these eruptive products is clearly represented by some of the figures on the accompanying plates, where these lapilli are shown as they appear aggregated in some of the deposits. The nuclei of the nodules of manganese from Station 276 and other stations in the South Pacific are in some instances crowded with splinters of basic glasses or palagonite. These fragments do not always belong to the same types; they present differences of structure and of mineralogical composition, such as might be found in volcanic tufas, but they have not the homogeneity of an accumulation of fragments derived from the trituration of a lava-flow. It is sufficient to cast a glance at Pl. XXI. fig. 1 to be convinced of the correctness of the above observations; this figure represents a thin section cut from the interior of an elongated manganese nodule, in which numerous fragments of basic glass, of felspathic basalt, and volcanic minerals may be observed, all presenting the character of lapilli. Not only the essentially vitreous nature, the mineralogical composition, and the structure, but also the form of the splinters—angular and without trace of wear and tear—all prove that these particles have not been submitted to the mechanical action of water. Commencing at the top of the figure there are large crystals of plagioclase surrounded by vitreous matter or by microliths; descending towards the centre of the figure is a large number of small angular fragments of basic glass, scoriaceous, yellowish, transparent, coated by zeolites, or black and opaque, and containing lamellæ of plagioclase; in the manganese to the right near the centre are small zeolitic crystals, and lower down is a large lapilli of black opaque volcanic glass; next to it is a section of very vesicular pumice, opposite which is a fragment of basic glass; near the lower part of the figure are accumulated plagioclases and splinters of volcanic glass more or less surrounded by zeolitic zones. In fact the aggregation of about fifty volcanic fragments in this nodule affords a very striking and typical example of the tufaceous character of these fragments of basic rocks as found at the bottom of the sea. This is also clearly shown by the palagonitic fragments enclosed in a manganese nodule, represented in Pl. XVIII. fig. 1. It seems necessary, then, to conclude that the angular form is original and due to the mode of projection, these splinters of basic glass being thrown out in the form in which they are now found. It does not seem possible to admit that they are *clastic* in the ordinary sense of the word, for there is no reason for believing that in the depths from which they were collected the mechanical movements of the sea are capable of producing the accumulation and fragmentation of these splinters. Still another argument in favour of the view as to the origin of these fragments here advocated, is their association with numerous volcanic fragments of very small dimensions; these latter are undoubtedly ashes, and it is necessary to admit the same mode of formation for them as for the larger fragments.

The cementation of these minute particles and lapilli by zeolites presents still another point of resemblance with palagonitic tufas. Not only have the zeolites crystallised in the internal pores and vesicles of these vitreous fragments, but they may be seen as coatings lining the empty spaces of the palagonite, as represented in Pl. XVIII. fig. 4. These secondary minerals also cement several adjoining lapilli, in a manner like that represented in Pl. XVIII. figs. 2 and 3. When several splinters of basic glass, or even several vitreous basaltic fragments, are enclosed in a manganese nodule, each one of them is usually bordered by a colourless crystalline zone. This zone, which follows the contours of each fragment, is composed of little prisms fixed at one extremity and fibro-radiate, the whole presenting a mammillated or festooned appearance. These zeolitic prisms become entangled by their free extremities with a similar zone surrounding an adjacent fragment. Pl. XVIII. fig. 2 gives a good example of this cementation by zeolites; five splinters of porous, greenish, and highly altered basic glass are in this manner united by zeolitic bands developed in the intervals between the lapilli. Fig. 3 of the same plate shows portions of two lapilli, where the basic glass with plagioclase is altered into a palagonitic substance, and each fragment is surrounded by a crystalline zone of zeolites; here the little prisms which carpet the two opposite sides do not unite, and the space between them is filled by earthy matters of a more or less brownish colour, and by deposits of manganese. These microscopic crystals of zeolites are often so minute, and their free extremities so entangled in a neighbouring zone, that it is difficult to determine the species. In some exceptional cases, however, as in the interior of the microscopic geodes of scoriaceous glasses, sections of a quadratic aspect can be observed, with terminal crystalline faces, which recall in all points the crystals of phillipsite found free in the surrounding clay. It is important to notice that these zeolitic crystals are always fixed, and have but one free extremity, for by this means it is possible to distinguish them from crystals of phillipsite formed in a free state in the clay. It frequently happens, in fact, that the palagonite becomes completely disintegrated, the broken-down fragments being found among the materials of the deposits, and amongst them are bands of zeolites and globules of the same nature as those which formerly filled the vesicles in the form of geodes. It cannot be doubted that these zeolites have formerly lined the lapilli, when it is remembered that these fragments of the bands have crystalline faces only at one extremity, and in the case of the globules that all the crystals of which they are composed have their heads turned towards the centre of the geode.

The hydrochemical modifications determining the decomposition of these fragments of glass into palagonite, and at the same time the formation of zeolites, have likewise resulted in the complete transformation of these lapilli into ferruginous argillaceous matter. Granted the facility with which these easily alterable glasses undergo hydration, and their perlitic structure, the lapilli should break up into minute particles, if they be not surrounded by more or less thick layers of manganese. If they remained isolated in the mud, we should expect to find, in the form of broken-down particles, the microscopic fragments of these palagonitised glasses, on which the chemical action would continue to be exercised more easily as the materials became more and more subdivided. We should also expect to find, in a more or less isolated condition, the crystals formerly imbedded in the glasses, as these offer more resistance to decomposition than the indeterminate silicate which formed their base. This is what is actually observed, for in the free state in the deposits there are found minute lamellar crystals of plagioclase, often in the form of rhombic tables, sometimes augite, more rarely olivine, magnetite, and fragments of the zeolitic bands just referred to.

It is true that many of these minerals, such as plagioclase, augite, and magnetite, might be projected as volcanic cinders, or be derived from floating pumice, and being surrounded with a vitreous coating this might subsequently be transformed into palagonite; but when these fragments are associated with fibro-radiate and globiform zeolitic minerals, it seems fair to conclude that the great majority of them have been derived from the disintegration *in situ* of brecciaform vitreous lapilli. The other part of the residue, that is to say, the palagonitic matter itself, must necessarily be reduced by transformation into argillaceous matter more or less charged with iron and manganese. The rocks of this type on land surfaces show transformation on a large scale into red argillaceous matter, as, for instance, the argillaceous deposits of Iceland, and the red earths of a large number of islands in the Pacific. We shall have to speak again of these transformations when describing the chemical deposits at the bottom of the sea, but it may now be pointed out that the hydrochemical modifications indicated for basic glasses must, in a certain measure, hold good also for the basalts with a vitreous base, which are so closely allied to the basic glasses.

It is difficult to offer an opinion as to the geological age of the eruptions which gave origin to these tufas, for nothing is known with regard to their stratigraphical relations; all we do know is that they are spread out on the superficial layer of the sea-bed at the points from which they were dredged. Remembering the profound analogies between these tufas and palagonitic tufas, some of which belong to the Tertiary Period, and their association in the deposits of the Pacific with sharks' teeth and earbones of Cetaceans, some of them similar to those of Tertiary species, it is probable that these tufas go back as far as the Tertiary Period. There is no certainty, however, on this point, since eruptions giving rise to basic glasses analogous to those described still take place in the region of the Pacific, where the submarine tufas collected by the Challenger are best represented. The smallest palagonitic particles found free in the deposits may possibly have come from eruptions much more recent than the large lapilli of the same substance, for minute vitreous particles would, on account of their microscopic dimensions, more rapidly undergo decomposition into hydrated silicate than would be possible for the more voluminous fragments enclosed as nuclei in some manganese nodules or free in the deposits.

These observations relative to the time at which the eruption of these lapilli took place are also applicable in a certain way to all the volcanic rocks found in a fragmentary condition in pelagic deposits. Some of these lapilli are allied in fact by insensible transitions to the vitreous type described above. Such, for instance, are fragments of felspathic basalt with a highly developed vitreous base; they are associated with the basic glasses, and probably belong to the same age.

In other cases some fragments of basalt, of augite-andesite, of trachyte, appear to be the products of eruptions of a more recent date, for, although there may be among them fragments coated with thick layers of manganese, there are others which have only a thin coating of that substance, and it seems legitimate to conclude that the greater or less thickness of the deposits of manganese indicates in a manner the relative length of time that the fragments have lain on the bottom of the sea. The relative age indicated by these different layers of manganese, which surround volcanic fragments and remains of organisms, will be fully referred to when treating of manganese nodules.

In the descriptions of the Challenger specimens, in Chapter II., palagonitic materials are mentioned twenty times in Red Clay, four times in Radiolarian Ooze, once in Diatom Ooze, ten times in Globigerina Ooze, three times in Blue Mud, four times in Volcanic Mud, and twice in Volcanic Sand. It will thus be observed that it is especially in the pelagic deposits, and among these in the red clay areas, that the palagonitic substances were most frequently observed.

Basaltic and other lapilli.—We may be brief with the description of *basaltic lapilli*, which are often found associated with the lapilli of basic glass, and form along with them centres of manganese nodules. Some basaltic fragments are less angular than those found in the manganese nodules, and might even be taken for rolled pebbles, from their smooth surface and rounded exterior, and these, from the thin coating of manganese with which they are covered, have not, in all probability, the same origin as those forming the nuclei of nodules. Basaltic fragments are as frequent in the deposits as the palagonitic lapilli, but their determination is not always so easy, especially when they are small and altered, for their characters are much less sharply marked than those of the palagonitic materials. In consequence we have often distinguished the basaltic fragments, in the Tables of Chapter II., under the vague names of scoriæ, lapilli, and glassy volcanic particles, it being impossible to be more specific. However, many of the little fragments thus indicated belong undoubtedly to basalts, generally to basalts with a vitreous base, to felspathic basalts; basalts with leucite or nepheline cannot be said with certainty to have been observed.

Basaltic fragments are found under the same conditions as the basic glasses, their dimensions are the same, and they are specially numerous in the same stations where the palagonitic tufas were dredged. They are distinguished from the vitreous lapilli by their mineralogical composition, which is that of ordinary basalts—olivine, plagioclase, augite, and magnetite—with or without a vitreous base. Generally they are fine grained; rarely they are seen to have the structure of dolerites. A great number are scoriaceous, the vesicles being filled with zeolites, or carpeted by zeolitic zones, as in the case of the palagonitic lapilli. They are often associated with volcanic ashes, in which the mineralogical elements of basalts predominate. Their alteration is less advanced than in the case of the basic glasses, which is undoubtedly due to the facts that they contain more crystalline elements, and are more compact. However, if they possess a vitreous base, or are porous, the hydrochemical decomposition appears to have advanced rapidly from the periphery towards the centre.

This decomposition attacks not only the base, but also the olivine and augite, transforming them into secondary products; the plagioclases, however, offer a greater resistance to this alteration, as may be seen by reference to Pl. XIX. figs. 2 and 4. The two fragments there represented come from Station 276 in the South Pacific; it will be at once seen how much they are altered, and how much their structure is masked by deposition of secondary products. Fig. 4 shows a felspathic basalt with a decomposed vitreous base coloured by manganese; the lamellæ of plagioclase alone seem to have remained intact, and they are sharply marked off from the fundamental mass. The pyroxene enclosed in the base is entirely decomposed, and often transformed into delessite; in order to recognise this mineral, it is necessary to clean the preparation with an acid, when the form of the sections of pyroxene is revealed, but the optical properties are effaced.

Olivine is the element in which the decomposition is most advanced; to such a point is this the case that it would be even impossible to recognise it except for the cleavages and the form of its sections. These sections are shown in Pl. XIX. fig. 4, where they appear regularly terminated with geometrical inclusions of the vitreous base with a fibrous structure, and covered with the red colour of hematised olivine. In the basalt represented in Pl. XIX. fig. 2, the alteration has attacked the olivine to such an extent that the crystal is almost destroyed; not only is it hematised, but it seems to be broken up and everywhere invaded by infiltrations of manganese disposed in large brown or opaque patches. No better example could be given of the state of decomposition of the volcanic rocks and minerals so frequently met with in deep-sea deposits.

The vitreous base of some of the basaltic specimens is the first portion of the rock to undergo alteration, and it generally presents the same palagonitic appearance as the basic glasses, forming irregular patches of variable dimensions, or thin veins between the crystallised minerals. When thus altered this base assumes a zonary structure, presenting a beautiful red tint, and reacting between crossed nicols; in fact it behaves in every way like palagonite. Generally manganese infiltrations follow with the progress of the decomposition, and the structure of the base is then entirely masked, as may be observed by reference to Pl. XIX. fig. 4. When it happens that this fundamental vitreous mass is still sufficiently intact to permit observation with high powers, it is sometimes seen to be devitrified by globulites, by trichites, and other embryonic crystalline elements. In short, the basalts met with in deep-sea deposits do not offer any peculiarities of structure or of composition different from those met with in similar rocks found on subaerial surfaces; that which more especially characterises them is their advanced state of alteration.

Fragments of *limburgite*, more or less palagonitised and filled with whitish zeolites, are also found under the same conditions in deep-sea deposits as the lapilli already referred to, from which they are distinguished by their mineralogical composition. In these, crystals of porphyritic augite and olivine are observed in an altered vitreous base. When the fundamental mass is still fresh it offers all the characters of the glass in the basic lapilli; when it is altered it presents all the characters of palagonite. These fragments of limburgite are relatively rare, and are easily confounded with the basic glasses and the vitreous basalts into which they pass. We have only found them sharply characterised at a few stations, and especially at Station 157, 1950 fathoms, in the Southern Indian Ocean, where they were associated with pebbles of ancient and recent volcanic rocks.

The fragments of *augite-andesite*, or of andesite with rhombic pyroxene, occur very frequently, and with the same external characters as the lapilli of the preceding types. They may be distinguished by their composition, the absence of olivine and the presence of sanidine and quartz separating them from the basaltic lapilli. Sometimes they contain rhombic pyroxene, and are associated frequently with tufaceous andesitic cinders. In the Tables of Chapter II. they are stated to occur at Stations 147 and 150, in the Southern Indian Ocean; Station 214, among the Philippines; Stations 276, 293, and 295, in the South Pacific. Some rare lapilli of hornblende-andesite were also met with; these had a fundamental mass with a fine greyish black grain, enclosing plagioclases, hornblende, and sometimes sanidine.

It may be said that, generally speaking, fragments of acid rocks are especially rare among the recent volcanic rocks in the Challenger dredgings. An exception must, however, be made with respect to pumice, for we have seen that its mode of transport may be quite different from that of the fragments and lapilli just referred to. Just as the lapilli of basic rocks are abundant in certain regions of the Pacific, for example, so, with the exception of pumice, are trachytic and liparitic lapilli rare in these same positions. At certain stations, however, the nature of the mineral particles, the relative abundance of sanidine and of hornblende, the occasional presence of quartz, and especially of splinters of acid glass, all indicate that eruptions of trachytic cinders and lapilli must have taken place at the bottom of the sea. But it is difficult to be quite certain upon this point, for after what has been said above with reference to the distribution of pumice, its origin, and its disintegration, it may quite well happen that what is regarded as trachytic ashes from a submarine eruption may be nothing else than the residue derived from the disintegration of liparitic pumice. Finally, it may be pointed out that just as the lapilli of compact basic glasses are abundant in a pelagic deposit, so are the splinters of obsidian, properly so called, rare in the same soundings or dredgings.

Volcanic Ashes.—The minuter glassy and mineral particles of a volcanic eruption are usually called volcanic ashes, and differ only from the lapilli, with which indeed they are often associated, by their smaller dimensions. They may, however, occur without these larger fragments, and they have as a general rule a much wider dispersion; indeed their distribution in deep-sea deposits is as extensive as that of pumice. By casting the eye down the columns of mineral particles in the Tables of Chapter II., it may be seen that fragments which might be called volcanic ashes are much more widely distributed than the lapilli or fragments of rocks. This arises from the circumstance that these volcanic mineral particles may have a double origin: they may have been projected as isolated grains by subaerial or submarine eruptions, or they may be derived from the mechanical disintegration or the chemical decomposition of pumice or lapilli, of which they formerly were constituent parts. In other words, they may be volcanic ashes in the proper sense of the term, or the residue of pumice and of lapilli more or less destroyed. All that was said at the commencement of this chapter with regard to the distribution of pumice applies equally to these incoherent particles. It will suffice to recall the phenomena witnessed in Iceland in 1874 and in Krakatoa in 1883, together with many similar instances, with reference to the projection of ashes, to understand the vast extent over which these particles may be spread. Granted the origin of these fragmental materials from the pulverisation of liquid lava, their transportation by air and by water, one would expect to find these volcanic dusts everywhere in the deep-sea deposits; and remembering the rapidity with which they must have cooled, they should be present as vitreous particles, with the minerals which were ejected with them, in more or less embryonic form, and generally covered with a vitreous coating. This is, in fact, what is observed in pelagic deposits.

It seems important here to recall what is understood by recent volcanic particles in opposition to mineral particles derived from the decomposition of ancient rocks of continental origin, which make up the larger part of terrigenous deposits. The researches of the last few years seem to have shown that the subdivision, before generally admitted, into Tertiary and Post-Tertiary volcanic rocks, and into Plutonic or Pre-Tertiary rocks, cannot now be maintained. If we have, however, designated as recent rocks those spoken of up to this point in the present chapter, it is only because their position at the bottom of the sea and their lithological nature appear to require this classification. We seem to be justified in regarding these volcanic ashes as recent volcanic products like the pumice and the lapilli, with which they are associated in deep-sea deposits. It becomes very difficult to make this distinction among the mineral particles, especially when the products of recent eruptions are mixed in the terrigenous muds with the debris of continental rocks, and the difficulty increases still more when, far from the coasts, the terrigenous materials transported by icebergs and atmospheric currents are encountered.

However, what permits us to pronounce upon the relative age of these particles, derived from showers of ashes or from the alteration of rocks of recent eruptions, is their position in the deposits; they are distributed in all the pelagic deposits in process of formation. They are found in the superficial muddy layers forming the bottom of the sea at points where mechanical actions could not have torn them from the subsoil and transported them to a distance; indeed, we must regard the bottom of the ocean as everywhere covered by deposits made up of free particles which have accumulated during long ages upon the solid rocks constituting the true subsoil. It must then be admitted that the muddy layer into which the dredge or trawl can sink only a few feet from the surface is of recent age, or at the most Tertiary in certain points of the Pacific, where numerous vertebrate remains were procured. We have still another proof of the recent age of these volcanic ashes in the fact that the vitreous particles have in many instances still preserved their original fresh characters, whereas in the older geological formations similar particles have undergone profound alteration. The same argument holds good for the isolated mineral particles associated with the vitreous splinters. Although alteration has commenced in an appreciable manner in many of these minerals and fragments, it may be said that in the majority of cases it is not far advanced.

In the year 1883 we published a memoir[1] on the characters of volcanic ashes and the products of the disintegration of pumice and lapilli found in marine deposits. These characters have been in part given under the heading of pumice. In addition to the characters due to form there pointed out, the abundance of embryonic crystals and of skeletons of crystals may be regarded as likewise characteristic of these particles. The presence of crystals arrested in their development may easily be accounted for if we remember that the vitreous material which encloses them has been suddenly cooled, and that molecular changes have consequently been suddenly interrupted.

The mineral particles in a deep-sea deposit having been derived from a great variety of sources, it is as a general rule impossible to say which of the volcanic particles have been derived from the basic, neutral, or acid series of rocks, and owing to this mixture chemical analysis is not available as a means of interpretation. Sometimes, however, it is possible to state with considerable certainty that the volcanic particles have been derived from a shower of ashes from a single eruption, as, for instance, in the case represented in Pl. IV. fig. 3 from the South Pacific, Station 281, 2385 fathoms. Here the coarser particles have fallen upon a Red Clay, the point of junction being represented by the dark line in the centre of the section, finer and finer particles lying in layers above these just as they have fallen more slowly through the water. In Pl. XXI. fig. 2 the larger mineral particles of this volcanic ash are shown at the line of junction

[1] *Proc. Roy. Soc. Edin.*, vol. xii. pp. 474 *et seq.*

between the ash and Red Clay, the left of the figure representing the ash and the right the Red Clay. In the volcanic ash all the minerals are clastic, irregularly disposed, with almost no interposition of clay. This accumulation has a greenish tint due to the presence of a large number of fragments of augite, hornblende, delessite or chloritic substance. The outlines of almost all the crystals are blunted as if broken. Hornblende is represented by fragments of a brownish or dark greenish colour, with the characteristic cleavages, strongly pleochroic. The crystals of augite are greenish or brown-violet; very often augite is present in the form of aggregated microliths surrounded by delessite. There is also a large number of sections of felspar belonging to plagioclase or sanidine; they are colourless, more or less irregular, and generally transformed into zeolitic matter. Moreover, there are in this ash rather small lapilli, principally formed of an aggregation of green microliths of augite and small fragments of basalts, or of highly-altered basic glass. Finally, there are numerous grains of magnetite, of manganese, and of olivine transformed into hematite. All these mineral particles are cemented by colourless zeolitic substances.

The general appearance of these particles under the microscope is further represented in some of the lithographic plates at the end of the volume. Plate XXVI. fig. 2 shows numerous minute vitreous splinters transformed into palagonite and coloured by manganese and iron, along with augite, plagioclase, magnetite, from a Red Clay, Station 282, 2450 fathoms, South Pacific. Fig. 3 of the same plate represents the mineral particles of a Red Clay from the South Pacific, off the coast of Australia, Station 165A, 2600 fathoms. There are numerous angular fragments of volcanic glass with elongated pores and ragged outlines among the particles of felspar, hornblende, grains of manganese, and minute rounded particles of quartz. The rounded fragments of quartz coloured with limonite, represented in this figure, are evidently wind-borne particles from the continent of Australia. Pl. XXVII. fig. 2 represents the mineral fragments and fine washings in a Red Clay from the South Pacific, Station 178, 2650 fathoms. Besides the crystals of felspar and augite there are numerous vitreous, colourless, volcanic particles with elongated pores, and in addition to these a very large number of extremely minute particles of the same nature, which make up the principal part of what we denominate in this work "fine washings." These smaller microscopic particles are more or less angular, forming an impalpable powder, and it will be seen that they cover the field of the figure between the larger mineral particles. Pl. XXVII. fig. 3 shows again abundance of vitreous particles of pumice, along with volcanic minerals, from a Red Clay in the North Pacific, Station 240, 2900 fathoms. As in all the preceding residues, the mineral particles are angular; the vitreous particles are sharply characterised by their ragged outlines and their structure, and among them are some vitreous grains transformed into palagonite. Pl. XXVII. fig. 4 presents once more an abundance of volcanic particles from a Red Clay, South Pacific, Station 294, 2270 fathoms. The vitreous particles present the same characters as in the preceding figures, associated with crystals or splinters of felspar, plagioclase, augite, and magnetite. Among the particles may be observed bipyramidal crystals of quartz, which may have come from the disintegration of a liparitic rock. In Pl. XXVII. fig. 5 the aspect of the minutest particles of the fine washings of a Radiolarian Ooze is represented, from Station 225, 4475 fathoms, West Pacific. In addition to the debris of organisms, there may be observed little fragments of volcanic minerals, or splinters of colourless glass with a porous appearance. Pl. XXVI. fig. 1 represents the mineral particles from the residue of a Globigerina Ooze, in the South Pacific, Station 300, 1375 fathoms; these are observed to have the same characters as in the case of the Red Clays, consisting of vitreous particles associated with splinters of felspar, plagioclase, magnetite, augite, and minute grains of manganese peroxide.

If now we pass to the mineral particles in terrigenous deposits, we may still in some instances recognise an abundance of vitreous particles, as, for instance, in the deposit called a Blue Mud, in the South Pacific, Station 303, 1325 fathoms, represented in Pl. XXVI. fig. 4. Here the mineral particles are almost exclusively formed of splinters of a brownish glass, more or less vesicular, the pores being generally rounded, but associated with these are colourless particles with a filamentous structure, which are probably derived from acid glasses. The predominance of vitreous particles and volcanic minerals in a Blue Mud is also represented in Pl. XI. fig. 2, showing the mineral particles from Station 237, 1875 fathoms, North Pacific. Here there are seen besides the fragments of plagioclase, sanidine, augite, hornblende, and magnetic grains, many splinters of vitreous matter which are present under three different aspects—some transparent, slightly violet, or almost colourless, fibrous with cylindrical pores, as may be seen in the lower part of the figure and near the upper left hand side; other vitreous splinters are deep brown, almost opaque, with large, more or less circular, pores; and again these vitreous particles are transformed into a reddish brown resinoid substance, resembling palagonite, as may be seen on the right hand side of the figure. In Pl. XXVII. fig. 1, which represents the mineral particles in a Volcanic Mud, off the Sandwich Islands in the North Pacific, Station 262, 2875 fathoms, we have a most typical example of these vitreous fragments. The whole field of the microscope is occupied by vitreous particles, slightly brownish in colour, with relatively few pores, but presenting the characteristic fracture and outlines of these glassy fragments.

All the figures to which we have referred represent these particles in an isolated condition in the deposit. In the compact tufas which were dredged from the bottom of the sea they present a slightly different aspect.

In the Tables of Chapter II. vitreous particles are recorded in 45 specimens of Red Clay, 6 of Radiolarian Ooze, 4 of Diatom Ooze, 63 of Globigerina Ooze, 6 of Pteropod Ooze, 20 of Blue Mud, 3 of Red Mud, 10 of Green Mud, 20 of Volcanic Mud, 3 of

Volcanic Sand, 7 of Coral Mud, and 1 of Coral Sand. This enumeration indicates the wide, even the universal, distribution of these particles over the floor of the ocean.

Recent Volcanic Minerals in General.—After what has been stated above, there can be little doubt as to the mode of origin and relatively recent age of the numerous vitreous particles scattered over the floor of the ocean. It has been indicated that the mineral particles and the more or less complete crystals, which are mixed with these vitreous fragments in deep-sea deposits, have in all probability a similar age and origin, having been derived from the disintegration of the pumice and lapilli of submarine and subaerial eruptions. While this is probably the correct interpretation for the mineral particles of those pelagic deposits in which all, or nearly all, the inorganic residue is made up of volcanic products, it cannot be held to apply to those deep-sea deposits around continental shores, in which the fragments of crystalline, schisto-crystalline, clastic, and organic rocks of various ages make up a large part of the deposit.

With reference to the origin of the mineral particles, we, in all cases, rely principally upon their association with larger fragments of rocks containing these minerals in the same deposit or in the same region of the ocean. Thus, when we discover in the free state crystals of plagioclase and augite, still in part covered by vitreous matter, associated in the same deposits with palagonitic lapilli or altered pieces of pumice, we conclude that these isolated minerals are of the same age as, and have had a similar origin to, the fragments which accompany them. In the same manner, if we find orthoclase, mica, or quartz, for example, along with fragments of granite, gneiss, and schist, we are led to conclude that the minerals in a free state in the mud have been transported by the same agents that have carried the rocks accompanying them, to which we assign a continental origin. This distinction has all the more force remembering what has been said as to the universal distribution of volcanic materials in the form of pumice, lapilli, and ashes, and the more limited distribution of the terrigenous minerals, which are transported only to a relatively restricted zone surrounding continental shores.

In some cases continental fragments may be carried much further than here indicated, and may be mixed with the volcanic fragments which are characteristic of pelagic deposits. In these cases the distinction between minerals derived directly from continental rocks and those derived from volcanic products becomes exceedingly difficult, and we must then rely upon the peculiarities which the minerals present, especially the silicates of eruptive rocks, according as they have crystallised in rocks of the ancient or of the more recent series. We will point out the distinctive characters which may serve as a guide in this classification, but it must be remarked that these characters have no absolute value, and that between the same species of minerals constituting the two series of rocks the differences are rather quantitative than qualitative. However, when these special details are taken into consideration along with the mineralogical and lithological associations, as well as the position with reference to distance from coasts, there is an excellent means of forming an opinion relative to the origin of the mineral particles that may be met with in deep-sea deposits. On pp. 19–23 we have indicated the properties most easily observed in free mineral particles, in the form of more or less perfect crystals or irregular splinters, that may serve to determine the species. It remains here to point out some special characters of volcanic minerals, which permit us to distinguish them from minerals of continental origin. Under each species, arranged alphabetically, are given the distinctive peculiarities on which we have relied in determining the species as having come from recent eruptions.

AMPHIBOLE, *Basaltic hornblende*, fragments of well-crystallised individuals, sometimes regularly-bounded crystals coated with volcanic glass, generally compact, no fibrous structure, well-marked cleavage, high lustre on the planes of cleavage, black by reflected light, brown or reddish brown by transmitted light, strong pleochroism and absorption, zonary structure, numerous vitreous and gaseous inclusions, coating of magnetite and characteristic corrosion. FELSPARS, (*a*) *Monoclinic, Sanidine,* often in crystals, with glassy habit, colourless and transparent, tabular parallel to M, or elongated parallel to the edge P/M, separation-planes parallel to the orthopinakoid, numerous gas and vitreous inclusions often crowded together in the same crystal, having sometimes geometrical outlines, and often regularly disposed in the interior of the crystal, often covered by or imbedded in a glassy coating. (*b*) *Triclinic, Plagioclase,* glassy habit, transparent, few decomposition products, crystals in the form of thin rhombic tables parallel to M, gaseous and vitreous inclusions. *Olivine,* regularly-formed crystals coated with volcanic glass or palagonite, often skeleton crystals, inclusions of vitreous particles, rarely decomposed into serpentinous matter, often reddish by decomposition of ferric oxide. PYROXENE, (*a*) *Rhombic, Hypersthene,* reddish or brownish fragments, or bounded by cleavage planes, or vaguely-outlined crystals, prismatic, intergrowth with monoclinic pyroxene. *Bronzite,* glass inclusions, no intergrowth with monoclinic pyroxene. (*b*) *Monoclinic, Augite,* often regularly-formed crystals, or fragments coated with volcanic glass, fresh, rarely decomposed into chloritic substance or into uralite, frequent glass inclusions. *Quartz.*—In exceptional instances quartz was observed as small crystals bounded by the planes of the hexagonal prism and pyramid; these may have been derived from liparitic ashes, or from the disintegration of liparitic rock fragments. In other cases a few quartz grains containing glass inclusions were observed, hence in all probability of volcanic origin.

It is evident that the distinctive characters given above are especially in relation with the less advanced degree of decomposition, which is itself a consequence of their recent eruptive origin. These characters have never been used exclusively, but always in conjunction with the mineral associations and positions in the deposits. There are other mineral particles in the sediments, which, in the free state, do not offer any distinctive characters to admit of even an approximate classification as to their origin. Among these are magnetite, black mica, apatite, epidote, zircon, delessite, and zeolites, such as analcim and chabasite. Some of these, as epidote and zircon, would not likely be found in any abundance among the debris of recent rocks; their presence, however, is possible. As to the secondary minerals and products of alteration, like glauconite, oxides of iron and manganese, zeolites, phosphates, and carbonate of lime casts, they will be considered in detail in the succeeding chapter.

Although it may be difficult to determine the relative abundance of the different kinds of mineral particles in each type of deep-sea deposit, still it may be stated generally that volcanic minerals, which bear distinctly the impress of their origin, are not only universally distributed throughout deep-sea deposits as a whole, but that they abound in the pelagic deposits properly so called, where they form essential constituents. In these pelagic regions the minerals are angular, generally of small dimensions, have a relatively fresh aspect, and are attached to vitreous particles or to rocks of volcanic origin. In certain cases these same volcanic minerals occur in the free state in Volcanic Muds and Sands close to the coasts, but then the dimensions and physical characters permit us to distinguish them from minerals of the same nature found in the deposits forming at depths beyond the mechanical action of the sea.

Some of the figures on the plates at the end of the volume represent the aspect of these volcanic minerals in the deposits of the littoral and shallow-water zones. Pl. XXVI. fig. 5 shows such particles from the littoral zone at the Sandwich Islands, where they are almost exclusively composed of broken crystals of olivine; this uniformity of the minerals proves that we are dealing with a deposit from a position in which the action of wind and water effects a separation according to specific gravity. A similar separation of minerals is never observed in deep-sea deposits, where the elements are much less voluminous, as may be seen by reference to figs. 1 to 4 on the same plate. Pl. XXVII. fig. 6 represents rounded grains of quartz, glauconite, tourmaline, and zircon, from Station 189, 28 fathoms, in the Arafura Sea. Pl. XXVI. fig. 6 represents the volcanic minerals of a shallow-water deposit off the Admiralty Islands. As in fig. 5 the grains are large; some are distinctly rolled, and among them are plagioclase, hornblende, augite, olivine, magnetite, fragments of volcanic glass, palagonite, rounded lapilli, and quartz. Pl. XI. fig. 2 shows the volcanic mineral particles in a deposit further removed from the coast, but not in pelagic conditions properly so called; these are from a Blue Mud, Station 237, 1875 fathoms, off Japan. Among the particles are plagioclase, sanidine surrounded and enclosed by a blackish opaque glass, hornblende, augite, little plates of black mica, magnetite, and fragments of volcanic glass more or less decomposed. In Pl. XXVII. figs. 1 to 3, and Pl. XXVI. figs. 2 to 4, the characters under which these volcanic minerals appear in pelagic deposits are represented, and may be compared with the figures above referred to.

(b) *Rocks and Minerals derived directly from the Continental Masses.*

The widespread mineralogical products in marine deposits, derived from the ejections of submarine and subaerial volcanoes, have been dealt with in considerable detail in the preceding section, and it is now necessary to consider the products of the second category, with a more restricted distribution, referred to at the beginning of this chapter, viz., those derived immediately from continental masses and emerged lands. In the first instance, we may direct our attention to the fragments of continental rocks, and their distribution in marine deposits, and afterwards consider the mineral particles derived from the disintegration of continental rocks.

Fragments of Continental Rocks.—It is unnecessary to treat in detail the fragments of rocks and minerals met with in the littoral and shallow-water zones. It is evident that these are, for the most part, derived from the adjoining coasts, by the action of tides, waves, currents, and winds upon the submerged and emerged rocks which crop out in the shallow-water and littoral zones, or they have been transported from the far interior of the continents by the action of rivers and the ice with which rivers may sometimes be covered. In this work we have especially to deal with the deposits formed in the deep sea, that is beyond the 100-fathom line, or beyond what we have called the mud-line, where currents, waves, and other mechanical agents, play but an insignificant role. From *à priori* considerations we would not expect large fragments of the continental rocks to be carried seaward beyond the mud-line, except in what might be called abnormal conditions. The larger fragments met with in such abundance in the shallow-water and littoral zones are, by the mechanical and chemical actions of the region, continually subject to disintegration and decomposition; the minute products of their destruction are transported by currents into the stiller waters of the deep-sea region, where they slowly settle to the bottom, forming muds and oozes. The minute fragments thus transported seawards are rarely fragments of rocks, being principally made up of the more resistant crystalline particles, together with clayey and other amorphous matters. Indeed, under all normal conditions, it is rare to find fragments of rocks among the mineral constituents of a deposit, even in depths of a few hundred fathoms, and thirty or forty miles seaward, even although the shallow-water zone towards the land be of great extent, and covered with continental blocks of all dimensions and of varied lithological constitution.

It is well known, however, that continental blocks are in exceptional circumstances carried to great distances fixed in the roots of trees, or entangled among the other materials that are borne as natural rafts into the ocean from great rivers. Rivers affected with ice during some part of the year are also the means of distributing continental rocks over the ocean to considerable distances from their embouchures, but icebergs effect this distribution to a much wider extent than any other agent with which we are acquainted.

In the examination of the deposits collected by the Challenger and other expeditions, fragments of continental rocks and minerals were rarely if ever found in any of the regions of the great ocean basins far from land, except in, or in the immediate neighbourhood of, those regions affected by floating ice and icebergs in the northern and southern hemispheres. It is true that these fragments of rocks have been found some distance beyond the known limits of floating icebergs, but it is evident that floating ice must have had a wider extension formerly than at the present time. In the Quaternary Period, for example, the great extension of glaciers indicates that the icebergs derived from them must have been more numerous, while the climatic conditions must have contributed to their wider distribution in low latitudes.

During the voyage of the Challenger, the fragments of ancient rocks and minerals were met with in more or less abundance in the following regions:—

Between Bermuda and Halifax:[1] large block of syenite, diabase, quartziferous diabase, basalts; fragments of gneiss and of mica-schists; quartzite containing tourmaline, zircon, kaolin, chloritic substance; dolomitic limestone.

Between Bermuda and Azores:[2] sandstone containing mica; mica-schist.[3]

Between Tristan da Cunha and Cape of Good Hope:[4] the presence of large fragments of quartz, orthoclase, hornblende, tourmaline, and augite, indicates that the Challenger here passed over a region occasionally affected with floating ice.

Between Heard Island and Melbourne.[5] During this trip towards the Antarctic regions, blocks, pebbles, and fragments of ancient rocks were found to make up a considerable proportion of the whole of the deposits, the following having been observed:—Granite containing orthoclase, plagioclase, quartz, black mica; granitite containing orthoclase, plagioclase, quartz, black mica, and hornblende; gneiss containing quartz, black and white mica, garnet; amphibolite with large crystals of green hornblende and quartz; metamorphic quartzite speckled with black mica; fine grained micaceous sandstone, with white mica; fine grained chloritic sandstone; red sandstone; slates containing sericite, rutile, and quartz.

Between Tahiti and Valparaiso.[6] Although the Challenger was considerably to the

[1] See pp. 151, 152. [2] See p. 152.

[3] The French ship "Talisman" dredged fragments of continental rocks even further to the south and east (see Fouqué and Lévy, *Comptes Rendus*, tom. cii. pp. 793–795, 1886).

[4] See p. 157. [5] See pp. 163, 164. [6] See p. 180.

north of the known limit of icebergs in this trip, still there were several fragments which appear to have been derived from icebergs:—

Station 285, rounded fragments of granite, arkose;
,, 286, granite pebble;
,, 289, fragment of diabase;
,, 299, angular piece of granite;
,, 302, piece of granite coated with manganese, fragment of flint.

If the positions of the fragments above enumerated be compared with a map showing the distribution of icebergs in the present seas, it will be observed that they are all within, or just beyond, the limits of the iceberg regions, and it cannot be regarded as other than a remarkable fact that the Challenger should not have found any fragments of continental rocks in the central portions of the ocean basins, except in the localities indicated. The position, then, in which these blocks and fragments of continental rocks were found is in itself sufficient evidence that they have been transported by floating icebergs and icefields of the present or of recent geological times. This view is confirmed by the nature and character of the transported material. The blocks are of all sizes, from several feet in diameter to the smallest dimensions; their angles are sometimes rounded or softened, at other times sharp, and the larger fragments are frequently covered on one or more surfaces by glacial striations. In their nature the fragments are very heterogeneous, being derived from almost all the varieties of the rocks that crop out on the surface of the continents. This great variety in the dimensions and lithological nature of the continental debris spread over the floor of the ocean towards the polar regions of either hemisphere is exactly what we would expect to find in materials transported by floating ice. The glaciers, which give birth to the icebergs, in passing over the continental surfaces would necessarily carry away large and small fragments of all the continental rocks cropping out at the surface. The icebergs, in widely distributing these continental materials, would produce in the deep sea a deposit containing fragments of granite, gneiss, quartzite, schists, dolomites, crystalline limestones, and even fragments of volcanic rocks. The heterogeneity of such a deposit is thus in striking contrast, so far as its mineralogical constituents are concerned, to the homogeneity presented by truly pelagic deposits, in which, as we have seen, volcanic materials alone make up the inorganic portion of the deposit.

While icebergs are the only agents that are capable of effecting this wide distribution of continental rocks and minerals, Mr. Murray has shown that both seals and penguins carry to sea large numbers of stones and rounded pebbles in their stomachs, to which the sealers give the name of "ballast."[1] These animals may therefore, to some extent, distribute rock fragments to great distances from the land. Should any of them be killed

[1] See Zool. Chall. Exp., pt. viii. pp. 126, 127; also Turner, Report on the Seals, Zool. Chall. Exp., pt. lxviii. p. 136.

or die at sea, their soft parts, and even their bony structures, might be entirely removed in solution, while the stones and pebbles contained in their stomachs would remain as a part of the deposit.

It has been pointed out that minute fragments of rocks, especially particles of quartz and other continental minerals, have been found in some of the deep-sea deposits at great distances from the coasts of Africa and Australia. This abnormal distribution is to be accounted for by the great distance to which winds may carry dust from desert regions on the continental surfaces, as, for instance, the Sahara and the interior of Australia.

It will thus be seen that the area to which continental debris may be transported over the floor of the ocean varies greatly in different localities. It is least along high and bold coasts in tropical and subtropical regions; it is more extensive off the mouths of great rivers, off the coasts of desert regions, and in enclosed seas, but is most extensive towards the polar regions, where blocks of all sizes and kinds are widely distributed by icebergs and other kinds of floating ice.

Minerals derived from the Disintegration of Continental Rocks.—An examination of terrigenous deposits shows that the prevailing minerals around continental shores are those that might be derived from the disintegration of emerged lands. The size of these minerals, as well as their abundance, is in direct relation with their greater or less distance from the coasts, except in iceberg regions. They have frequently a rolled aspect, their angles being softened, and they recall by all their peculiarities the same mineral species which constitute most of the geological layers making up the continental masses. Quartz plays the principal role. The normal position of these minerals is coincident with the distribution of terrigenous deposits, and if exceptionally they are found in pelagic deposits, they have been in these cases transported by icebergs, by atmospheric currents, or other agencies to which we have just referred in speaking of the distribution of continental rocks.

In some cases there are special characters which may serve as a guide in attempting to establish the terrigenous origin of these particles, but it must not be denied that this subject is surrounded with many difficulties. It is often difficult to determine the age of certain rocks by a study of their lithological composition; in a much higher degree, therefore, is the determination of the isolated minerals which constitute these rocks a matter of great uncertainty. In all these cases the most certain guide is the mineralogical association with the rock fragments in the deposits. There are some minerals which have not been recognised in recent eruptive rocks, or at least are extremely rare in these masses, while on the contrary they are extremely abundant in the rocks of the ancient eruptive series; tourmaline and muscovite are examples. If minerals, about which there is uncertainty as to their age and origin, be associated with fragmentary masses of crystalline and sedimentary rocks of the ancient series, we may conclude with very great probability that these minerals have been derived from the disintegration of rocks found at the surface of the continents. These determinations rely not so much upon any isolated characters, as upon the union of a variety of conditions, such as geographical position, size and form of the grains, specific nature of the minerals, characters indicating the mode of transport, and especially the lithological and mineralogical associations.

After these general remarks we may give an enumeration of the principal species of minerals which are considered as having a terrigenous origin, along with some of their most striking peculiarities. It must be remembered, however, that these characters are not absolute, and that their value is important only when taken along with associated rocks and minerals.

Amphibole, *Common Hornblende*, generally greenish, rarely brownish, more or less distinctly prismatic, fibrous structure, rarely zonary or containing inclusions, cleavage planes not well marked nor very shining, associated with debris of crystalline or schisto-crystalline rocks. *Actinolite*, found as columnar or fibrous aggregates, associated with large fragments of actinolite-schists. *Glaucophane*, small prismatic fragments, pronounced violet-blue colour, associated with land debris and fragments of mica-schists and gneissic rocks. *Apatite*, although mineralogically no distinction possible from apatite derived from volcanic rocks, the larger grains of this mineral, often elongated or rounded fragments, occur associated with debris of older rocks. *Calcite*, fragments of compact limestones. *Chlorite* cannot be determined by its proper characters as originating from older rocks, but frequently occurs with debris of schistose rocks, with amphibolic or schistose fragments, also as coatings of some continental rocks and minerals. *Chromite*, with debris of olivine rocks. *Dolomite*, as fragments of dolomitic limestones and dolomitic rocks, with blocks and gravel of older eruptive and sedimentary rocks transported by icebergs. Felspars (*a*) *Monoclinic, Orthoclase*, generally fragments bounded by cleavage planes following P and M, often altered grains, no glassy habit, dull and milky, no glass inclusions, some liquid inclusions, intergrowth with quartz or with triclinic felspar, decomposition into kaolin or muscovite, no zonary structure nor fissures as in sanidine, associated in the deposits with debris of crystalline schists, and principally with older eruptive rock fragments. (*b*) *Triclinic, Microcline*, always associated with debris of continental origin. *Plagioclase*, dull and cloudy, generally altered, associated with debris of older eruptive rocks. *Garnet*, although mineralogically no distinction possible, must be of continental origin when coated with green chloritic or serpentinous substance or phyllitic matter, and occurring with fragments of schisto-crystalline rocks. *Glauconite*.[1] *Magnetite* cannot be distinguished from the same mineral in the recent volcanic rocks and particles, but often associated with land debris. Mica, *White Mica*, always associated with older eruptive rocks and continental debris; *Sericite*, associated with fragments of schistose

[1] See Chemical Deposits, Chapter VI.

rocks. These two micas are very characteristic of terrestrial rocks and mineral particles. *Olivine*, distinction difficult, but sometimes irregularly-bounded fragments, decomposing into serpentine, and with fragments of older eruptive rocks. PYROXENE (*a*) *Rhombic*, *Bronzite*, lamellar aggregates, generally large fragments found with older eruptive rock debris, with peridotite fragments. (*b*) *Monoclinic*, *Augite*, fragments irregularly bounded or bounded by cleavage planes, transforming into uralite or chlorite, rarely vitreous inclusions, associated with fragments of diabase. *Diallage*, grains bounded by cleavage planes, associated with mineral particles and fragments of older eruptive rocks. *Quartz*, grains generally without crystallographic outlines, rounded or angular, sometimes covered with oxide of iron, liquid inclusions, some with carbonic acid or small cubic crystals, needles of rutile, tourmaline, scales of chlorite, hematite, &c. Occurs always with granitic, porphyritic, schisto-crystalline rocks, or with fragments of continental sedimentary rocks; the minerals and rocks associated with the quartz grains give a clue as to the matrix rock. In some cases grains quite rounded, and all of about the same dimensions, with thin coating of limonite, found far from coasts in pelagic deposits, are to be considered as wind-borne.[1] *Rutile*, small grains, or microscopic prismatic crystals imbedded in schistose rock particles, always associated with continental debris. *Serpentine*, compact or fibrous grains, associated with fragments of older crystalline rocks, principally with peridotic rocks. *Tourmaline*, often in small prismatic fragments of crystals, almost always of continental origin and associated with debris of crystalline schists, granitic rocks, &c.[2] *Zircon*, small quadratic crystals, more or less rounded, as in the case of tourmaline, almost always of continental origin, and found with debris of crystalline schists and of older eruptive rocks; associated frequently with quartz grains, and other minerals derived from the disintegration of sedimentary rocks.[3]

The above are the principal mineral particles in the marine sediments to which we attribute a continental origin. The mineral characters of many of them are not, however, of a nature to give certain and satisfactory indications; especially is this the case for the particles of apatite, chlorite, chromite, epidote, garnet, hematite, magnetite, olivine, and pyrites. It is only the geographical position, along with the mineralogical associations, that permits a satisfactory determination in any particular case. On the other hand, for several of the species a continental origin seems to be indicated beyond all doubt; this is the case with glaucophane, white mica, sericite, tourmaline, zircon, microcline, and for the great majority of the grains of quartz.

[1] See Plate XXVI. fig. 3; these rounded grains of quartz are here associated with particles of felspar, green hornblende, glassy volcanic fragments, grains of manganese, very rarely fragments or particles of vein quartz, milky, and of irregular form, found with continental land debris.

[2] See Plate XXVII. fig. 6; black fragments of prismatic crystals of tourmaline, with rounded grains of quartz glauconite, and zircon.

[3] See Plate XXVII. fig. 4; small bipyramidal crystals, one in the centre, the other a little higher in the figure.

II. Mineral Substances of Extra-Terrestrial Origin.

Among the many substances contributing to the formation of deep-sea deposits, there are a few of small dimensions which it has not been possible to refer to a terrestrial origin. Both on account of their small size and their rarity, they make up only an insignificant part of any of the samples of the different types of deep-sea deposits, but on account of the extra-terrestrial origin attributed to them, and their peculiar distribution over the floor of the ocean, they are exceedingly interesting, have given rise to much discussion, and therefore merit a detailed description. Mr. Murray first called attention to certain of these particles from the deep-sea deposits in the year 1876,[1] and described them as cosmic dust, pointing out at the same time that these particles were much more abundant in all the deep-water deposits far from land, where accumulation must be relatively slow, than in other regions of the ocean's bed. The detailed characters of these magnetic spherules, with illustrations, were given by us in a special paper published in 1883, in which were also described the brown-coloured spherules or chondres.[2]

When the magnetic particles are extracted from a marine deposit, in the manner described on page 17, and placed under the microscope, it will be found that the great majority consist of magnetite derived from eruptive and other rocks. Many of these are still attached to silicates or vitreous volcanic matter, which clearly indicate their origin. But along with these fragments of magnetite or titanic iron, there are other grains equally magnetic which do not present crystalline contours, and do not occur in the form of irregular grains;—it is to these that the name of cosmic dust has been applied. They may be divided for the purposes of description into two groups:—first, black magnetic spherules, with or without a metallic nucleus; second, brown-coloured spherules resembling chondres, with a crystalline structure.

(a.) *Black Magnetic Spherules.*

These magnetic spherules rarely exceed 0·2 mm. in diameter. Their black and shining surface is formed by a coating which possesses the properties of magnetic iron. This coating is absolutely opaque and black in thin splinters, has a metallic lustre, is attracted by the magnet, and is soluble with difficulty in acids. There is often at the periphery of the spherule a more or less pronounced depression. Such are the general external characters, which may be verified by reference to the various figures on Pl. XXIII., chiefly devoted to a representation of particles believed to have a cosmic origin. Fig. 1 shows one of these spherules extracted from the powder of a manganese

[1] *Proc. Roy. Soc. Edin.*, vol. ix. p. 258.

[2] Murray and Renard, "On the Microscopic Characters of Volcanic Ashes and Cosmic Dust, and their Distribution in Deep-Sea Deposits," *Proc. Roy. Soc. Edin.*, vol. xii. pp. 474–495.

nodule from the South Pacific, Station 285, 2375 fathoms. This grain is perfectly spherical, and is drawn so that the little depression is on the opposite side from the observer; it shows the aspect presented by these granules in reflected light under the microscope. The surface with metallic lustre is not perfectly smooth, but appears as if scattered with a large number of little asperities or pores. Fig. 4 represents a spherule from the same station identical in form and aspect with the preceding, but showing the cupule which is seldom absent in these magnetic globules. This cupule, it will be seen, is a circular depression attaining sometimes a diameter equal to half of that of the spherule, and appears to be characteristic of these granules; we shall presently endeavour to interpret its formation. The spherule represented in fig. 6, from the South Pacific, Station 276, 2350 fathoms, is much the same as the two others just described, but is interesting, showing, as it does, the manner in which it reposed at the bottom of the sea, being surrounded and fixed among little crystals of phillipsite, found in abundance at the bottom of the sea in certain regions. In some cases, which have not been figured, two spherules are coupled together, the one much smaller than the other, resembling two drops of molten matter soldered together in solidifying.

Turning now to their internal structure, the nature of the nucleus furnishes the principal characteristic uniting these spherules to the meteorites. The superficial crust may be easily detached, by breaking one of the spherules, and is usually found to cover a nucleus of a metallic nature, as shown in fig. 8, representing a spherule from the South Pacific, Station 285, 2375 fathoms, in which a part of the outer coating of magnetite has been removed. In this spherule, which resembles in every respect those previously referred to, the nucleus is seen with its metallic lustre, grey colour like steel, and slightly granular. Oxidation has apparently only taken place at the periphery, where magnetic oxide has been formed, while the centre, protected from further oxidation by this coating of magnetite, has remained in the state of native iron or alloy of iron. Fig. 5 shows a similar spherule from the South Pacific, Station 276, 2350 fathoms, in which the thin shell of magnetic iron has likewise been partially removed to show the metallic nucleus. This nucleus behaves like iron, being malleable and taking the impress of the pestle; treated under the microscope with an acid solution of sulphate of copper it is at once covered by a coating of copper. Fig. 9 represents a nucleus from the same station (Station 276), treated in a similar way, showing the coppery coating; it has become discoid under the pressure of the pestle and bears its impress. In some cases the nucleus, though malleable, does not present this reaction with sulphate of copper solution. Fig. 7 represents such a nucleus, from the same station (Station 276), which, though treated with the copper solution, has retained its original grey steel-like colour. This nucleus, unaffected by the copper, may be schreibersite (Ni_2Fe_4P), or an alloy of iron, cobalt, and nickel, as in certain meteorites in which the last two metals are present in considerable quantities. It is known, in fact, that certain meteoric irons are insensible to the reaction here employed, or it takes place only imperfectly, and this is especially the case where the bands are rich in alloys of nickel and cobalt. In some of the spherules we ourselves detected traces of cobalt, though the experiments were always more or less doubtful owing to the small amount of material at our command, and it must be remarked that the manganiferous nodules from which the spherules were frequently extracted, or with which they were closely associated in the sediments, in nearly all cases contained cobalt and nickel, as may be seen by consulting the analyses in Appendix III.

Fig. 2 represents a magnetic fragment from the same station (Station 276), which presents certain peculiarities, and differs from those hitherto noticed. Its form is irregular, or only partially rounded; its mineral nature is also different, as it has no metallic nucleus. With reflected light it appears bluish-black, and the surface is less brilliant than that of the spherules with metallic centres. The interior of this fragment presents a crystalline structure shown by lines of cleavage and by rather regular fractures with acute angles; the direction of the fractures, however, is not constant, but varies at different points. The fractures cannot be said to have the same character as the cleavages observed in certain meteoric irons. On the whole, it is very questionable if this magnetic fragment be of cosmic origin, and it is merely represented here as a doubtful specimen.

Fig. 12 represents the appearance of the magnetic particles extracted by the magnet from a Red Clay in the Central Pacific, Station 274, 2750 fathoms, after being broken down in an agate mortar and treated with an acid solution of sulphate of copper. It is to be observed that a certain number of the particles have been covered by copper, and are believed to be the flattened metallic nuclei of the black spherules which were observed in the sample before pounding in the mortar. The black and opaque fragments are pieces of the outer coatings of the black spherules, together with irregular fragments of magnetite and titanic iron, derived from the volcanic materials present in the deposit. While it may be urged that some of these particles of iron have been derived from fragments of eruptive rocks, there seems to be little doubt that those of a circular form must have been derived from the black magnetic spherules, and hence are probably of cosmic origin. Support is lent to this view from the circumstance that magnetic particles from a volcanic tufa from the sea-bottom, in which no spherules are observed, rarely contain any of these metallic particles, while they are generally more or less abundant in the magnetic particles from a Red Clay in which the black spherules are observed under the microscope.

Finally, it may be pointed out, with reference to these black magnetic spherules, that some of them, and especially the smaller specimens, do not contain any metallic nuclei whatever, being formed throughout of a material similar to the black coating surrounding the metallic centres. Gustav Rose pointed out long ago that at the periphery of meteorites rich in iron there was a coating of magnetic oxide similar to that present in these spherules from the deposits. It is easy to indicate the origin of this coating if we grant the rapidity with which meteorites penetrate the atmosphere. This would determine a superficial fusion, and the formation of a coating of magnetic oxide, as in the case of these spherules. Their formation may, indeed, be compared to what is observed in the little particles of iron that fly away from the anvil under the stroke of the hammer, and are transformed in part or entirely into magnetic oxide. The non-oxidised nucleus being placed under protection by the layer of magnetic iron remains in a metallic condition, and in this way we may account for the presence of these unoxidised metallic particles at the bottom of the sea.[1] It is the same phenomenon as takes place with iron in industrial processes by the coating of Barff. The superficial fusion and oxidation of the external coating thus probably took place in the atmosphere at a very high temperature, and on account of their small dimensions the particles at once assumed a spherical form. The contraction of the superficial crust on cooling would lead to the formation of the cupule. Thus the composition of the nucleus, the formation of the black coating and the cupule, the form, and, in short, all the peculiarities of these spherules, lead us to regard them as cosmic bodies that must be grouped with the holosiderites.

(*b.*) *Brown-coloured Spherules or Chondres.*

If we now turn to the spherules with a crystalline structure, there are many reasons for believing that they, too, have probably a cosmic origin. It is well known that chondres are more or less spherical concretions, and are characteristic elements of a great group of meteorites—the chondrites. Tschermak considers them as drops of matter of cosmic origin, in fusion, that have become solidified. Chondritic globules have never, moreover, in spite of all the researches that have taken place, been found in eruptive rocks, nor, indeed, in any rocks of terrestrial origin.

The distinguishing characters of these globules of silicates from the deep-sea deposits, and their relations to the chondres of meteorites, may now be referred to in detail. In the first place, they present profound analogies in external aspect with the chondres of meteorites, although, as will be presently pointed out, they differ from them in some of their crystallographic details. These brown-coloured spherules are either yellowish or brown, with a pronounced bronze lustre. Under the microscope, in reflected light, this metallic lustre is seen to be due to a finely lamellated structure; their surface, in place of being smooth as in the black spherules, is seen to be striated. Their diameter rarely attains a millimetre, and their mean diameter may be about 0·5 mm. They are not regularly spherical. The cupule, when it exists, is not very deep, but rather

[1] It may be well to recall here that some meteoric irons, *e.g.*, the meteoric iron of Santa-Catarina (Brazil), do not oxidise under the action of water; this is the case when the iron contains a relatively large amount of nickel (see Boussingault, *Comptes Rendus*, tom. lxxxvi. p. 513, 1878).

flattened. They are insoluble in hydrochloric acid. The small quantity of material at our disposal did not permit of complete analysis, but we found them to contain silica, magnesia, and iron. The external characters show on a small scale so many of the peculiarities of the chondres of meteorites, that celebrated experts in meteoric stones pronounced them as such without being aware of the source from which they were procured. These characters may be best realised by reference to the figures on Pl. XXIII.

Fig. 11 represents the external aspect of one of these spherules from a Globigerina Ooze, Station 338, 1990 fathoms, South Atlantic. It was procured from the residue after treating about two quarts of the deposit with dilute acid. It is about 1 mm. in diameter, being magnified twenty-five times in the figure; it is yellowish brown, but the bronze metallic reflection is not rendered in the figure. At the upper part a shallow depression or cupule is seen. The internal structure is leaf-like, excentric, and more or less radial, and is seen to consist of the apposition of fine lamellæ. It might be said that these lamellæ take their origin from a centre situated near the left hand side of the spherule. This radial, excentric, lamellar structure is one of the characteristics of the chondres of meteorites; indeed, this structure has been considered diagnostic of chondritic forms of bronzite, for example. Microscopic examination by means of transmitted light, however, only partially confirms this relationship with the chondres of bronzite. The small size, as well as the friability, of these spherules, make it impossible to cut them into thin sections; we were, therefore, limited in our examination to splinters obtained by breaking these little bodies between two glass slides. In consequence, however, of their lamellar structure they break into extremely thin plates that are perfectly transparent except at those points where there are numerous dark, opaque inclusions, believed to be titaniferous magnetite. Under a magnifying power of 200 or 300 diameters, the details shown in figs. 10 and 13 can be observed. These thin plates are almost colourless, or at most they are slightly brownish, and present two systems of crystalline lamellæ. Both of these systems are formed by little prisms, grouped in a parallel fashion, which on crossing cut each other at angles of about 70° and 110°, as represented in fig. 10. The small prisms juxtaposed in a parallel manner, and forming what we have called a system, all extinguish at the same time; their colours of polarisation are not very pronounced.

When we published the preliminary results of our researches some years ago, it was stated that these prisms always extinguished following their longer axis; later measurements, which we consider as quite definite, have shown that this observation was not exact. Relying upon the preliminary observation, we believed that they belonged to the rhombic system, but by operating upon little detached prisms we have observed that while in the great majority of cases the extinction followed their longer axis, in others the little prisms are extinguished under a maximum angle of 40°. The lamellæ are thus crystallised in the monoclinic system.

Examination in convergent light does not give precise indications concerning other optic phenomena that might be used for a more exact determination of the species. The blackish brown inclusions represented in figs. 10 and 13 present vaguely regular contours, recalling crystallites, such as magnetite, found in eruptive rocks and in certain slags. In fig. 10, where they are seen under a magnifying power of about 300 diameters, they have a crystalline aspect; in all probability these inclusions are magnetic, more or less titaniferous, iron, and their presence explains why these spherules may be extracted from the mud by the aid of a magnet. It will be observed that these dark-coloured inclusions are disposed in a parallel manner following the system of lamellæ, and that they remain constant in this direction, even in thin plates. At certain points they are so abundant as to completely veil by their accumulation the structure of the mineral with which they are associated, as represented in the upper part of fig. 13. This regular arrangement of the inclusions in the interior of the lamellæ shows an approach to minerals belonging to the group of rhombic pyroxenes. It is known that the species of this group richest in iron contain tabular or prismatic inclusions of a submetallic and very characteristic aspect. Enstatite, bronzite, and even hypersthene, which constitute chondres, are of the rhombic system, but we have just seen that the mineral constituting these brown spherules belongs to the monoclinic system, perhaps, to judge from the extinctions, to a monoclinic pyroxene. Up to the present time, it must be added, no chondres have been found with other than rhombic pyroxenes, so that there is an important difference between these spherules and the chondres, if our determination of the mineral of the spherules as belonging to the monoclinic system be correct. There would, however, be nothing astonishing in the existence of chondres with monoclinic pyroxene, as this mineral is known to exist, for example, in eukrite, and it must be remembered that only a small number of the brown spherules found in the deposits were examined for their optical properties.

The external characters of these spherules, their bronze colour with metallic lustre, their excentric lamellar structure, in a word, all their properties, except the difference revealed by optical examination, show profound analogies between these spherules and the chondres of meteorites, so that we seem justified in attributing to them a cosmic origin, and this opinion is confirmed by their association with the black magnetic spherules and their distribution over the floor of the ocean, which will now be referred to in greater detail.

(c.) *Distribution of Cosmic Spherules in Marine Deposits.*

Magnetic or cosmic spherules were found in greatest abundance in the Red Clays of the Central and Southern Pacific; in short, in the deepest water, at points furthest removed from continental masses of land. When the magnetic particles are extracted from about a quart of the clay from these regions, it is usual to observe among these between twenty and thirty of the small black spherules, with or without metallic nuclei, and five or six of the brown magnetic spherules with crystalline structure. In the same deposits in which these spherules occur in greatest abundance, there were always found associated with them many manganese nodules, numerous sharks' teeth, and bones of Cetaceans, highly altered volcanic lapilli, and usually crystals of phillipsite. If the coatings of manganese, formed around nuclei of sharks' teeth, volcanic lapilli, fragments of earbones of Cetaceans, or other substances, be separated and reduced to a fine powder in a large mortar, and the magnetic particles be then extracted by means of a magnet, it will be found that, in addition to crystals of magnetite evidently derived from volcanic rocks, there are always a few of the black spherules above described; but our observations have not detected the presence of the chondritic spherules in the manganese nodules.

If, however, manganese nodules from a Globigerina Ooze, or any of the shallower depths, as, for instance, from Station 3, 1525 fathoms, North Atlantic, and Station 297, 1775 fathoms, South Pacific, be treated in a similar manner, it is generally impossible to detect any of the black magnetic spherules among the magnetic particles extracted from the manganese powder.

Again, if a quart of Globigerina Ooze, Pteropod Ooze, Diatom Ooze, Blue Mud, or other terrigenous deposit, be examined in the same way as a Red Clay or Radiolarian Ooze from the deep region of the Central Pacific, as a general rule no, or at most only one or two, magnetic spherules will be observed among the magnetic particles. It is evident, however, that the cosmic spherules are not absent from these deposits, for if a diligent search be made with the magnet through a large quantity of the deposit, one or two can usually be detected; for instance, the spherule represented in Pl. XXIII. fig. 11 was procured in the residue of a Globigerina Ooze after dissolving away a very large quantity of the calcareous matter by dilute acid, and it may be mentioned that no spherules were obtained during the examination of a large quantity of the deposit from the same station before the removal of the carbonate of lime.

The general conclusion forced upon us as to the distribution of these magnetic spherules in marine deposits, after a careful examination of a large number of samples, is that, while they are universally distributed, they are more abundant in regions where the accumulation of the deposit is relatively slow, and most abundant where the rate of deposition is reduced to a minimum, viz., in the deepest water far removed from continental land.

(d.) *Cosmic Dusts in General.*

It will be gathered from what has been said in the preceding paragraphs, that we believe ourselves justified in attributing a cosmic origin to some of the magnetic particles found in marine deposits, and that we have been led to this interpretation from a careful consideration of the external form, internal structure, and distribution of the magnetic spherules which have just been described. This conclusion is further confirmed by the fact that these spherules do not present any analogies with terrestrial bodies which, up to the present time, have been found in sedimentary or igneous rocks, while, as stated above, they present striking analogies with meteoric bodies, known with certainty to have fallen from extra-terrestrial space.

The question of cosmic dusts has been discussed by Nordenskjold,[1] Daubrée,[2] Tissandier,[3] and Meunier,[4] and these, together with other scientific men, have presented numerous facts in support of the cosmic origin of certain metallic particles or silicates collected as atmospheric precipitations. It has been urged, however, with great justice, against the extra-terrestrial origin of certain reputed cosmic dusts, that they are constituted, from a mineralogical point of view, of the same mineral species as those forming the rocks appearing at the surface in the neighbourhood of the regions from which the dusts were collected.

With reference to the particles of magnetic iron very often met with in atmospheric precipitations, which have sometimes been considered of cosmic origin, it may be pointed out that these, in all probability, have been derived from some telluric source; especially is this the case when they are of irregular form, without a black coating, unaccompanied by silicates of a spherical form, and associated with organic or inorganic products derived from our soils. It may also be pointed out that many of these so-called cosmic dusts differ widely from each other in their chemical and mineralogical composition, which in itself points to a terrestrial rather than an extra-terrestrial origin.

Although native iron is extremely rare in terrestrial rocks, careful researches have shown that native iron, even cobaltiferous or nickeliferous, is present in terrestrial rocks, for instance, in the basaltic rocks of Ireland and Iceland.[5] In this particular case it may

[1] The dust collected in Greenland in 1870 by Nordenskjold, and believed by him to be of cosmic origin (Kryokonit), has been examined by von Lasaulx (*Min. u. petr. Mittheilungen von Tschermak.*, Bd. iii. p. 517, 1881), who came to the conclusion that the mineral particles in question were of telluric origin. The specimens collected by Nordenskjold in his second journey in 1883 were examined by Wülfing (*Neues Jahrb. für Min., etc.*, Beilageband vii. p. 152, 1890). According to Wülfing the greatest part of the dust is composed of terrestrial minerals and organic matter, but he found some rare magnetic spherules, 0·1 to 0·2 mm. in diameter, of an opaque or transparent substance, which is in some cases isotropic, and in others birefrangent; he refers them to chondres. Wülfing did not find spherules with metallic nuclei in the dust he examined.

[2] In a paper just published, Daubrée (*Comptes Rendus*, tom. cxi. and cxii., 1890–1891), alluding to the cosmic spherules of the deep-sea deposits, expresses the opinion that they may be of volcanic origin, having been formed and projected by the gaseous explosions. But, so far as we know, such spherules as those described are not found in volcanic ashes.

[3] G. Tissandier, *Comptes Rendus*, tom. lxxxi. p. 576, 1875; tom. lxxxiii. p. 76, 1876.

[4] In their paper: "Présence de sphérules magnétiques analogues à ceux des poussières atmospheriques, dans des roches appartenant à d'anciennes périodes géologiques" (*Comptes Rendus*, tom. lxxxvi. p. 450, 1878), St. Meunier and Tissandier describe some magnetic spherules dredged in deposits on the coasts of Tunis and Algeria and of Possession Bay, or contained in strata of Cretaceous, Liassic, and Triassic age, also in rocks of the carboniferous or Devonian formation. But it appears from their description that all the spherules collected in these various conditions seem to be hollow spherules with a neck.

[5] See Andrews, *Brit. Ass. Report* for 1852, pp. 34–35.

be urged that the native iron described from deep-sea deposits may have been derived from the decomposition of the basaltic lapilli or vesicular pumice, which are widely distributed over the sea-bed. In reply to this objection it may be pointed out that the native iron in eruptive rocks is never circular in form, nor is it surrounded with a black magnetic coating, like the spherules from marine deposits. In the reputed cosmic dusts found in atmospheric precipitations or collected in snow-fields, there are frequently numerous, more or less hollow, spheres, or particles elongated like a bottle, with a cracked, brownish, more or less oxidised, surface. These we have found, from a careful examination, to be extremely numerous in industrial centres as well as in the scoriæ of steamships, and when they are broken down in an agate mortar they will sometimes yield minute particles of native iron. It is true that these particles are carried far and wide by atmospheric currents, and it has been suggested that the spherules of the deep sea have been derived from this source, but our examination shows that the cosmic spherules of deep-sea deposits are markedly different both in form and structure from the products of our furnaces, steam-engines, and materials of combustion. It has been stated that the particles of iron on the floor of the ocean may be due to the reduction of oxides of iron into metal under the influence of organic substances; the consideration, however, of the form, structure, and distribution of the spherules does not in any way warrant this interpretation.

During the past few years we have examined a large number of atmospheric precipitations collected from various parts of the world, for instance, from the Ben Nevis Observatory, from the coral island of Bermuda, and other isolated situations. In all these cases the bulk of the solid materials found in the precipitations was undoubtedly of terrestrial origin, and consisted chiefly of minute mineral particles derived from the rocks of the district from which the collections were obtained. In one instance from Ben Nevis there were two black spherules which approached in character those figured on Pl. XXIII., but they were too minute to admit of any definite opinion being formed, and the same was the case with one or two black spherules and crystalline flakes from the collections at Bermuda, which resembled the magnetic spherules and the plates of the crystalline spherules allied to the chondres, but here too the evidence was inconclusive.

If particles of extra-terrestrial origin be continually attracted to the surface of the earth, which is in all probability the case, we should not expect them to fall more abundantly at one part of the earth's surface than at another. In atmospheric precipitations, and on the surface of the continents, their recognition would necessarily be difficult on account of their small size, the large amount of telluric matter associated with them, and the mechanical actions to which they would be subjected. Those, however, falling upon the ocean would gradually sink to the bottom, and in those areas of the ocean to which little or no detritus from the continents is carried, and in depths from which all carbonate of lime organisms are removed, they would, from these very con ditions, accumulate and form a relatively larger proportion of the deposit than in other regions where the accumulation is more rapid, or where they are submitted to the wear and tear of mechanical forces. For all the reasons then that have been set forth in the preceding pages, we appear justified in regarding the small black shining spherules with metallic nuclei, as well as the chondritic spherules, discovered in deep-sea deposits as extra-terrestrial bodies allied to meteorites, and in all probability thrown off by them in their passage through the earth's atmosphere.

CHAPTER VI.

CHEMICAL PRODUCTS FORMED *IN SITU* ON THE FLOOR OF THE OCEAN.

THE organic remains met with in marine deposits, as well as the mineral particles derived directly from the crust of the earth and from extra-terrestrial sources, have been fully described in the preceding chapters. We have now to direct attention to some other substances in marine deposits, in the formation of which neither physiological nor physical phenomena can be said to be directly concerned. In the production of the substances to which we shall have to refer in this chapter chemical action plays the principal role; these substances indeed owe their origin to the reactions between sea-water and the heterogeneous solid materials making up the bulk of marine deposits. On account of the great variety in the composition of the deposits, and the varied conditions under which the chemical changes take place, it is evident that the reactions resulting in the formation of these secondary substances are of a very complex nature. What we here call chemical deposits are produced in situations rendering direct observation impossible, and under conditions differing widely from those obtaining where somewhat similar products have been formed on terrestrial surfaces.

It has been recently stated that the chemical action of sea-water is less powerful than that of pure water in bringing about the solution and destruction of silicates and other minerals.[1] However this may be, it is known as a matter of fact that mineral substances are attacked by sea-water, and in the discussion of this subject it is important to remember the influence time may exercise in all changes at the bottom of the sea, as well as the immense quantity of the solvent. The chemical products under consideration nearly all originate in a sort of broth or ooze, in which the sea-water is but slowly renewed. Many of them appear to be formed at the surface of the deposit,—at the line separating the ooze from the superincumbent water, where oxidation takes place. In the deeper layers of the deposit a reduction of the higher oxides frequently occurs, and at the surface of the mud or ooze there are many living animals as well as the dead remains of surface plants and animals. It must be admitted that the reactions referred to are effected very slowly, although there is evidence that in special localities, and at certain periods, some of them may be much accelerated.

It is not proposed to enter into any general considerations with reference to such chemical reactions in sea-water, but in each particular case we will give

[1] Thoulet, "Solubilité de divers minéraux dans les eaux de la mer," *Comptes Rendus*, tom. cviii. p. 753, 1889.

the interpretation that seems the most probable. As a general rule an attempt will be made to explain the facts by reference to similar phenomena taking place on the land surfaces, or in shallow water, which have been for a long time under the direct observation of geologists and chemists. In sea-water the sulphates are deoxidised by carbon and hydrogen,—one of the greatest chemical changes which occurs in the sea; in fresh water, where sulphates are absent or present in small amount, this reaction cannot take place. It is probable that the reactions follow a nearly similar order in the shallow waters of the ocean and in the abysmal regions, but at the same time the intensity of these reactions, and their subsequent results, may be considerably modified in those deep-water deposits where there is a great pressure, an absence of mechanical action and of solar rays.

The chemical products under consideration will be discussed under the following heads:—I. Clay; II. Manganese Nodules; III. Zeolites; IV. Phosphatic and other concretions.

I. Clay.

The fundamental basis of all clayey deposits, whether in geological formations or the deposits of modern oceans, is the hydrated silicate of alumina—$Al_2O_3, 2SiO_2, 2H_2O$, which is derived from the decomposition of all the aluminous silicates in rock masses under the action of water, and especially of water containing carbonic acid. The silicates of potash, soda, lime, protoxides of iron and manganese are thus decomposed at ordinary temperatures, and these silicates—the felspars, pyroxenes, amphiboles, for instance—also contain more or less alumina and magnesia. The first-mentioned bases—the potash, soda, lime, and protoxides of iron and manganese—are transformed into carbonates and, dissolving in the water, may be carried away in solution, silica being at the same time set free; the silicates of alumina and magnesia, being much less soluble, remain behind as a residue, are transformed into hydrated silicates, and give rise on the one hand to clay, and on the other to talc. As all the eruptive and metamorphic rocks are composed for the most part of aluminous silicates, they all undergo these changes resulting in the production of hydrated silicate of alumina, and it follows that these rocks and minerals are the original source of all the clayey material so widely distributed in recent and past geological formations.

Although hydrated silicate of alumina may occur, in nature, in a pure state in the form of crystals, they are exceedingly rare. It usually occurs in an amorphous condition and mixed with many foreign substances. Even kaolin, which is usually regarded as pure clay, always contains more or less debris derived from the rock from which it originated. Kaolin, and clays approaching kaolin in composition, have always been transported suspended in water from their place of origin, and thus when deposited may, in special circumstances, be freed from many of the extraneous particles with which they were originally associated. Such pure clays are, however, relatively rare in nature, and they do not occur as marine, or at all events deep-sea, deposits. The great majority of ordinary clays contain a large number of impurities, and especially is this the case with all those occurring in the deep-sea regions. These clays are fusible before the blowpipe. They are coloured brown, yellow, or red by the oxides of iron and manganese, and, as we shall see, these oxides may have been derived, as carbonates, from the same rocks as the clayey matter, but have subsequently been deposited in the clays on oxidation.

The clays of marine deposits may, from the point of view of their origin, be divided into two varieties: first, those in which the clayey matter has been chiefly transported by rivers from continental and other land surfaces, and second, those in which it has principally been formed *in situ* from the decomposition of rocks and minerals scattered over the bottom of the ocean. The former corresponds to the clayey matter in all terrigenous deposits in close proximity to the land, while the latter corresponds generally to the clayey matter in all truly pelagic deposits laid down towards the central regions of the great ocean basins, but as we shall presently show there cannot be such a strict separation between these two kinds of clay in the deep-sea deposits, for the clay transported from land surfaces may contribute in some measure to the formation of deposits far from coasts in the oceanic basins.

It has long been known that nearly all the fine clayey and other matters, transported by rivers into the ocean, fall to the bottom at no great distance from the coasts, owing to the action of the salts contained in the sea-water. They there form, along with mineral particles, the greater part of the detrital matters present in the terrigenous deposits of the shallow-water and deep-sea zones. The clay in the Blue and Green Muds and other terrigenous deposits near the coasts has thus been transported chiefly from the land or from the shallow-water and littoral zones. The minerals and rocks making up a part of these deposits may, it is true, yield clay by decomposition *in situ*, but the amount thus formed appears generally to be much less than that transported by the action of rivers, tides, waves, and currents.

Murray and Irvine have shown, by a series of experiments upon fine clay suspended in sea-water of different salinities and temperatures, that while the great bulk of the clay is precipitated in brackish water where the salinity only reaches between 1·005 and 1·010, still a small residuum is held in suspension even in water with a high salinity. They have also shown that temperature has a marked effect upon the amount held in suspension, as well as upon the rate with which it is thrown down. At a temperature between 40° and 50° F., and a salinity of 1·027, 0·0064 grm. per litre of clay remained in suspension at the end of 24 hours, while, under the same condition as to time, at a temperature of 80° F., only 0·0033 grm. remained in suspension. Again, at a temperature between 40° and 50° F., 0·0018 grm. remained in suspension at the end of 106 hours, and at a temperature of 80°, only 0·0003 grm. at the end of 120 hours. By operating upon very large samples of sea-water carefully collected from the central regions of the Atlantic, Mediterranean, and Indian Ocean, they have shown that a small quantity of mechanically-suspended hydrated silicate of alumina is always present in the water of these regions.[1]

If these observations be confirmed by further investigations, it must be admitted that a small quantity of clay can be transported to the central regions of the great ocean basins, and, falling to the bottom, may there make up a part of Red Clays and of the clayey matter in pelagic deposits. The amount of clay thus transported must, however, be very small, for otherwise it would mask the minute fragments of pumice, or the organic remains, which there make up so large a part of the deposits.

In the deep-sea regions far from land the clay on the floor of the ocean appears, for the most part, to arise from the decomposition *in situ* of water-borne pumice and other volcanic rocks and minerals, which make up the principal inorganic constituents of the deposits of these regions. The vitreous and vesicular nature, as well as the small dimensions, of these volcanic fragments render them in a special manner liable to disintegration and decomposition, with the production of clay; especially is this the case with the basic volcanic glasses. All the deep-sea clays contain a large number of minute glassy and other mineral particles, and hence they fuse readily before the blowpipe into a black magnetic bead. The amorphous material observed in these deposits is regarded as the argillaceous matter; it presents essentially vague characters, resembles a colloid substance, has no definite contours, is perfectly isotropic, is generally colourless, and forms a gelatinous-like mass that connects and agglutinates the other materials in the clay or mud. With these indefinite physical characters it becomes very difficult to estimate even approximately the amount of pure amorphous argillaceous matter in the samples of a marine deposit. A very small quantity of this slimy-like matter, however, may give a distinctly clayey character to a calcareous or siliceous mud or ooze, especially when the mineral particles in the deposit are of small dimensions.

The clayey matter of marine deposits must then be regarded as a chemical product arising from the decomposition of the aluminous silicates composing the crust of the earth, exposed to the action of water, either on the dry land or at the bottom of the sea. It may be formed *in situ* on the sea-bottom, and this is especially the case in pelagic deposits, or the clayey matter may be transported from the land surfaces and coasts to the ocean basins, and this is what especially takes place in terrigenous deposits. The amount of clay varies according to the abundance of other substances in deposits, being least in calcareous deposits like Coral Muds and Pteropod and Globigerina Oozes, where it becomes masked by the accumulation of carbonate of lime, and greatest in Red Clays

[1] Murray and Irvine "On Silica and the Siliceous Remains of Organisms in Modern Seas," *Proc. Roy. Soc. Edin.*, vol. xviii. pp. 229–250, 1891. Further experiments have shown that sea-water with a salinity of 1·025, after remaining for over thirty days absolutely at rest, holds up in suspension finely-divided clay in amount equal to 625 tons in one cubic mile of the water (J. M.).

and Blue Muds, the carbonate of lime shells being removed from the Red Clays, and masked in the Blue Muds by the abundance of detrital matter. A description of the clayey materials in the different varieties of marine deposits has been given in Chapter III. when discussing the several types of Pelagic and Terrigenous Deposits.

II. Manganese Nodules.

The hydrates of manganese[1] along with ferric hydrate are among the most widely distributed bodies in marine deposits, being especially abundant in those of the abysmal regions. In the descriptions of the samples of the deposits from the various stations of the Challenger Expedition, as well as when referring to the organic remains, we have often had occasion to point out the presence of these oxides as colouring matters, or as thin or thick coatings on shells, Corals, sharks' teeth, bones, and fragments of rocks. It may be said that manganese in this form exists in all deep-sea deposits, for rarely can a large sample of any mud, clay, or ooze be examined with care without traces of the oxides of this metal being discovered, either as coatings or minute grains. In some regions of the ocean the Challenger discovered ferro-manganic concretions in great abundance, the minute grains giving a dark chocolate colour to the deposit, while the dredges and trawls yielded immense numbers of more or less circular nodules or botryoidal masses of these oxides of large dimensions.

Mode of Occurrence.—To mention all the regions where manganese was observed would take up too much space, but reference will now be made to those stations at which it was found in greatest abundance or in some special form. Many of the remarkable and characteristic concretionary shapes assumed by the ferro-manganic nodules are represented in the Plates at the end of the volume, and these illustrations will be specially referred to in the following descriptions, in which the associations of the manganese nodules, and the conditions under which they occur, at each locality will be pointed out with considerable detail. In these descriptions we shall almost exclusively refer to specimens examined by us, forming part of the collections brought home by the Challenger. When large hauls of manganese nodules were obtained members of the expedition were, at the time, permitted to retain specimens for their own use, so that in many instances the nodules, teeth, bones, and rocks actually dredged were more numerous than here stated.

Atlantic Ocean (outward voyage).

Station 3, 1525 fathoms.—The dredge brought up several large flat pieces of rock, consisting for the most part of peroxide of manganese. Some of these fragments were

[1] In this chapter, and other parts of this work, the terms: manganese, hydroxides of manganese, hydrates of manganese, peroxide of manganese, black oxide of manganese, are all used for the same black substance.

fully a foot in diameter, and had a thickness of several inches. The inferior surfaces were irregular and earthy, while the upper surfaces were mammillated and covered with little asperities, as is usually the case with the manganese nodules of the deep sea. The colour of the broken surfaces was black with reddish layers, and when polished they in places presented a massive appearance, with a dark lustrous aspect. The fragments were composed of successive, more or less concentric, layers, and were evidently torn away from very much larger masses or nodules by the action of the dredge; a small portion of one of the fragments is figured in Pl. III. fig. 1.

Along with these manganese fragments were numerous branches of a Gorgonoid Coral (*Pleurocorallium johnsoni*). In some instances the axis of the Coral was attached to the manganese nodules; at the upper right-hand side of Pl. III. fig. 1 a portion of the base of this Coral is seen to be attached to the nodule. All the Coral was dead, and in some instances had a much decayed and corroded appearance, as shown in Pl. III. fig. 2. The whole surface of the branches was coated by a thin rind of peroxide of manganese, sometimes about 0·1 mm. in thickness, which cracked off easily on receiving a smart blow. The axis of the Coral was sometimes 2 cm. in diameter, was generally pure white, and took on a high polish; it still retained a considerable quantity of organic matter, and contained 6 per cent. of carbonate of magnesia. In some instances the interior was dull white and largely impregnated with manganese following the minute structure of the branches, thus producing alternate zones of black and white. A portion of one of the smaller branches is represented in Pl. III. fig. 3, to which, at the lower part of the figure, a valve of *Lepas* is seen cemented to the branch of Coral by means of the manganese depositions. A large living siliceous Sponge (*Poliopogon amadou*) was attached to the branches of this dead Coral, along with other living animals. It is not impossible that the Coral may have lived at the depth from which it was dredged, but if the bottom has not sunk the other conditions of the locality appear to have changed since the time when the Coral lived, otherwise it is difficult to account for the fact that all the Coral obtained here, and at two neighbouring stations, was dead. From the large amount of organic matter in the axis of the Coral, it cannot be regarded as fossil, but the carbonate of magnesia indicates that it is, at least, very old.

Station 16, 2435 fathoms.—Three or four manganese nodules, some of them nearly an inch in diameter, were obtained in the dredge. They are round, with a mammillated surface; one of them had a palagonitic nucleus. Fragments of palagonite were also present in the deposit at this station, as well as at Station 12, 2025 fathoms. Along with the nodules there were two or three sharks' teeth and valves of *Scalpellum* thinly coated with manganese.

Station 61, 2850 fathoms.—In the trawl were a piece of pumice, about 4 cm. in length, and several concretionary lumps of tufa, the largest about 7 cm. in length. The fragments of tufa are quite unlike the deposit, and have a slight coating of manganese on the surface, to which specimens of *Scalpellum* were attached. The fragments are whitish or yellowish, ellipsoidal, more or less flattened, and divide into parallel layers. Some of the layers contain larger fragments of minerals than others, but generally the layers are very fine grained. The mass of the concretions has a soft and earthy appearance, can be scratched with the nail, and easily broken; the fragments are more or less argillaceous, and are traversed in many directions by perforations of Annelids or Sponges. The surfaces are also frequently furrowed by striæ and worm tracks. Examined by the microscope with transmitted light, they are seen to consist largely of a great many volcanic minerals cemented by argillaceous matter; among the minerals are plagioclases, fragments of hornblende, magnetic iron, and rarely some glauconite-like grains.

In addition to these concretions were one or two small rounded manganese nodules, with concentric layers, and a pale earthy nucleus. These were not preserved in the collection brought home.

Station 71, 1675 fathoms.—In the trawl were several aggregations of the ooze, 3 to 4 cm. in diameter, traversed by worm-tubes, which were lined with a deposit of manganese. There was also a fragment of compact volcanic rock, more or less rounded, about 7 cm. in longest diameter; it had a slight deposit of manganese over the whole surface, to which a *Serpula*-tube was attached.

Station 85, 1125 fathoms.—There were several large fragments of a dead Gorgonoid Coral, coated with manganese, similar in every respect to that described from Station 3, also some fragments of volcanic rock, about 1 cm. in diameter, coated with depositions of manganese.

Station 87, 1675 fathoms.—Several pieces of a Gorgonoid Coral, similar to the above, were taken in the dredge and sounding tube.

Station 131, 2275 fathoms.—The trawl brought up the earbone of a *Ziphius*,[1] to which a polyp was attached, and a piece of pumice, 3 to 4 cm. in diameter, with an egg-capsule of a Mollusc attached to it. Both the earbone and pumice were coated with manganese. The pumice is rounded, white coloured, very fibrous, and contains magnetite and small crystals of hornblende.

SOUTHERN INDIAN AND ANTARCTIC OCEANS.

Station 143, 1900 fathoms.—The phosphatic nodules from this station had a slight coating of manganese (see description of phosphatic concretions).

Station 147, 1600 fathoms.—Several basaltic lapilli, covered and cemented by manganese, were obtained in the trawl.

[1] See Zool. Chall. Exp., part iv. p. 39, pl. ii. fig. 10.

Station 157, 1950 fathoms.—Among the stones dredged at this station were numerous glaciated fragments, the largest weighing over 20 kilogrammes. Some of them were only partially imbedded in the Diatom Ooze, the depth to which they were imbedded being marked by a sharp line. The portions above the surface of the deposit had a slight coating of the black oxide of manganese, and this substance was most abundant just at the line marking the separation between the deposit and the superincumbent water. In the same deposit some fragments of Hexactinellid spicules had a rather thick coating of manganese peroxide.[1]

Station 160, 2600 fathoms.—The trawl at this station contained about 16 litres of manganese nodules, pumice stones, earbones of Cetaceans, and sharks' teeth. With respect to their form the nodules may be arranged into three groups: first, more or less pyramidal or irregularly grape-shaped; second, spheroidal or ellipsoidal; third, flattened, mammillated, and irregular in form. A typical example of the first group is represented, natural size, in Pl. II. fig. 3. It measures about 5 cm. in longest diameter; its fundamental form may be compared to a triangular wedge, with a curved surface at the superior part. The surface is entirely mammillated, but the rounded rugosities are not very pronounced, being much softened down, and but slightly projecting, with a diameter of 5 to 6 mm. Upon one face the mammillæ are much more abundant than on the other. Animals are usually attached to the smoother face, and we are inclined to believe that this face projected above the surface of the deposit, while the rougher one was imbedded in the clay. The figure represents the smoother face of this nodule, and shows more or less pronounced reliefs in two directions, following which the fracture usually takes place with the greatest facility. The first is parallel to the lateral edges of the wedge along the radii; the second is more or less parallel to the superior surface of the figure, and follows a curved direction, answering to the disposition of the layers in the interior as represented in fig. 3*a*, showing a section of a nodule similar to that of fig. 3. The first direction answers to the fracture running from the periphery to the inferior point of the wedge. This form may indeed be compared to a fragment of a more or less regular spherical body, where the fractures had taken place along the radii, thus leaving a triangular solid terminated in one aspect by the primitive peripheral face. Fig. 3*a* shows the internal structure of this type of nodule, and it will be observed that parallel to the curved superior surface there are alternating zones, sometimes yellowish white, sometimes black-brown, the last having the character of earthy manganese. These internal curved bands follow very regularly the external curved surface, and have a thickness of about 2 mm. Notwithstanding their homogeneous appearance, microscopic examination shows that the light-coloured bands are traversed by fine arborescences or dendrites of manganese. The existence of these dendrites is also shown by attacking the nodule with hydrochloric acid, and examining the skeleton with a lens; a portion of a nodule so

[1] Murray, *Scot. Geogr. Mag.*, vol. v. p. 427, 1889.

treated is represented in fig. 3*b*.[1] This examination shows likewise that the yellowish white matter extends into and across the dark bands. It is also to be noted, as seen in fig. 3*a*, that these alternate bands are not continued quite to the edge of the section, but are surrounded by a black layer in which no alternation of light and dark bands is at once visible, although when a surface of the section is demanganesed, alternating bands may be distinguished, the lines being very fine. This external black layer is much more compact than the internal portions of the nodule, and follows perfectly the contours of the triangular wedge, covering the whole of the periphery. The internal parts are much more friable and porous than the external layer, and the separation between them is very well marked and rather sharp. Sometimes there is an interruption of continuity between the internal concentric alternating layers, which causes this variety to break into coatings and peel like an onion more easily than the spherical variety. There is no central nucleus in this pyramidal variety, unless the whole interior be regarded as a nucleus surrounded by the layers forming the black border. There were some twenty or thirty nodules of this variety, but large numbers, although presenting certain analogies with these typical forms, are much more irregular.

Of the nodules which we would designate as grape-shaped, it is impossible to give a morphological description. This arises from the fact that the mammillæ are superposed the one on the other, so as to recall a bunch of grapes, or they may present all the irregularities of certain volcanic scoriæ. The majority of these irregular forms, however, have internal alternating bands, more or less resembling those shown in fig. 3*a*. The peculiarities of this pyramidal and irregular variety of nodules might be explained by supposing the central parts with the alternating bands to have once formed parts of a larger nodule, which had been broken up along the radii, and these broken fragments to have been subsequently surrounded by the deposition of the more compact external layers.

There were about fifteen nodules belonging to the second, spherical or ellipsoidal, variety, resembling in form the nodule figured on Pl. IV. fig. 8 from Station 276. They have a diameter of 1 to 5 cm., are much less mammillated than the irregular varieties, and consequently preserve their spherical form more or less perfectly. They have a fine concentric structure, like that represented in Pl. IX. fig. 7, showing a section of a nodule from Station 252. The zones surround a central nucleus of volcanic glass, palagonite, shark's tooth, or bone; two palagonite nuclei are shown in Pl. XVI. fig. 2 and Pl. XVII. fig. 3. Sometimes, however, there is no apparent nucleus. These nodules are more compact, heavier, and break less easily than the preceding variety. Their fractures are, however, very well defined, and always follow the rays and concentric layers. They take a beautiful metallic polish, and on the polished surface the fine concentric arrange-

[1] The dendritic arrangement of the manganese is well seen in the thin sections of the nodules under the microscope, as shown in Pl. XXVIII. figs. 1, 2, 4, 5.

ment of the nodule is well seen. One of these nodules, about 4 cm. in diameter, had attached to it two Ascidians and a Brachiopod (see Fig. 34), so that a portion of the nodule probably projected above the mud when at the bottom.

A great many nodules belonging to the third, flattened, mammillated, or irregular variety were present. They vary greatly in size, contour, and internal structure, some resembling the first, others the second, varieties above described. Those resembling the first variety are mammillated on the exterior, while the interior is friable, sometimes mottled, or with ill-defined black and whitish bands, but not concentric. Those resembling the second variety are less mammillated, are generally compact throughout, with fine concentric layers, and, when cut in section and rubbed with a chamois leather, give a fine black shining submetallic surface. Sometimes they have a volcanic fragment, or a fragment of bone, for a nucleus, and then the external form of the nodule resembles closely the shape of the enclosed fragment. Frequently the nucleus appears to be pseudomorphosed by manganese, especially when it consisted of carbonate or phosphate of lime. Sharks' teeth and earbones of Cetaceans also give a form to the nodules when forming the nuclei.

FIG. 34.—Manganese Nodule with two Tunicates (*Styela squamosa* and *Styela bythia*) and a Brachiopod attached. Station 160, 2600 fathoms, Southern Indian Ocean.

Two or three nodules, or fragments of nodules, merit a special reference. They appear to be fragments of the spherical variety, and we have every reason to believe that the nodules of which they once formed part were broken while yet at the bottom of the sea. The structure and angular form, as well as the radial and concentric fractures, of one piece, leave no doubt that it once formed part of a large spherical nodule. The surfaces of the broken part are covered with fine rugosities, indicating a deposition of manganese over the fragment after its separation from the original nodule, and upon these same surfaces of fracture two Brachiopods and a Hydroid have subsequently attached themselves. Another and smaller fragment, with concentric structure, in which a portion of the palagonitic nucleus is still to be observed, is wedge-shaped, and has been formed by a fracture following the direction of the rays of the original nodule. That the nodule had been broken while yet at the bottom of the sea is proved by the fact that the fragment is entirely surrounded by a new concentric deposit of manganese about 0·5 mm. in thickness. This fragment must then be regarded as having been separated from the original nodule at the bottom, and to have subsequently become the nucleus of a new nodule.

About twelve of the nodules contained nuclei of basic volcanic glass or of palagonite. In some the unaltered glass was surrounded by coloured bands of palagonite or altered material, similar to the specimen represented in Pl. XIX. fig. 3 from Station 293. In other cases the whole of the glass had been converted into palagonite, and these nuclei, when freshly taken from the sea, might be cut with a knife like new cheese. In other cases, again, all that remained of the nucleus was a patch of white matter, soft to the touch, easily cut with a knife, and having an argillaceous aspect, resembling some of the outer palagonitic zones of other nuclei. Again, in some of the nodules all trace of the nucleus seems to have disappeared, but the centre is composed of very compact, black, shining, highly-oxidised manganese. This centre recalls, by its form and aspect, a fragment of volcanic glass, which, in the first instance, had become transformed into palagonitic material, and subsequently a replacement of palagonite by manganese had taken place. There is nothing improbable in this supposition, when we remember the pseudomorphism of hydroxide of manganese upon calcite, fluorite, pharmacosiderite, &c.

The *Carcharodon* and *Lamna* teeth, as well as their broken fragments, and the earbones and other bones of Cetaceans, were sometimes covered with but a slight coating of manganese; at other times they were surrounded by concentric layers of manganese fully 1 cm. in thickness. One of the deeply embedded earbones is shown in Pl. VIII. fig. 11, which represents in section a tympanic bulla of *Mesoplodon* (?). The earbone determines the external form of the nodule; the manganese enveloping the bone breaks up radially and concentrically, and can be easily detached, the layers presenting all the physical and microscopical characters already described. The bone itself is penetrated by dendritic ramifications of manganese, and some portions of the substance of the bone appear to have been wholly removed. The specimen represented in Pl. VIII. fig. 10 resembles the petrous bone of a *Globiocephalus.* It has but a slight coating of oxides of manganese and iron, but in some places it is much penetrated by dendrites of those substances. A large compact fragment of bone, about the size of a cricket-ball, appears to have been the earbone of a Balænid or Balænopterid. The external form of the bone has, however, been quite lost; much of the substance seems to have been removed, and dendritic ramifications of manganese penetrate the surface in all directions. The interior is very compact, the bluish colour, cherty aspect, and the fracture, recalling what is observed in some fossil phosphates; it has not, however, the hardness of chert, nor any of its physical properties, but merely presents a strong analogy of aspect. The microscopic structure is identical with that of recent earbones, but most of the organic matter seems to have been removed.

In many nodules a structure was observed indicating that the nuclei were originally portions of bone, which have subsequently been entirely removed, and replaced by manganese depositions.

Among the nodules were over a dozen rounded pieces of pumice, from 0·5 to 2·5 cm. in diameter; some belong to the felspathic, and others to the basic, varieties. While the interior of these fragments presented a fresh aspect, the surface to the depth of 1 or 2 mm. had undergone profound alteration. At the periphery the pumice is transformed into earthy matter of a yellowish brown colour, mixed with depositions of the oxides of iron and manganese. Two ice-borne fragments of granite, covered with manganese, are noted as having been obtained at this station, but these have not been preserved in the collections.

Pacific Ocean.

Station 175, 1350 fathoms.—The trawl brought up a branch of a tree and a large number of fragments of pumice. The pumice fragments vary much in size, the largest being 6 to 8 cm. in diameter. They had all undergone considerable alteration, the surfaces being covered with hydroxides of iron and manganese. The fragments effervesced when treated with acid, owing to the presence of Foraminifera shells, the deposit having infiltrated in some cases into the pores, as well as the oxides of iron and manganese. Most of the fragments may be referred to augite-andesite, while others belong to the basic series and have rounded pores. In thin sections under the microscope it can be seen that in the external altered zones the manganese has been introduced following exactly the contours of the scoriaceous rock. It might be said that a replacement of the pumice had taken place, but in a certain sense it is rather an impregnation or moulding. This structure, however, apparently reappears in many of the manganese nodules at other stations, where all trace of the pumice has disappeared, but where, from all appearances, the nodules were originally formed around fragments similar to those above described.

Station 176, 1450 fathoms.—The sounding at this station seemed to indicate that there was a large amount of manganese in the deposit, associated with numerous fragments of pumice. Many of the Foraminifera were covered with minute grains of the peroxide of manganese, while others were filled and coated with a red-brown silicate, containing a considerable quantity of manganese.

Station 181, 2440 fathoms; Station 184, 1400 fathoms.—The trawl brought up from these stations pumice stones similar to those described from Station 175, although the alteration in most cases was not so far advanced.

Station 213, 2050 fathoms.—There came up in the trawl several hardened pieces of mud or clay of a slate colour, in which were embedded pieces of wood. These hardened lumps were made up of the same materials as the deposit procured in the sounding tube, but were traversed by, and in some places coated with, deposits of manganese; apparently the lumps came from a deeper layer than that usually procured in the sounding tube. The trawl may have dragged them up along with the remains of a water-logged tree.

Station 215, 2550 fathoms.—The trawl contained several pumice stones coated with manganese, all of them less than 4 cm. in diameter.

Station 216A, 2000 fathoms.—A large number of pumice stones, varying from the size of a hen's egg to that of a marble, was in the trawl. The surfaces of most of these were coated with peroxide of manganese, and to the upper portions there were attached Brachiopods, Hydroids, and Foraminifera.

Station 225, 4475 fathoms.—The sounding at this station indicated a considerable quantity of manganese, the sample of the deposit containing a very large number of grains of the black oxide of manganese, many of them of considerable size.

Station 226, 2300 fathoms.—There was over a litre of pumice stones in the trawl, all coated by layers of manganese.

Station 227, 2475 fathoms.—The sounding at this station indicated a large quantity of manganese.

Station 230, 2425 fathoms.—More than a dozen rolled pumice fragments, about the size of a hen's egg, covered with deposits of manganese, to one of which was attached a small Brachiopod, were collected.

Station 236A, 420 fathoms.—Several very large hardened pieces of the bottom, perforated by worms, whose tracks were frequently coated with manganese, were in the dredge.

Station 237, 1875 fathoms.—There were several large, very hard and compact, blocks of the deposit. Black coatings of manganese lined the surfaces of the worm-tubes which perforated the blocks. Several pieces of pumice had likewise on some portions of their surfaces deposits of manganese.

Station 241, 2300 fathoms.—Large numbers of pumice stones of all sizes, the majority covered with deposits of peroxide of manganese, were obtained. Two of these are represented in Pl. I. figs 7 and 8. Fig. 7 shows an irregular, white coloured fragment of liparitic pumice, the outer parts of which have been transformed into earthy matter, while in many of the fissures there are considerable deposits of peroxide of manganese, and in some parts concentric zones of manganese may be observed. Fig. 8 shows a black-brown scoriaceous fragment of basaltic pumice, which has an areolar rather than a fibrous structure, and the rounded vesicles are frequently filled with infiltrated clay, giving the fragment an oolitic appearance; crystals of plagioclase, 4 to 6 mm. in diameter, can be observed at the surface by the naked eye.

Station 242, 2575 fathoms.—There were several manganese nodules, the largest a little over 1 cm. in diameter, with nuclei of pumice.

Station 244, 2900 fathoms.—The bag of the trawl contained much clay and many pumice stones or manganese nodules, together with two sharks' teeth. The nodules in this instance all consisted of pumice stones, with deposits of manganese on the outside.

Station 246, 2050 fathoms.—In the trawl were procured several hundred rounded fragments of pumice. About forty of the largest had a diameter of about 30 cm., a large number about 2 cm., while in the washings of the ooze there were numerous fragments down to the minutest dimensions. Most of them were covered with deposits of manganese, and to the outer surfaces were attached Ascidians, Brachiopods, Hydroids, and Rhizopods. The appearance of these fragments of pumice is represented in Pl. I. figs. 1–4. Fig. 1 shows (one-fourth natural size) a characteristic specimen of the light, porous, filamentous variety of liparitic pumice ; the form is rounded or egg-shaped, many of the pores and areolar spaces are filled with the deposit, and the whole surface of the fragment has undergone a slight alteration into a clayey or earthy substance. A few crystals are visible to the naked eye projecting from the surface, and large portions of the surface are discoloured by the peroxide of manganese. Fig. 2 represents a rounded specimen (natural size) of the same variety as the preceding, to which several deep-sea organisms are attached. The surface is coloured brownish or black by the hydrated oxides of manganese and iron. Fig. 3 exhibits a similar specimen, with a segment removed to show the discoloured altered zone towards the periphery, and the light-coloured, less altered, internal parts. Fig. 4 represents a similar and smaller specimen cut in section to show the discoloured altered zone towards the periphery.

Station 248, 2900 fathoms.—The trawl contained a large number of manganese nodules and many pumice stones, together with a *Lamna* tooth, 2 cm. in length, and many other sharks' teeth of smaller size. Some of the pumice stones had but a slight coating of manganese, while others were surrounded by concentric layers of this substance over 9 cm. in thickness. Some of the manganese nodules were 2 to 3 inches in diameter, composed almost entirely of dense, black, concentric layers of manganese, surrounding one or more small nuclei. Pl. II. fig. 1 represents one of the most characteristic, as well as one of the most abundant, forms of nodule at this station, about thirty nodules more or less resembling this one in shape and in size being procured. The general form is round; the mammillæ are not prominent, but run the one into the other without forming marked reliefs. Two surfaces of these nodules present a marked difference of aspect ; the inferior surface, which we believe to have rested in or on the clay, is represented in the figure, and is seen to be covered with an immense number of little rugosities, or rounded points, about 1 to 2 mm. in diameter, and the same in height ; these asperities, being scattered over the whole of the surface, render the nodule rough to the touch and somewhat like shagreen in appearance. On the other, or superior, surface of the nodule, which appears to have projected above the surface of the clay, the asperities are not nearly so numerous, and the mammillæ are smoother, larger, and less pronounced than on the surface here represented. Pl. IX. fig. 4 shows the internal structure of these large round nodules, the left half of the figure giving the appearance of a nodule when cut in section and polished, the right half showing a similar surface after the manganese has been removed by steeping it for some time in strong hydrochloric acid. In both these nodules the nuclei may be referred to fragments of pumice which have undergone profound alteration. Around these nuclei undulate fine alternating zones of manganese peroxide, separated by other lighter coloured zones in which this material is less abundant. These alternating zones give to the nodule a well-marked concretionary and shelly structure. What would appear to have been the original nucleus of pumice has likewise assumed a concentric arrangement. Two processes probably took place: the one a deposition of manganese layers on the outside in successive bands, and a simultaneous alteration of the nucleus, which likewise produced a concentric arrangement. The external zones of the nodule are not so dark coloured as those towards the centre, and the fine, black, undulating, concretionary lines are less numerous, but the whole face of a nodule like this one takes on a beautiful, black, metallic lustre when polished with the hand or with a piece of cloth. The demanganesed portion represented in the right half of the figure is of a whitish colour, and easily pulverised into an impalpable powder. The dark shaded portions in the left-hand figure represent the zones in which the manganese is most abundant, and these appear on the right-hand figure as empty spaces on the surface treated with concentrated hydrochloric acid. Pl. II. fig. 4 represents another of these nodules in section (natural size). In this case there are several nuclei, all probably highly altered fragments of pumice, surrounded by concentric layers of manganese, and the whole cemented into one large nodule. This figure shows again the concretionary and shelly structure, the nodule frequently breaking up into successive scales like an onion. Pl. II. fig. 2 represents still another nodule from this station, the central parts of which are occupied by a siliceous Sponge (*Farrea*). Although in some places portions of the skeleton appear to have been removed in solution, still on the whole it is very well preserved; it is everywhere surrounded by the manganese depositions, and the manganese has even penetrated into the canals of the spicules. In the stalk-like portion at the lower part of the figure there were numerous Sponge spicules. Fig. 2*a* represents a magnified portion of the Sponge skeleton, which retains its vitreous and brilliant appearance. Among these large rounded nodules there were several tube-like bodies composed of manganese, 4 to 5 cm. in length and 1 cm. in diameter, with a hollow centre in which were many spicules of siliceous Sponges. Pl. I. figs. 5 and 6 represent (natural size) the appearance of a good many nodules from this station. The nuclei consist of pumice, much decomposed, especially on the surface in contact with the enveloping layers of manganese, which vary from a millimetre to several centimetres in thickness. In fig. 5 the pumice at the centre of the fragment is white, and retains nearly all its characters, but close to the manganese layers decomposition is much more advanced and it assumes a brown colour. When examined under the microscope with reflected light, the pores of the pumice are seen to be filled with an earthy matter, which forms casts of the little vesicles. They do not disaggregate under the action of hydrochloric acid, but simply undergo discoloration; sometimes these granules give a black cross with polarised light, in fact they have a great resemblance to certain casts of Foraminifera observed at Station 176, 1450 fathoms, South Pacific. In fig. 6 the pumice has undergone greater alteration than in the specimen represented in fig. 5, and is surrounded with a thicker deposit of manganese.

The nucleus of one nodule broke down into a floury material, which under the microscope seemed to be composed of a large number of prismatic crystals belonging to the monoclinic system. Besides the larger nodules to which we have referred, there was a considerable number of smaller ones varying from 0·5 to 2 cm. in diameter, almost all formed round minute fragments of pumice. Frequently numbers of these were cemented together by the manganese, and appeared to be in the process of formation into larger nodules.

Station 252, 2740 fathoms.—The trawl brought up many hundreds of manganese nodules along with some rounded fragments of pumice; there was no clay mixed with these nodules, having apparently been all washed away as the trawl was hauled up through the water. The largest nodules were about the size of cricket balls; they were more or less round or ellipsoidal, and when rolled on the deck they looked like a pile of dirty potatoes. Pl. III. fig. 5 represents (natural size and in section) the prevailing form, size, and structure of the nodules from this station. Three zones may be distinguished in the figure:—(*a*) The elongated yellowish white centre or nucleus penetrated by dendrites of manganese; it is hard and compact, and rather sharply separated from the dark layers which surround it. It may be observed that the elongated form of the nucleus appears to be the cause of the ellipsoidal form of the nodule, the nearly spherical nodules having a round nucleus. (*b*) The zone of manganese immediately surrounding the nucleus has a thickness of about 1 cm., and in it no concentric arrangement can be observed. This intermediate zone is generally terminated externally by a band of more compact manganese, separating it in a manner from the more external layers, and appears, for many reasons, to have formed part of the original nucleus, which may possibly have been a fragment of pumice. There is almost always an interruption of continuity between the intermediate and outer zones, accompanied by a layer of light brown clay or mud. (*c*) In the outer zone there is a distinct concentric structure, determined by small alternate layers of manganese and clayey matter; these layers have each a thickness of about 1 mm., and the depth of the whole zone is about 7 mm. The manganese in this zone is purer than in the others, and on a polished surface it has a semi-metallic lustre. Pl. IX. fig. 7 represents a section of one of the round nodules. The manganese has here been removed by placing the face of the section in strong cold hydrochloric acid; in this way a clayey skeleton is obtained showing distinctly the structure of the nodule. The three zones indicated above may again be observed; the nucleus, however, is small, having a diameter of only 2 mm. This is surrounded by an area showing no concentric arrangement, then follows the outer zone with concentric layers. Fig. 7*a* represents a portion of the outer zone (*c*) magnified 25 diameters. The manganese has been removed and the empty spaces indicate the positions occupied by the manganese, which had a dendritic arrangement throughout the earthy or clayey matter. This clayey skeleton is fine grained, and is with difficulty held together. It may be remarked that the outer layers of the external zone (*c*), with a distinct concentric arrangement, have a very constant thickness of about 7 mm. for the majority of the nodules from this station, while the inner zones are variable in thickness. On the fracture of these nodules by a blow, they separated into large concentric scales. Pl. III. fig. 5 represents (natural size) a nodule (7 × 7 × 5 cm.) broken to show the nucleus, which in this case is a large *Carcharodon* tooth, about 4 cm. in its greatest length; the tooth is surrounded by concentric layers of manganese 1·5 cm. in depth, and the whole nodule has roughly the form of the tooth. The tooth is black and shining, and is thoroughly impregnated with manganese; the vaso-dentine has entirely disappeared from the centre, the hard dentine of the outer surface alone remaining. There were three or four other nodules with sharks' teeth (*Oxyrhina* and *Lamna*) occupying the centres. Pl. IV. fig. 1 represents the external form and aspect of a typical nodule from this station. The mammillæ vary much in size, and are applied against and pass into each other without any very marked outlines; each mammilla corresponds to a concretionary centre, and, when cut into, these parasitic concretions are found to be pieces of more or less altered pumice or small sharks' teeth. Among the nodules were one or two that appear to have been broken while yet at the bottom of the ocean, and these fragments have subsequently formed the nuclei of other nodules. In some cases small fragments of palagonite are found in the centres of the nodules. The most frequent nucleus, however, is a hard white or yellowish substance, which, when examined in thin slices, is slightly transparent, but does not show any special structure to indicate its origin. In the fundamental mass little prismatic bodies are seen, but they have no characters which permit them to be referred to any mineral species. The fundamental mass appears to be composed of extremely fine grains, and sometimes there may be observed among these opaque points of manganese or fragments of sharks' teeth; between crossed nicols the mass behaves like an isotropic body, only some grains show, sporadically, birefrangence. When these nodules are broken down, crystals of hornblende, felspar, and magnetite may be extracted from the mass, yet it is extremely rare to observe these minerals in the microscopic sections. Among the magnetic particles are also metallic spherules of cosmic origin. Between twenty and thirty pieces of pumice were among the manganese nodules; these were either highly altered at the surface or surrounded with a coating of manganese 0·5 cm. in thickness.

It may be noticed that an analysis of the clay brought up in the sounding tube yielded only traces of manganese; the trawl, however, here yielded one of the largest hauls of manganese nodules taken during the cruise. It would appear as if the trawl had been dragged over a considerable surface of the deposit, the nodules being retained by the net while the clay in which they were imbedded was washed away. If this be the correct interpretation it is quite possible that the nodules are but sparsely scattered throughout the deposit, and that they had segregated nearly all the manganese from the clay. The quantity of manganese in the clay in which the nodules were imbedded in any case was very small compared with the larger indications in the clays at other stations where the deposit is of a dark chocolate colour. The surfaces of many of the nodules were covered with Rhizopod tubes and the stolons of Hydroids.

Station 253, 3125 fathoms.—The small dredge, as well as the tow-nets attached to it, contained clay and manganese nodules. One of the nodules was of large size, and flat or slab-like in form. It measured 31 × 20 × 6 cm.; a fourth part of this nodule is shown in Pl. IX. fig. 1. There was a great difference in appearance between the upper and lower surfaces; the lower surface, that which rested on the deposit, or was immersed in it, is very rough and uneven, consisting of numerous closely-set mammillæ; these mammillæ are more numerous near the outer edges of the block, and the whole under surface has a scoriaceous aspect. The upper surface, on the other hand, has relatively few mammillæ, and these are smooth, rounded, and softened, when compared with those of the under surface. Small pieces of pumice appear to have fallen on the upper surface of this block, and to have been cemented to the upper surface of the nodule by subsequent depositions of peroxide of manganese. In the same way a Nodosarian Foraminifer and worm-tubes, that lived attached to the upper surface, have become imbedded by the successive additions of manganese. Attached at different parts of the surface of this nodule were four living specimens of a Hydroid (*Stephanoscyphus*), a Tubularian, two small Actinians, a Serpularian, two Polyzoons, and the whole surface had a reticulated appearance from the presence of Rhizopod tubes or the stolons of the Hydroids. An Annelid with a muddy tube was attached to the under surface. Fig. 1*a* shows a portion of a section of this nodule, from which the manganese has been removed to show its structure. The whitish coloured irregular nucleus is surmounted by successive layers of manganese 3 to 4 cm. in thickness, while beneath this nucleus the layers are only about 1 cm. in thickness. It will be observed that many of the layers above the nucleus terminate rather abruptly towards the periphery, which structure seems to suggest that this nodule was once a part of a larger mass that had subsequently been fractured and surrounded by the external layers. The nucleus is irregular and of an elongated form, and in its centre are hollow spaces filled with clay; it is very hard and compact, but can be scratched with a knife. When examined in thin slices this nucleus is yellowish and finely granular, the grains being about 0·001 mm. in diameter. The whole mass is streaked with colourless lines, resembling in some respects certain microliths; it is isotropic, some colourless fragments being birefrangent; it did not present cleavages nor crystallographic contours. Two or three fragments of felspar and some elongated fragments, which appear to be mica, were observed, as well as some prismatic sections of zeolites. The nucleus is penetrated by dendrites of manganese in many directions. In all probability this nodule projected about an inch above the general level of the deposit when at the bottom of the ocean.

In addition to this large nodule was another with a diameter of 8 to 9 cm., resembling in many respects the nodules dredged at Station 252. The mammillæ are, however, more separated, and the surface has a more rugged appearance. The nucleus of this mass had probably originally been a fragment of pumice. The dredge and tow-nets contained about twenty fragments of pumice, all rounded, and from 0·5 to 2 cm. in diameter. Their surfaces were coated with manganese, and in some instances the fragments were cemented together by the manganese.

Station 254, 3025 fathoms.—One manganese nodule, about 1½ inches in diameter, was procured in the water-bottle, and in the sample of the deposit from the sounding tube there were numerous black grains of manganese.

Station 256, 2950 fathoms.—A few manganese nodules, sharks' teeth, and pumice fragments were obtained in the clay from the dredge. In some instances the sharks' teeth had but a slight coating of manganese, and in others they were surrounded by concentric layers nearly 1 cm. in thickness. One nodule had a nucleus of bone, but most of the others had apparently formed around pumice.

Station 258, 2775 fathoms.—Two small nodules came up, adhering with some clay to the under surface of the water-bottle, and in the specimen of clay obtained by the sounding tube were a good many manganese particles.

Station 264, 3000 fathoms.—The trawl brought up seven or eight small manganese nodules and hardened pieces of the deposit, frequently traversed in every direction by worm-tubes and coated with manganese. One or two of the nodules had palagonitic nuclei.

Station 265, 2900 fathoms.—The dredge and tow-nets brought up a large quantity of Radiolarian Ooze of a dark colour. Almost the whole of this ooze passed through the finest sieves, but in the siftings were several pieces of pumice, and one small manganese nodule about 2 cm. in diameter. The nodule had a rugged exterior; the nucleus consisted of a yellowish homogeneous substance, penetrated in all directions by dendrites of manganese. Under the microscope this nucleus appeared finely granular, and contained many Radiolarian skeletons, but no crystalline particles were observed. This nucleus was probably an agglomerated portion of the deposit.

Station 272, 2600 fathoms.—The trawl and attached tow-nets brought up some Radiolarian Ooze, in which was a small piece of basic pumice, and two or three small manganese nodules; in some of the nodules the nuclei were composed of pumice, while in others no nucleus could be recognised.

Station 274, 2750 fathoms.—The trawl and attached tow-nets brought up a quantity of chocolate-coloured ooze, and over a peck (9 litres) of manganese nodules, earbones of Cetaceans, sharks' teeth, and pumice fragments. The manganese nodules were oval, flattened, or somewhat kidney-shaped, the largest specimens measuring $10 \times 7 \times 4$ cm. Pl. IV. fig. 2 represents a typical specimen; there were about one hundred more or less resembling this one in form and appearance. These nodules are heavier and more massive than the generality of those procured at other stations, and they have almost all the same shape and internal structure. Some of the nodules appear to have been broken *in situ*, and a deposit of manganese to have subsequently taken place around the pieces of the original nodules. The superior surface is smoother than the inferior, as is usually the case. These nodules with a blow break up more easily following the radii than following the concentric layers of which they are composed. Plate IX. figs. 5 and 6 represent transverse sections, and show the peculiarities of internal structure. The nucleus is, as a rule, small and not sharply marked off from the concentric manganese zones; in some cases it is impossible to find any trace of a nucleus. In fig. 5 the face of the section has been polished, and when the black shining surface is closely examined, it is seen to be made up of undulating lines or zones superposed the one upon the other. Hundreds of these fine wavy lines succeed each other without any apparent interposition, and they are much more numerous than shown in the figure. The nodules at this station are therefore much more compact than is generally the case, from the hydrates being less mixed with extraneous substances. The polished surface has a metallic mirror-like lustre. Fig. 6 shows the face of one of these nodules in which the manganese has been removed by strong hydrochloric acid; the clayey skeleton that remains in this case is so scanty that it does not hold together, in which respect it differs considerably from the specimen shown in figs. 7 and 7*a* on the same plate, representing the clayey skeleton of a nodule from another station. Pl. IX. fig. 2 exhibits another nodule from this station that has been formed around a large triangular tooth of *Carcharodon*, there being in fact three centres of concretion, one at each corner of the triangle. Each of these has augmented by successive depositions, and they have united to form a single nodule. The figure represents the under surface of the nodule, which is rough from the presence of small mammillæ, especially at the borders. Pl. IX. fig. 10 shows a portion of one of the nodules from this station in which the manganese has been removed by hydrochloric acid; several tubes of Rhizopods appear between two successive layers of the nodule. Pl. VI. figs. 8, 11, and 16, represent sharks' teeth from this station, and Pl. VIII. figs. 4, 5, 12, and 13, earbones of Cetaceans. Other teeth and bones were much more thickly covered with layers of manganese and iron hydrates. When the manganese nodules are reduced to powder, and the magnetic particles extracted by means of a magnet, these are found to consist of magnetite and small black cosmic spherules with nuclei of metallic iron. The appearance of these fragments is represented in Pl. XXIII. fig. 12, after they have been pounded in an agate mortar and treated with an acid solution of sulphate of copper. The nodules also contain fragments of siliceous organisms, zeolitic crystals, fragments of felspar and other minerals, similar to those found in the ooze itself.

Station 275, 2610 fathoms.—The sounding tube brought up over half a litre of the darkest chocolate-coloured clay procured during the cruise; the colour was due to small pellets of manganese and minute grains of the same substance, the centres of which appeared black and opaque under the microscope, and the margins red. The deposit contained no carbonate of lime, but enormous numbers of crystals of phillipsite, either simple, twinned, or aggregated into spherules, were present. Some of these had a coating of manganese. A few Radiolaria were observed, but their rarity was in striking contrast with the extraordinary abundance of these organisms at the previous station to the northward (Station 274).

Station 276, 2350 fathoms.—The sounding tube had sunk about a foot into the deposit, and the specimen consisted of two layers, the deeper one being darker coloured and containing less carbonate of lime than the upper. The trawl contained some Red Clay along with five or six bushels[1] of manganese nodules, sharks' teeth, earbones of Cetaceans, pumice stones, and volcanic lapilli. The nodules were on the whole of small size when compared with those taken at other stations, their mean diameter being between 2 and 3 cm. Pl. IV. fig. 8 represents one of these nodules (natural size); it is spherical, with a scaly surface, and exhibits the general form and aspect of the spherical nodules from this station, although many of them are much smaller, while a few are a little larger. Pl. IV. fig. 7 represents a similar nodule in section. It is seen to consist of three zones: an external thin layer, which corresponds to the scales that can be removed from the outside of the nodules, and is about 1 to 2 mm. in thickness. The median zone is more massive; upon a polished surface no pronounced concentric structure can be seen, but the compactness of the manganese diminishes towards the centre, which is occupied by a yellowish earthy nucleus, originally a piece of pumice in all probability. Pl. IV. fig. 6 shows the upper surface of an irregular form of nodule, several of which were obtained at this station. They present a scoriaceous aspect, and are sometimes perforated by holes, the contours being rounded. The interior is formed by a great number of little earthy concretions, or by a palagonitic tufa. Pl. IX. fig. 8 shows another spherical nodule, from which the manganese has been removed. The external zone retains its normal concentric structure; the intermediate zone does not show any concentric arrangement, but presents a peculiar spongy structure. The nucleus is a fragment of basic volcanic rock.

The nuclei of the nodules from this station consisted of lapilli belonging to the basaltic series of rocks, of pumice, of aggregations of the deposit, of palagonitic fragments, of sharks' teeth, of otoliths of fish, of the earbones and other bones of Cetaceans. An unaltered fragment of volcanic glass, forming the nucleus of one of the nodules, is shown in Pl. XVI. fig. 1. Nuclei of palagonitic lapilli are represented in Pl. XVIII. figs. 2, 3, and 4, along with the zeolitic crystals which surround and fill the pores. Other palagonitic lapilli from this station are represented in Pl. XIX. figs. 1, 2, and 4. Pl. XXI. fig. 1 represents the palagonitic tufa forming the nucleus of one of the flattened nodules. The four figures on Pl. XXII. represent crystals of phillipsite, isolated and in

[1] About 200 litres.

spherules, also from this station. The external aspect of one of these spherules of phillipsite is shown in Pl. XXIII. fig. 3, while figs. 2, 5, 6, 7, and 9, on the same plate, represent cosmic spherules extracted by means of a magnet from the nodules or the clay in which they were imbedded.

There were about 300 sharks' teeth and fragments of sharks' teeth, either with a slight coating of manganese or forming the nuclei of nodules, some of which are represented in Pl. V. fig. 12 and Pl. VI. figs. 1 and 19, and about twenty petrous bones and tympanic bullæ and other smaller fragments of bones of Cetaceans. Two of the tympano-periotic bones are shown in Pl. VII. figs. 6 and 7, and were attached when brought up. Among the nodules were also four large otoliths of fish, about the size of those of the Tunny, as well as two of the tabulated teeth of *Tetrodon*. For many reasons it seems probable that this station is not far removed from the seat of some old submarine eruption.

Station 280, 1940 fathoms.—There were two or three hardened pieces of the deposit, perforated in all directions by worm-tubes, and coated with deposits of peroxide of manganese. One piece was 2 inches in length and very irregular in outline; two smaller pieces were flat, and to one of them an *Esperia* was attached.

Station 281, 2385 fathoms.—In the bag of the trawl there were some dark chocolate-coloured clay, many manganese nodules, large slabs of volcanic tufa covered with manganese, many sharks' teeth, and a few earbones and fragments of other bones of Cetaceans. There were between two and three bushels[1] of manganese nodules. Among these were several large slabs, from 1 to 2 inches in thickness; one of them measured 18 × 12 inches. A portion of one of these slabs is shown in Pl. IV. fig. 3. About the middle of the section will be noticed a dark line; beneath this line there is a Red Clay that would seem to have been at one time the upper surface of an old sea-bottom. Here manganese nodules were in process of formation, some of them nearly imbedded in the Red Clay forming the lower part of the figure, while others projected partly above the surface. A fall of volcanic ashes appears to have taken place upon this old sea-bed, and to have covered the floor of the ocean, in some places at least, to the depth of an inch, as represented in the figure above the dark line. The minerals making up the ashes lying immediately upon the Red Clay are coarser than those above. The appearance of these volcanic minerals at the junction with the Red Clay is represented in Pl. XXI. fig. 2, the right-hand side of the figure representing the Red Clay deposit, and the left the volcanic ash. In most cases the slabs are coated with layers of peroxide of manganese only on the upper surface and along the edges, the under surface being composed of red or chocolate-coloured clay. The nodules imbedded at the junction between the shower of ashes and the Red Clay have a concentric arrangement, and sometimes have sharks' teeth as nuclei. In some of the slabs, as has been stated, the layer of ashes is fully an inch in thickness, in others it is less than half an inch. Pl. IV. fig. 4 shows a nodule, on

[1] About 80 litres.

the upper surface of which there is a layer of ashes only one-eighth of an inch in depth, covered by a thin layer of manganese. The majority of the nodules at this station have a layer of this volcanic tufa or ash in the position represented by the figure. None of the nodules, however, in the position of those represented in Pl. IV. fig. 3, *i.e.*, along the line separating the tufa from the Red Clay, exhibit this layer of ash on the superior surface. Pl. IV. fig. 5 shows a nodule in which a *Carcharodon* tooth forms the nucleus. In addition to the nodules above referred to, there were numerous small nodules about the size of marbles, some of them having tufa in the centre and others with nuclei of sharks' teeth or their fragments. Some very irregular flat fragments had Red Clay in the centre. Sharks' teeth from this station are represented in Pl. V. figs. 1, 2, 3, 4, 5, and 13, and Pl. VI. figs. 9, 10, 13, 15, and 17.

The volcanic islands of Rurutu and Tubuai are each distant from this station between fifty and sixty miles, the former to the west and the latter to the south. One or other of these islands is probably the source of the volcanic ashes which have fallen upon this old sea-bed. The arrangement of the volcanic ashes, the coarser particles lying on the Red Clay and these being covered by finer and finer particles, seems to indicate that they have been derived from a terrestrial eruption, to have fallen upon the surface of the ocean, and, in falling through the water, to have been arranged in layers according to size and specific gravity. After this tufa had consolidated, the bottom would seem to have been broken up by some disturbance, and the manganese to have been subsequently deposited over the surface and down the cracks between the different fragments. The minerals in the Red Clay portion of the slabs are much more highly altered than in the portion composed of tufa.

Station 283, 2075 fathoms.—In the upper part of the sounding tube was a light-coloured Globigerina Ooze containing many pelagic Foraminifera; in the lower six inches of the tube was a very dark chocolate-coloured clay, containing much manganese in the form of round balls and many crystals of phillipsite.

Station 285, 2375 fathoms.—The trawl at this station contained several quarts of dark chocolate-coloured clay, and large numbers of manganese nodules, sharks' teeth, earbones and fragments of other bones of Cetaceans, pumice stones, and angular and rounded pebbles, apparently ice-borne. The specimen of the deposit procured in the sounding tube contained carbonate of lime in the form of pelagic Foraminifera in the upper layers, but that in the trawl did not show any effervescence when treated with dilute acid.

There were between two and three bushels[1] of manganese nodules. The great majority of these were of small size, from 1 to 2·5 cm. in diameter, resembling a lot of marbles. One large nodule, however, with a large white-coloured nucleus, appeared to have been broken to pieces in the trawl. The white nucleus had at one time been a

[1] About 80 litres.

portion of a deep-sea deposit, but not like the dark-coloured clay that came up in the trawl, for it contained numerous casts of *Globigerina* shells, along with many angular fragments of basic volcanic glass. Pl. II. fig. 7 shows the external aspect of four of the smaller nodules, while Pl. II. fig. 5 shows one of the larger nodules, with portions removed to show the internal structure. The inner concentric layers of the great majority of these nodules form light brown coloured nuclei, which have frequently been compared to coprolites by geologists who have examined them. These lighter layers are less than 1 mm. in diameter, and are arranged concentrically around altered pieces of volcanic glass, sharks' teeth or their fragments. The outer layers are of a darker colour, and contain much more manganese than the inner ones. The appearance under the microscope of the internal parts of these nodules is shown in Pl. XXVII. fig. 3, and in all the figures on Pl. XXIX. The typical nodules contain about 37 per cent. of manganese peroxide, and 24 per cent. of ferric oxide. The structure of bone can be readily recognised in some of the nodules, while others appear to have been originally formed upon fragments of bone, though now all traces of the bone have disappeared. One of the largest tympanic bullæ from this station (*Balænoptera*) is represented in Pl. VII. fig. 1. Altogether about fifty petrous and tympanic bones of Cetaceans were procured. Many of these were deeply imbedded in concentric layers of manganese, while in other cases large portions of the bone had been removed and substituted by depositions of manganese.

More than fifteen hundred specimens of sharks' teeth and fragments, over 1 cm. in length, were present, while immense numbers of smaller teeth and fragments were found in the deposit or in the nodules. Specimens of these teeth are represented in Pl. V. figs. 6, 7, 10, and 11, and Pl. VI. figs. 2, 3, 4, 5, 6, 7, 12, 18, 20, 21, and 23. Some of the larger teeth were surrounded with layers of manganese, but, as a rule, they were not so deeply imbedded as the smaller teeth and fragments. The internal portions of the teeth were generally filled with deposits of manganese; the vaso-dentine and osteo-dentine had been entirely removed, the hard external enamel-like dentine alone remaining.

The nuclei of the nodules were occasionally pieces of volcanic rock; most of these had undergone considerable alteration, the glassy base having been converted into palagonite. Many of the specimens showed agate-like bands, similar to the specimen represented in Pl. XIX. fig. 3 from another station. These palagonitic layers were soft and could be cut with a knife like cheese when taken from the sea, but they have since become quite brittle. Two of these nuclei are represented in Pl. XVI. fig. 3, and Pl. XVII. fig. 7. Among the nodules were several bomb-like fragments about 1 cm. in diameter, with a hard thin exterior, and a hollow interior partly filled with ferruginous matters. Some of the nodules contained hollow spaces, in which the manganese assumed a radiate, crypto-crystalline, structure. The outside of the nodules was generally covered with Rhizopod tubes, or the stolons of Hydroids, and these could sometimes be observed in the body of the nodules, incorporated between the successive layers. There were six rounded or rolled pebbles; the largest, having in one direction a diameter of over 3 cm., was a basaltic rock, while the others were fragments of granitic and gneissic rocks. These pebbles are believed to have been ice-borne, this station being just beyond the borders of the region of floating ice in the southern hemisphere.

Twelve rounded pieces of pumice, the largest about the size of a hen's egg, were also met with; the outer portions were decomposed into earthy matter, and covered with layers of manganese, which also penetrated in the form of dendrites throughout the whole of the mass.

The magnetic spherules extracted from the deposit at this station, as well as from the manganese nodules, were numerous; some of them are represented in Pl. XXIII. figs. 1, 4, and 8.

Station 286, 2335 fathoms.—There were two layers in the sample of deposit obtained in the sounding tube, an upper dark-coloured layer containing but little carbonate of lime, and a lower light-coloured layer containing many *Globigerinæ* and Coccoliths. The trawl contained about two bushels[1] of manganese nodules and pumice stones, along with a large number of sharks' teeth and bones of Cetaceans. Pl. II. fig. 6 shows five of the nodules from this station. They are formed around sharks' teeth, or splinters of teeth, and small particles of pumice, and it will be seen from the figure that these are cemented into little groups of an irregular form. The striking characteristic of the nodules at this station is that the great majority of them are formed round fragments of teeth or of bone. Sometimes these organic fragments are surrounded by layers of manganese of considerable thickness, while at other times there is only a slight coating, although the bone may have dendrites of manganese ramifying throughout its whole mass, and the teeth are usually filled with manganese depositions. The manner in which the manganese penetrates and covers these organic fragments is represented by the figures on Pl. X.

Over 350 sharks' teeth and fragments were observed among the nodules; some of them are represented in Pl. V. figs. 8 and 9, Pl. VI. figs. 14 and 22, Pl. X. figs. 4 and 5. Numerous bones of Cetaceans were obtained at this station, including tympanic bullæ and detached petrous bones, beaks of Ziphioid whales, fragments of flat and spongy bones, and numerous other small fragments forming nuclei of the manganese nodules. Some of these are represented in Pl. VII. figs. 2, 3, 4, and 5, Pl. VIII. figs. 1, 2, 3, 6, 7, 8, 9, and 14, and Pl. X. figs. 1, 2, and 3.

A few of the nodules contained nuclei of basic volcanic glass and palagonite. There were several pieces of rolled pumice, and one large granitic pebble, over 3 inches in diameter, apparently ice-borne. Among the nodules were numbers of clayey concretions

[1] Over 70 litres.

of a greyish colour, perforated by worm tracks, and coated with manganese; these concretions contained a few Coccoliths and crystals of phillipsite.

Station 287, 2400 fathoms.—The deposit in the sounding tube was of a dark chocolate colour, and contained a considerable amount of manganese, along with crystals of phillipsite, palagonitic fragments, and small sharks' teeth.

Station 288, 2600 fathoms.—The sounding tube had sunk 18 inches into the deposit; it was of a red colour throughout, and contained an immense number of manganese particles, zeolitic crystals, and palagonitic fragments.

Station 289, 2550 fathoms.—The trawl brought up over a bushel[1] of manganese nodules, to some of which clay adhered, but at this station no specimen of the deposit was obtained, either in the bag of the trawl, in the tow-net attached to the trawl, nor in the sounding tube. This, together with the fact that the sounding tube and the ironwork of the trawl were scored with manganese, indicates that the nodules must have been very abundant. They were nearly all of large size, some being 6 or 7 cm. in diameter. Their surfaces were exceedingly irregular, and they easily broke into segments following the radii and the concentric layers. The nuclei were generally deeply imbedded, there being very few sharks' teeth or earbones with a slight coating of manganese as at Stations 285 and 286, indeed, only two sharks' teeth were noticed as nuclei of the nodules; there were, however, seven earbones forming nuclei. Some of the nuclei were formed of basic volcanic glass and palagonite. The internal concentric layers were, in some of the nodules, of a lighter colour than the external ones, as shown in Pl. III. fig. 7, representing one of the nodules from this station. Another nodule is represented in Pl. IX. fig. 3; the upper portion of the figure shows the manner in which the segments break away from the nodule. In the hollows between the rather large mammillæ a ramifying Rhizopod tube is shown, but on the whole the surfaces of the nodules from this station were remarkably free from organisms.

Station 290, 2250 fathoms.—The outside of the sounding tube was covered with black streaks of manganese; the leads and ironwork of the trawl were also covered with similar streaks, as if they had been rubbing on nodules at the bottom. In the bag of the trawl, however, there was only a single small nodule about the size of a marble, to which an egg-capsule was attached.

Station 292, 1600 fathoms.—The deposit at this station was a Globigerina Ooze of a dark brown colour from the presence of manganese peroxide. Some of the Foraminifera shells were covered with black specks of manganese, while numerous grains of manganese and some palagonitic fragments were also observed.

Station 293, 2025 fathoms.—The deposit was dark brown in colour from the presence of manganese grains, and in the bag of the trawl were about a dozen manganese nodules, to which several organisms were attached. Some of these nodules had nuclei of basic

[1] About 38 litres.

volcanic glass, surrounded by different coloured bands altering into palagonitic material. One of these is represented in Pl. XIX. fig. 3; another nucleus, in which the vitreous base is transformed into palagonite, is shown in Pl. XVII. fig. 2.

Station 294, 2270 fathoms.—In the lower six inches of the sounding tube there was a dark-coloured deposit, containing a large quantity of manganese, together with palagonitic fragments, sharks' teeth, and zeolitic crystals.

Station 296, 1825 fathoms.—The mud in the lower half of the sounding tube was of a dark brown colour from the presence of manganese grains, and in the trawl were several small manganese nodules, about the size of peas, together with numerous splinters of basic volcanic glass and palagonite.

Station 297, 1775 fathoms.—The deposit here was a Globigerina Ooze containing 71 per cent. of carbonate of lime. The trawl contained about 4 litres of manganese nodules, while about 3 litres were obtained in the tow-net attached to the trawl, along with a quantity of the yellow-coloured Globigerina Ooze. The weights, 300 fathoms in front of the trawl, were scored with black streaks, as if they had been dragged over lumps of manganese. The nodules rarely exceeded 4 cm. in diameter, were round in form, and not so massive as nodules of a similar size dredged from a Red Clay. The great majority had large, whitish, yellowish, or greenish nuclei, evidently originally composed of aggregations of the deposit, for very many casts of Foraminifera were observed in a yellowish or whitish substance, which is unaffected by dilute acids. In general these nuclei are soft, but at other times they are harder, and the casts of Foraminifera are very perfect. One of these nuclei contained iron, alumina, and magnesia, with small quantities of soluble silica, manganese dioxide, and soda. The portion insoluble in hydrochloric acid, amounting to 53 per cent., consisted mainly of free silica. The general appearance of these nodules is represented in Pl. III. fig. 8, while in fig. 9 of the same plate one of the nodules is broken to show the nucleus. In some cases the nucleus consists of a fragment of basic volcanic glass surrounded by altered palagonitic zones; in other cases the central unaltered portion has entirely disappeared, the whole nucleus being converted into palagonite. Occasionally the nucleus is composed of a large number of angular fragments of palagonite with hollow spaces in the centre (see Pl. XVIII. fig. 1). When the manganese is removed from these nodules by concentrated hydrochloric acid the skeleton that remains has a very areolar structure, as represented in Pl. IX. fig. 9.

This station is instructive as being one of the few instances in which manganese nodules were found in a Globigerina Ooze. It may be pointed out that the manganese nodules are here associated with a considerable quantity of basic volcanic glass, fine areolar volcanic ash, and palagonitic grains; indeed, this association of altered basic volcanic material and manganese is very constant in deep-sea deposits. While there were perfect casts of Foraminifera observed in the nuclei of many of the nodules, no casts of these organisms were found in the deposit itself. The accumulation of free silica in these nuclei is very remarkable, especially when the small proportion of siliceous organisms in the deposit is remembered. One of the tow-nets contained several rounded lumps of the deposit, loosely held together by dendritic depositions of manganese and iron, which seemed to indicate the beginning of the nodule formation.

Station 299, 2160 fathoms.—The deposit at this station was a Blue Mud, but just on the border-line between Blue Mud and Red Clay. There was over a litre of manganese nodules in the trawl. Some of these were formed round nuclei of pumice, while in others no apparent nucleus was present. The prevailing form, represented in Pl. III. fig. 4, is like an inverted cone with the apex removed. The lower part of the nodule was very areolar in structure, containing much clayey matter in alternate layers, and concentric round a point which would be represented by the apex of the cone. The upper part of the cone is also made up of concentric layers, but is much harder and more compact. Another nodule from this station is represented in Fig. 35, with a *Scalpellum* attached. There were also in the trawl a tympanic bulla of a *Globiocephalus*, with the petrous bone attached, and a Cephalopod beak, both coated with manganese.

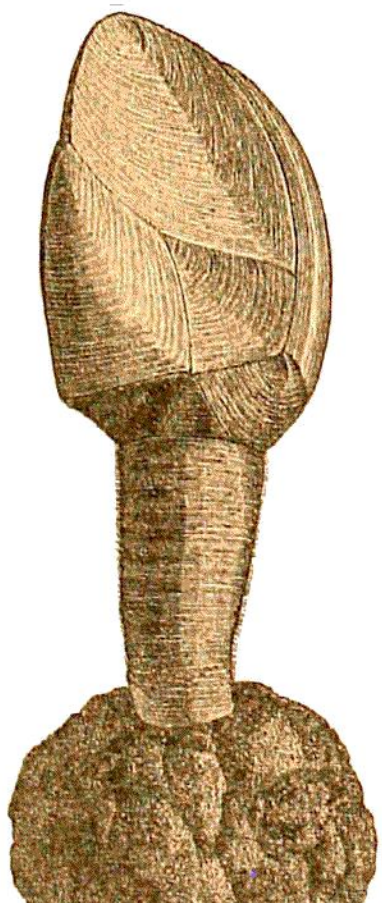


Fig. 35.—Manganese Nodule with *Scalpellum darwinii* growing on it. Station 299, 2160 fathoms. South Pacific.

Station 300, 1375 fathoms.—The trawl appeared to have caught on the bottom, and it was with great difficulty that it could be released, the accumulators being stretched to their utmost. The beam of the trawl was scored in several places by patches of black manganese, as if the beam had caught on something coated with that substance. Amongst the ooze in the bag of the trawl were three or four basaltic pebbles, coated with manganese, and four flattened pieces of volcanic tufa, coated on one surface by deposits of manganese, 6 to 12 mm. in thickness.

Station 302, 1450 fathoms.—The trawl, as at Station 300, caught upon the bottom, and was with difficulty released. The bag of the trawl contained about a peck of ooze, containing many manganese concretions and volcanic pebbles. Among the manganese nodules were some large flat-shaped fragments, apparently torn from larger masses. They consisted of alternate layers, and were black-brown throughout. The majority of the nodules had nuclei of basic volcanic glass, surrounded by altered layers; one of the nuclei is represented in Pl. XVI. fig. 4, and another in Pl. XVII. fig. 4. Other nodules appeared to have been formed around small aggregations of the deposit, for in them could be seen many casts of Foraminifera.

ATLANTIC OCEAN (HOMEWARD VOYAGE).

Station 330, 2440 fathoms.—There were a good many manganese particles in the deposit, sometimes in the form of tubes, and one worm-tube appeared to be filled in the inside with deposits of manganese.

Station 337, 1240 fathoms.—The sounding tube here brought up a number of Pteropod and Heteropod shells, with a thin coating of manganese, and similar shells were found in the bag of the dredge.

Station 339, 1415 fathoms.—The larger Pteropod and Heteropod shells in this Pteropod Ooze were covered on the outside with thin coatings of peroxide of manganese.

Station 341, 1475 fathoms.—The sounding tube came up empty, except for a few Pteropod and Foraminifera shells, and small particles of peroxide of manganese. On the outside of the tube were several black streaks, which on examination proved to be due to peroxide of manganese.

Station 343, 425 fathoms; Station 344, 420 fathoms.—Some pieces of dead Coral, fragments of rocks and shells, coated with manganese, came up in the sounding tubes. Some of the small rock fragments are black vesicular basalts transforming into palagonite.

There do not appear to have been any large hauls of manganese nodules from the abysmal regions other than those made by the Challenger Expedition. H.M.S. "Egeria" in the centre of the Indian Ocean, and the U.S.S. "Tuscarora" in many parts of the Pacific, have, however, procured in the sounding tube samples of red and chocolate clays identical with those obtained by the Challenger in the regions from which the large numbers of manganese nodules were trawled. It may therefore be assumed that very wide regions of the deep sea, other than those examined by the Challenger, are covered with nodules and organic remains similar to those described in the foregoing enumeration.

In the Atlantic no indications have as yet been forthcoming of manganese areas similar in character and extent to those of the Pacific and Indian Oceans, containing many sharks' teeth, earbones of Cetaceans, crystals of phillipsite, and numerous cosmic spherules, for in none of the samples of deposits procured in the sounding tube are there any of the dark chocolate-coloured Red Clays.[1] The manganese deposits in the Atlantic appear

[1] Mr J. Y. Buchanan has described some small manganese nodules and manganiferous deposits dredged first by himself and subsequently by Mr Murray, in the estuary of the Clyde, Scotland, in 104 fathoms and lesser depths (see *Nature*, vol. xviii. p. 628, 1878; *Trans. Roy. Soc. Edin.*, vol. xxxvi., 1891). The small nodules resemble in some respects those from the deep sea; they contain more quartz and larger traces of copper, but smaller traces of cobalt and nickel. The state of oxidation of the manganese is, according to Buchanan, very little over Mn_2O_3, while in deep-sea nodules it falls very little short of MnO_2. The peroxide of manganese in the deposits of Loch Fyne and other parts of the Clyde sea-area appears for the most part to have been derived from the chemical works of the district, and not from the decomposition of the minerals and rocks of the deposits; one firm alone, Messrs C. Tennant and Co., state that between the years 1818 and 1846 they threw into the river Clyde over 56,000 tons of chloride of manganese as a waste product of their manufactures. This view as to the source of the manganese seems to be confirmed by Mr Murray's recent extensive dredgings on the west coast of Scotland, for while manganese nodules and coatings are abundant in many regions of the Clyde sea-area—for instance, on the Skelmorlie Bank, in Loch Strivan, Loch Goil, and Loch Long—only relatively small traces of manganese peroxide can be found in the more northern lochs of the west coast, where the rocks and minerals in the deposits are similar in nature to those in the Clyde area.

to be much more limited, and have chiefly been found in more or less close proximity to volcanic islands. There are, however, indications of an approach to the condition of the chocolate-coloured clays of the Pacific in the deep water about 20° N. and 50° W. in the Atlantic.

If now we attempt to summarise the foregoing descriptions, it may be said that these concretionary masses of manganese assume a great variety of forms in modern deep-sea deposits. Sometimes the oxides cover consolidated masses of tufa, fragments of rocks, portions of the deposit, branches of Coral, and remains of other calcareous organisms. At other times fragments broken off from what must have been huge concretionary masses were obtained in the trawl and dredge; this was especially the case in the shallower waters near to, or on the slopes of, volcanic islands. The prevailing concretions, however, were more or less rounded nodular masses, from 1 to 10 or 15 cm. in diameter, and hence resembling all concretionary bodies formed in a plastic or liquid medium. As will have been noticed in the descriptions of the nodules at each station, they may present great variations in the dredging, but as a rule the nodules at any one station have a family resemblance, and differ, in size, form, and internal structure, from those at another station; so much so that now, after a detailed study of the collections, it is usually possible for us and our assistants to state at sight from which Challenger station any particular nodule had been procured.

In a great many cases the external form depends on the shape of the nucleus, but there are a number of minor peculiarities which afford indications of the station to which the samples belong. The great irregularity of some nodules depends on the fact that the nucleus is not simple. The concretionary depositions have commenced around several adjacent foreign bodies; by the increase of the successive layers around the several nuclei, the little nodules have come in contact with each other, have become united, and finally have developed into a large single nodule with several protuberances, assuming the aspect of double, triple, or quadruple nodules. In the case of very large nodules the multiple origin becomes for the most part obliterated at the external surface. The surfaces of the nodules are covered by all sorts of asperities and mammillæ, these being generally more pronounced on the under surface which had been immersed in the deposit.

Sometimes there is no apparent nucleus, and nodules of this character usually contain more manganese, being dark brown or black to the very centre, and take on a bright metallic lustre when polished with chamois leather or a piece of cloth. Almost always, however, there are one or more recognisable nuclei, around which the manganese and iron have concreted. It may be remarked that there is no chemical relation between the manganese and the nucleus to initiate the depositions, for the nuclei may be indifferently carbonates, phosphates, silicates, or silica. Any solid body suffices for the support of the original and subsequent concretionary deposits. Basic and acid silicates

—like pumice and glassy lapilli, almost always profoundly altered—are perhaps the most frequent nuclei, then follow teeth of sharks and other fish, otoliths, bones of Cetaceans, siliceous and calcareous Sponges, and even agglomerations of the deposits in which casts of Foraminifera can be recognised.

Not only the external form and the presence of nuclei, but also the internal structure, indicate the concretionary nature of the nodules; the sections, in fact, show that the nodules are built up of successive concentric zones. The inner zones follow closely the form of the nucleus, while those towards the exterior are more regular and have more ample curves. Some zones are darker than others, and in these the manganese is more abundant than in the intervening ones, which have a large admixture of earthy and clayey materials. The zones vary in thickness in different specimens; sometimes they are thinnest in the central, and sometimes in the outer, layers. This zonary structure is well exhibited when the nodules are demanganesed; the clayey and earthy skeletons that remain after this treatment resemble strikingly all the varieties of urinary calculi. The empty spaces in these skeletons show the positions occupied by the eliminated manganese in the nodules, and it may be seen that the dendrites had passed across the earthy and clayey zones.

The concretionary arrangement of the nodules is likewise clearly exhibited by the facility with which the successive zones may be separated into concentric shells or scales following the earthy layers. In some of the more compact and purer nodules, and in spaces free from foreign substances, a distinct fibro-radiate disposition may also be observed, recalling the structure of pyrolusite, and there is nearly always a tendency to a fracture following the radii of the nodule. Some of the nodules, indeed, have broken up in this fashion while still at the bottom of the sea, and the separate fragments or wedges of the original nodule have become the centres or nuclei around which new concentric layers have been deposited.

Microscopic Characters.—The microscopic characters of the manganese concreted in the nodules do not present any peculiarities to allow of a specific determination of the mineral. Like all the oxides of manganese, it appears, in the thin slices of the nodules, as absolutely opaque: a black mass sometimes with a brownish tint. There is no trace of internal structure nor of crystalline form, if we except some small patches in a few of the denser nodules, whose crypto-crystalline appearance has been compared to pyrolusite. When mixed with the clayey matters of the deposits the manganese is often seen as minute roundish grains with a black opaque centre and a brownish coloured border. But generally the red-brown or chocolate pigment of the deposit is indefinite, and the oxides of iron and manganese occur with very vague contours. In the nodules the manganese appears to be amorphous, but as we have said it assumes a dendritic arrangement which can be well seen under the microscope. All the details of this structure, and the form of the manganese in the nodules, are represented by the figures on Pls. XXVIII. and

XXIX., but these figures show rather the structure of the nodules themselves than the microstructure of the mineral. It may be seen from the figures that the manganese is disposed in fine concentric layers, marked off by black opaque or brown lines. The fine black undulatory zones may be recognised as having a concretionary arrangement even with high powers, as represented in Pl. XXIX. fig. 3. The appearance of nodules with many centres, and other peculiarities of structure, are well shown in many of the microscopic sections. In Pl. XXVIII. fig. 3 there are several centres of concretion, organic and inorganic—fragments of teeth, palagonite, and other volcanic rocks; the deposition has commenced around each of them, and they ultimately became united into a single nodule by successive layers of manganese. In Pl. XXIX. fig. 2 another concretion is represented containing several nuclei; near the upper part of the figure there is a section of a shark's tooth as one of the principal centres, and immediately below this another large nucleus consisting of a volcanic lapilli containing green augite and plagioclase. Pl. XXIX. fig. 4 shows again the zonary arrangement of the manganese around two centres composed of altered material and their subsequent envelopment in one nodule by the continuous deposition of manganese, which has enclosed at the same time the clayey matters with fragments of minerals and organisms.

The microscopic as well as the macroscopic examination shows a well-marked zonary structure, always combined with a dendritic arrangement. In Pl. XXVIII. fig. 1 the arborescent form of the black manganese is directed parallelly to the radii of the nodule, and is intercalated in yellowish brown muddy materials. This is quite the ordinary aspect of dendrites of this mineral; the figure also shows the zonary structure indicated by curved bands of a deep brown colour. Pl. XXVIII. fig. 2 shows likewise the dendritic arrangement, but not so well marked; the large ovoid body occupying the centre of the figure was probably the primary form of the original nucleus, now mostly transformed into manganese. In Pl. XXVIII. figs. 4 and 5 variations of the same zonary and dendritic structure are represented.

It may be concluded from the study of the microscopic sections that the deposition of the manganese has been continuous, for the manganese oxides can be seen to ramify across the earthy or clayey layers, and are thus continuous with the manganese in the purer and darker zones. In all respects the microscopic examination confirms the views arrived at from a macroscopic examination as to the structure of the nodules and their varied nuclei.

Chemical Composition.—To what mineral species or ore of manganese are these nodules to be referred? The numerous analyses given below prove that we have to do with a hydrated oxide of manganese, mixed with variable quantities of limonite, clay, and other earthy and sandy matters. Among the associated substances there are several which are in a way peculiar to the concretionary and reniform manganese ores, for instance, copper, cobalt, nickel, &c. The general mass of the substance of the nodules is dull, dirty brown, earthy, soiling the fingers, and easily scratched with a knife. The streak is reddish brown or chestnut brown, like the hydrated oxides: manganite and hausmanite. The hardness is variable, being greater in the purer specimens, which are capable of taking on a beautiful polish with a bluish black reflection, like that of psilomelane. Sometimes little divergent crystalline fibres, resembling pyrolusite, may be observed. When freshly taken from the sea, they were soft, heavy, and easily pared down with a knife; they have on drying become harder, lighter, and much more brittle. These concretions present in the different specimens the characters found in quite distinct oxides of manganese, and as we shall see they are made up of a mixture of these different oxides. Fused with soda they give the reaction of manganate of sodium; chlorine is set free when they are attacked by hydrochloric acid. The somewhat low specific gravity of most specimens is remarkable, this being evidently due to the mixture of foreign substances, and in some instances to the nucleus of pumice.

The following analyses show clearly the mixed composition of the nodules. Among the substances indicated by the analyses, the oxides of manganese are the most abundant, and these may make up more than one-half of the total mass of the nodules. The hydrated oxide of iron is nearly as abundant as that of manganese, indeed in not a few instances the peroxide of iron present in the nodules exceeds the peroxide of manganese. In addition to these oxides of manganese and iron there occur all the constituents found in the deposits in which the nodules were embedded. This is indicated by the hydrated silica often in excess of the alumina, and may be due to the presence of the skeletons of siliceous organisms. The carbonate and phosphate of lime, as well as the carbonate of magnesia, point to the presence of carbonate of lime shells and other organic remains. In the insoluble portion there is evidence of anhydrous silicates, referable no doubt to the small fragments of volcanic rocks and minerals, answering to silicates of alumina, iron, lime, magnesia, and alkalies, enclosed along with the deposit in the zones of growth. Finally nickel, cobalt, and other rare substances are indicated, as is specially shown by Dr Gibson's more detailed analysis at the end of the volume (Appendix II.).

Station.	Depth in Fathoms.	No.	Loss on Ignition.	Portion Soluble in HCl. SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	Ca_32PO_4	$MgCO_3$	Cu Ni Co	Total.	Portion Insoluble in HCl. SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
3	1925	96	24·84	4·00	2·50	31·60	25·64	3·15	1·16	0·90	1·51	Cu tr.	70·46	2·00	1·00	1·30	0·30	0·10	4·70
,,	,,	97	18·30	5·00	1·70	40·71	22·80	5·15	1·17	0·34	1·51	Cu Ni Co tr.	78·38	1·66	0·55	0·68	0·25	0·18	3·32
16	2435	98	13·63	7·05	2·95	36·08	29·32	1·96	1·05	g. tr.	4·32	Cu Ni tr.	82·73	Al_2O_3, Fe_2O_3, SiO_2					3·64
160	2600	99	20·40	11·17	2·00	19·08	32·48	3·07	0·58	0·20	1·72	Cu Ni g. tr.	70·30	7·80	0·45	0·50	0·35	0·20	9·30
,,	,,	100	11·00	9·80	4·60	16·70	39·32	3·00	0·58	tr.	1·60	Cu abund. tr.	75·60	12·00	1·00		0·28	0·12	13·40
,,	,,	101	10·25	16·60	1·80	15·10	33·62	3·00	0·58	tr.	3·02	Cu abund. tr.	73·72	11·73	2·10	1·50	0·40	0·30	16·03
248	2900	102	16·50	11·00	2·50	20·50	22·50	2·65	0·85	g. tr.	1·10	Cu Ni g. tr.	61·10	18·10	2·17	1·16	0·65	0·32	22·40
252	2740	103	10·60	11·00	3·50	19·33	28·50	3·37	0·88	tr.	1·90	Cu sm. tr. Ni g. tr.	68·48	16·74	2·35	1·15	0·45	0·23	20·92
,,	,,	104	20·80	9·90	5·00	17·83	25·37	3·58	0·58	tr.	2·27	Cu tr.	64·53	11·37	1·70	0·90	0·50	0·20	14·67
,,	,,	105	15·20	9·20	4·50	16·92	25·48	3·58	0·58	tr.	2·27	Cu tr.	62·53	18·42	2·10	0·90	0·65	0·20	22·27
253	3125	107	12·10	15·97	4·70	21·20	26·21	3·06	0·75	0·45	0·86	Cu Ni g. tr. Co tr.	73·20	11·16	1·80	0·90	0·52	0·32	14·70
256	2950	108	11·30	9·20	2·30	18·80	39·57	2·58	0·58	g. tr.	4·54	Cu l. tr. Ni g. tr. Co tr.	77·57	8·60	1·40	0·80	0·33	g. tr.	11·13
264	3000	109	8·90	24·20	2·65	21·38	29·09	2·58	0·62	tr.	3·40	Cu l. tr. Ni g. tr. Co tr.	83·92	4·10	0·60	1·70	0·45	0·33	7·18
274	2750	110	12·60	10·50	1·00	8·41	51·46	3·58	0·59	1·35	4·92	Cu 0·79 Ni g. tr.	82·60	3·00	0·60	0·60	0·45	0·15	4·80
,,	,,	111	12·50	9·80	0·30	11·97	52·39	3·95	0·75	0·83	2·12	Cu 0·79 Ni g. tr.	82·90	2·65	0·56	0·94	0·34	0·11	4·60
,,	,,	112	11·40	8·80	0·30	9·75	55·89	3·88	0·58	0·35	4·16	Cu 0·79 Ni g. tr.	84·50	2·54	0·31	0·78	0·33	0·14	4·10
276	2350	113	16·30	13·60	5·00	40·50	11·40	5·06	0·87	fair tr.	1·13	Cu g. tr. Ni Co tr.	77·56	1·94	1·30	1·50	0·70	0·70	6·14
,,	,,	114	14·40	9·76	2·00	45·00	14·82	4·30	0·99	sm. tr.	1·13	Cu g. tr. Ni Co tr.	78·00	3·90	1·10	1·40	0·70	0·50	7·60
,,	,,	115	14·10	36·30	8·90	21·00	1·91	2·70	0·41	g. tr.	1·53	Cu tr.	72·75	8·00	1·80	2·00	0·85	0·50	13·15
281	2385	117	16·00	15·40	2·00	29·00	22·22	2·79	0·29	tr.	1·51	Cu Ni g. tr. Co tr.	73·21	7·22	1·25	1·38	0·84	0·15	10·79
,,	,,	118	10·98	15·12	3·38	32·50	19·92	2·81	0·63	...	1·41	Cu g. tr.	75·77	9·24	1·30	1·52	0·84	0·35	13·25
,,	,,	119	5·66	30·40	2·70	27·80	6·51	2·79	0·29	g. tr.	1·13	Cu Ni Co tr.	71·62	12·50	2·13	5·04	2·69	0·36	22·72
285	2375	120	12·90	9·20	2·50	24·63	36·54	1·86	0·34	g. tr.	1·13	Cu Ni g. tr. Co tr.	76·20	7·58	1·94	0·72	0·56	0·10	10·90
,,	,,	121	9·25	12·68	7·42	11·64	24·71	3·59	0·73	7·15	1·30	Cu tr.	69·22	15·06	3·80	2·20	0·38	0·09	21·53
,,	,,	122	19·30	12·10	6·20	20·10	16·14	4·36	0·87	g. tr.	0·75	Cu tr.	60·52	12·55	2·40	3·00	1·91	0·32	20·18
,,	,,	123	13·00	9·50	9·50	16·40	22·06	0·97	1·05	2·63	0·98	Cu tr.	63·09	16·50	4·70	1·10	1·40	0·21	23·91
,,	,,	124	8·23	30·60	8·14	25·04	8·54	2·49	0·38	tr.	0·62	Cu tr.	75·81	10·00	1·25	3·49	0·70	0·52	15·96
,,	,,	125	13·60	33·30	9·50	18·98	13·98	3·00	tr.	tr.	1·04	Cu tr.	80·30	2·36	1·15	2·00	0·45	0·14	6·10
,,	,,	125a	23·40	9·62	8·15	12·75	22·20	4·15	0·75	0·90	0·14	Cu g. tr.	58·52	12·18	3·33	1·44	0·99	g. tr.	18·08
286	2335	75	4·70	3·24	2·30	13·88	3·62	11·56	2·62	53·12	0·75	Cu Ni Co tr.	91·09	1·35	0·50	1·70	0·51	0·15	4·21
,,	,,	126	8·70	17·10	2·50	24·00	27·40	4·37	0·87	0·70	1·36	Cu Ni g. tr. Co tr.	78·30	8·91	1·90	1·20	0·84	0·15	13·00
,,	,,	127	15·50	14·10	2·31	21·87	22·79	2·65	0·51	0·69	0·68	Cu Ni g. tr. Co tr.	65·60	14·30	1·60	2·20	0·50	0·30	18·90
,,	,,	128	11·35	9·50	1·63	16·48	38·15	5·01	0·94	g. tr.	3·26	Cu Ni g. tr. Co tr.	74·97	10·51	1·18	1·40	0·37	0·22	13·68
289	2550	129	13·80	8·90	2·50	19·79	32·02	3·08	0·58	0·40	1·87	Cu 0·31 Ni Co } 0·25.	69·70	12·60	1·66	1·20	0·78	0·26	16·50
293	2025	130	11·20	8·00	1·00	20·06	37·61	4·21	0·70	0·69	3·93	Cu Ni g. tr.	76·20	8·70	2·21	0·80	0·78	0·11	12·60
297	1775	131	11·30	10·20	0·50	28·48	30·77	6·36	0·87	g. tr.	4·39	Cu Ni Co sm. tr.	81·57	4·54	0·50	1·30	0·61	0·18	7·13
299	2160	132	11·80	7·00	0·70	6·08	55·67	5·57	0·58	tr.	1·90	Cu tr. Ni sm. tr.	77·50	7·10	2·30	0·70	0·49	0·11	10·70
,,	,,	133	10·00	9·00	0·30	14·00	46·89	2·57	0·58	tr.	4·16	Cu tr. Ni sm. tr.	77·50	8·40	2·60	0·70	0·51	0·29	12·50
,,	,,	134	10·40	5·60	...	5·86	63·23	2·79	0·51	tr.	2·65	Cu tr. Ni sm. tr.	80·64	5·49	2·40	0·60	0·34	0·13	8·96
302	1450	135	11·40	11·40	0·55	39·75	22·27	4·08	1·27	g. tr.	3·48	Cu Ni sm. tr.	82·80	3·60	0·60	1·10	0·39	0·11	5·80

No. 75, bone nuclei.

The two analyses, Nos. 106 and 136, which could not well be tabulated with the rest, are given apart:—

STATION 252, 2740 fathoms (No. 106).

	Total water,		24·90
	Total carbonic acid,		0·38
	Total phosphoric acid extractable by HCl,		0·07
a. In Acetic Acid Extract.	Lime,		0·45
	Magnesia,		0·36
	Soda,		0·60
b. In Hydrochloric Acid Extract from Acetic Acid Residue.	Silica,		7·47
	Lead,	0·01	0·93
	Copper,	0·272	
	Cobalt,	0·25	
	Nickel,	0·40	
	Manganous oxide,		19·39
	Loose oxygen,		3·95
	Lime,		1·33
	Magnesia,		1·42
	Alkalies,		0·34
	Alumina,		3·03
	Ferric oxide,		16·20
c. In Sulphuric Acid Extract from Hydrochloric Acid Residue.	Alumina and ferric oxide,		1·62
	Silica,		0·83
d. Ultimate Residue.	Silicates and Silica,		14·91
			98·18

STATION 276, 2350 fathoms (No. 136).

Water,	9·51
Silica,	19·34
Lime,	3·19
Alumina,	6·36
Ferric oxide,	26·70
Magnesia,	1·79
Manganous oxide,	26·46
Nickel oxide,	1·82
Oxygen,	6·31
	101·48

The analyses Nos. 106 and 136 were undertaken with the view of determining the degree of oxidation of the manganese in the nodules. The results of Dittmar's experiments show that the quantity of peroxide-oxygen in the samples examined by him is slightly greater than what would be required by the assumption that the manganese exists in the state of binoxide.[1] Buchanan arrived at similar results from his analyses of some nodules.[2] We obtained the same result in analysing a nodule from Station 276, 2350 fathoms.[3] In this case we have been able to determine that the oxidation and hydration of the manganese answers approximately to $MnO_2 + \frac{1}{2}H_2O$, and that this hydrated oxide is united with limonite $(2Fe_2O_3 + 3H_2O)$, 26·7 per cent. The estimation of peroxide-oxygen was also made by Dr Gibson in nodules from Station 285, 2375 fathoms; the quantity found by him showed that barely all the manganese might exist as peroxide, and he points out that the cobalt, nickel, and thallium, present in the nodules, may also exist as peroxides, and thus account for the excess of oxygen.[4]

We thus arrive at the conclusion that these nodules of iron and manganese must be classed along with the impure variety of manganese known as wad or bog manganese ore. Under this name are included the manganese ores occurring in amorphous and reniform masses, made up, in addition to manganese, largely of a mixture of limonite and sandy materials, together with small percentages of cobalt, nickel, copper, and other substances. They are related to psilomelane under the formula $ROMnO_2 + H_2O$, but are mixtures of different oxides and cannot be considered distinct mineral species. In continental rocks wad or bog manganese occurs often as a deposit formed under water, and has originated from the decomposition of other manganese ores, principally manganese carbonates.

[1] See Analysis No. 106, App. III.
[2] *Proc. Roy. Soc. Edin.*, vol. ix. p. 287, 1877.
[3] See Analysis No. 136, App. III.
[4] See Appendix II.

Origin of the Manganese and Manganese Nodules.—The source of the manganese, and the mode of formation of the ferro-manganic concretions in marine deposits, have been the subjects of numerous publications.

In 1877 Murray[1] referred to the association of manganese with abundance of basic volcanic debris at the bottom of the ocean, and attributed the origin of the manganese nodules to the oxidation of the carbonate of manganese arising from the decomposition of manganiferous rocks, and its subsequent deposition in concretionary form.

In 1878 Gümbel[2] analysed some nodules sent to him by Willemoes-Suhm, a distinguished naturalist of the Challenger Expedition, who died at sea. He recalls that Forchhammer had made known the presence of manganese in sea-water, and that Bischof had shown the presence of the same substance in the ashes of *Zostera maritima*. But he does not admit the concentration of manganese under the influence of organisms, because it is dissolved in sea-water in such small quantity, and because the manganese is found in great abundance over a large area of the sea-bed. He refers the formation of the nodules to the influence of submarine springs holding manganese in solution, which is precipitated on contact with the sea-water. Agglomerates of a rounded form are thus produced by repeated turnings and rollings in the clay and water.

In 1881 Buchanan suggested that the manganese nodules originated through the intervention of organic substances, which changed to sulphides the sulphates of the sea-water, thus causing the formation of sulphides of iron and manganese, these becoming subsequently oxidised. Recently in 1890 he repeated this view.[3]

In 1882 Boussingault[4] discussed the formation of coatings of manganese in various regions, due to the presence of water charged with compounds of this element. He rejects the views of Buchanan and Gümbel as insufficient to explain the facts, and holds that the submarine concretions and manganiferous coatings are derived from the carbonates.

In 1883 Dieulafait[5] rested an explanation on the fact that sea-water collected between New York and Marseilles, as well as in the Red Sea and Indian Ocean, deposited in the

[1] *Proc. Roy. Soc. Edin.*, vol. ix. pp. 255–258, 1877; also *Proc. Roy. Soc.*, vol. xxiv. p. 529, 1876.

[2] Gümbel, "Die am Grunde des Meeres vorkommenden Manganknollen," *Sitzb. d. k. bayer. Akad. d. Wiss.*, Math.-phys. Cl., 1878, ii. pp. 189–209; also *Neues Jahrb. f. Min.*, &c., 1878, p. 869. See also: ıe mineralogische-geologische Beschaffenheit der auf der Forschungsreise S.M.S. 'Gazelle' gesammelten Meeresgrund-Ablagerungen," pp. 33–36, Berlin (no date).

[3] *Brit. Ass. Report* for 1881, pp. 583–4; *Proc. Roy. Soc. Edin.*, vol. xviii. pp. 17–39. With reference to this view it may be stated that in our experiments at the Scottish Marine Station it was found that manganese dioxide, when exposed to the action of sulphuretted hydrogen or alkaline or earthy sulphides, becomes reduced to a lower oxide; this reaction takes place when the manganese nodules themselves are so exposed. For example, powdered manganese nodules were introduced into sea-water, along with decomposing mussel-flesh; in a few days the sulphates present in the sea-water had been reduced to sulphides, which firstly altered the manganese peroxide to protoxide, which, being soluble in the carbonic acid (the product of the oxidation of the organic matter), remained as soluble bicarbonate of manganese in the sea-water, while the iron sesquioxide present in the nodules was thrown down as insoluble sulphide. It does not therefore seem possible that the nodules can be formed in the way indicated by Buchanan (Murray and Irvine).

[4] "Sur l'apparition du manganèse a la surface des roches," *Annales de Chimie et de Physique*, 5th ser. tom. xxvii. pp. 289–311, 1882.

[5] "Le manganèse dans les eaux de mer actuelles et dans certains de leurs dépôts; conséquences relatives à la craie blanche de la période secondaire," *Comptes Rendus*, tom. xcvi. p 718, 1883.

bottles a residue rich in manganese. He argues that the manganese exists in the water in the form of carbonate, and that at the surface gaseous exchanges take place transforming the carbonate into oxide, which falls to the bottom of the sea where it takes a concretionary form.[1]

In 1891 Irvine and Gibson[2] pointed out that sulphide of manganese could not be formed in the manner maintained by Buchanan, as it is readily decomposed by the action of carbonic acid, whether free or loosely combined as in the bicarbonates of sea-water, carbonate of manganese being formed, which would go into solution as bicarbonate of manganese.

These various opinions as to the mode of origin of manganese nodules may be summarised as follows :—

1. The manganese of the nodules is chiefly derived from the decomposition of the more basic volcanic rocks and minerals with which the nodules are nearly always associated in deep-sea deposits. The manganese and iron of these rocks and minerals are at first transformed into carbonates, and subsequently into oxides, which, on depositing from solution in the watery ooze, take a concretionary form around various kinds of nuclei (Murray).[3]
2. They are formed under the reducing influence of organic matters on the sulphates of sea-water, sulphides being produced and subsequently oxidised (Buchanan).
3. They arise from the precipitation of manganese contained in the waters of submarine springs at the bottom of the ocean (Gümbel).
4. They are formed from the compounds of manganese dissolved in sea-water in the form of bicarbonates, and transformed at the surface of the sea into oxides, which are precipitated in a permanent form on the bottom of the ocean (Boussingault, Dieulafait).

Without discussing these diverse opinions it may be stated that we accept the

[1] We have been unable, in all our attempts, at the laboratory of the Scottish Marine Station at Granton, to determine even approximately the amount of manganese present in solution in surface waters from the Atlantic, Mediterranean, Red Sea, and Indian Ocean. Nor have we been able to detect the presence of manganese in the boiler deposits of several ocean-going steamers; we have detected carbonate of manganese in the muds of the Clyde sea-area (Murray and Irvine).

[2] "Manganese Deposits in Marine Muds," *Proc. Roy. Soc. Edin.*, vol. xviii. pp. 54–59. Mr Irvine and Dr Gibson say:—"From the behaviour of manganese, we have come to the conclusion that the formation of sulphide of manganese cannot be a result of the animal life, or the decomposition of animal matter at the sea-bottom, as supposed by Buchanan, inasmuch as sea-water containing excess of carbonic acid must be always present. Buchanan does not give any evidence whatever to show that sulphide of manganese is formed, but appears to rely upon the supposed analogy in the behaviour of iron and manganese. Under conditions such as those referred to by him, sulphide of iron is necessarily formed. Unlike sulphide of manganese, sulphide of iron is readily formed in the presence of sea-water, whether mixed with carbonate of lime or not, and solutions of carbonic acid or bicarbonates do not decompose it or prevent its formation. Thus in all cases where, through the life processes of animals, sulphide of iron is formed as a result of the reduction of sulphates the excess of carbonic acid necessarily formed at the same time must prevent the formation of sulphide of manganese. This holds equally in the case of the decomposition of the dead bodies of animals at the sea-bottom."

[3] While admitting that a part of the manganese accumulated at the bottom of the ocean may be derived from the decomposition of volcanic rocks, in the manner described above (No. 1), it appears to me that the greater part must have been derived from the manganese in solution in the sea-water (A. Renard).

first interpretation, and we shall endeavour to show that this view accords best with all that is known with respect to the distribution and conditions under which these ferro-manganic concretions are found at the bottom of the ocean.

It may be accepted as a fact that all the hydrated oxides of manganese found at the surface of the globe as coatings, concretions, or depositions, as well as the greater part of the hydrated oxide of iron, have their original source in the decomposition of the crystalline rocks containing these two metals in the form of silicates or anhydrous oxides. This decomposition takes place generally under the action of water, almost always containing carbonic acid. It is not necessary to insist upon the wide distribution of iron in volcanic rocks; manganese is rarer in these rocks, but is found as a constituent of pyroxenic, amphibolic, and peridotic minerals, and also of some varieties of magnetic and titanic iron, which are all so abundantly distributed on the bottom of the sea.

It is well known that, under the influence of water charged with carbonic acid, such silicates are decomposed at ordinary temperatures, and that the contained protoxides of iron and manganese are transformed into soluble bicarbonates, leaving a residue in which the hydrated silicate of alumina plays a large part. As soon as the loosely-combined carbonic acid is given off from the bicarbonates, the carbonates are precipitated and rapidly absorb oxygen, becoming hydrates corresponding to higher oxides of the metals, the remaining carbonic acid being of course set free. The metals are now in the form of compounds which are insoluble in water. Such is the order in which the formation of manganiferous and ferruginous minerals takes place on land surfaces, forming coatings, concretions, and dendrites on ancient and recent and other eruptive rocks and minerals.

In the case of the manganese deposits of the deep sea, there are many indications that an identical interpretation of the phenomena may be given. It may be granted that the manganese in solution in the superficial layers and in the whole mass of the ocean might contribute a small part to the deposits of great depths, still the great bulk of the oxides of manganese in these deposits has evidently had another origin. The greater part of the manganese and iron of these deposits almost certainly comes directly, along with clay, from the alteration of the manganese and iron-bearing silicates scattered over the bed of the ocean, and especially from those of volcanic origin. In describing the rocks and mineral particles, and in speaking of the formation of clay, we have shown that the alteration which these substances undergo in sea-water may be compared in all respects with the general processes just indicated. We have laid special stress on the occurrence in the deposits of volcanic materials, generally in a vitreous condition and of a spongy nature, or in microscopic fragments. On the other hand, we have shown that nearly all these rocks and minerals are decomposed or in process of alteration, and that they nearly all contain protoxides of iron and manganese combined with silicic acid, as for instance in augites, hornblendes, magnetite, and the easily alterable basic volcanic glasses. It is known besides that sea-water contains free or loosely-combined carbonic acid, furnished by the decomposition of organic substances, or augmented in certain cases by gaseous emanations from submarine volcanic centres. Here all the conditions are favourable for the formation of manganese nodules. In the plastic materials of the broth-like ooze or clay we may picture the reactions that take place. The fragments of rocks and minerals yield earthy and alkaline carbonates, which go into solution along with carbonates of the protoxides of iron and manganese. The carbonates of the protoxides are in turn decomposed, absorbing and combining with oxygen in solution in sea-water; they are precipitated as sesquioxide of iron and peroxide of manganese in the mud, clay, or ooze, whilst clay and precipitated silica represent the insoluble portion of the original mineral. The oozy surface layers of the deposit and the immediately superincumbent water must, from many indications, be regarded as the seat of these reactions.

At whatever point at the surface of the deposit a particle of peroxide of manganese be formed and deposited, this will gradually attract from solution all the manganese in the neighbourhood. It is well known that the higher oxides of iron and manganese possess in an eminent degree the property of taking a nodular or botryoidal form. Especially do they affect this concretionary and dendritic disposition when formed in a plastic or fluid medium, like the deep-sea deposits. In such a plastic mass precipitation commences generally around some solid substance; this first deposit initiates attractive molecular actions, collecting around itself substances of the same nature disseminated in solution in the water of the adjacent layers of the deposit. In this way have originated the nodules in the clays of geological formations, in particular the concretions of carbonate of iron in shales and septarian nodules in clays.

In the deep sea the points of attraction have been nuclei of various kinds, such as sharks' teeth, earbones of Cetaceans, Sponges, and volcanic fragments, as pointed out in the foregoing descriptions. Concretionary deposits of salts of manganese and iron have taken place around these centres in definite well-marked layers of different degrees of purity. There is no reason to suppose that, like, for example, the spherosiderites, the deep-sea nodules were deposited as carbonates and subsequently converted into oxides by pseudomorphism; according to our view the oxides have been formed from solution simultaneously with deposition.

As these concretionary deposits must necessarily in the process of formation embrace the surrounding argillaceous matter containing numerous organic and inorganic particles, it is evident that these substances have been inclosed in the body of the nodules with increase in size. The foreign materials thus mechanically inclosed during the growth of the nodules produce zones of a lighter colour, which alternate with darker ones where the manganese is purer and more compact. From the study of the zonary arrangement in the nodules, it becomes evident that the deposit of manganese is more rapid or more abundant at some periods than at others. The dendritic arrangement traversing the earthy zones, pointed out in the description of the microscopic structure, as well as the aspect of the demanganesed nodules, show, however, that the deposition of iron and manganese during the formation of the nodules has been continuous.

This variation in the abundance of manganese deposited at different times may be explained by the variable quantity of carbonic acid in the sea-water, or the new additions of volcanic materials. Everything seems to indicate that these concretions increase in size with extreme slowness, and during their formation the chemical conditions of the solvent may have undergone many changes. The emanations of carbonic acid from submarine volcanic regions may have varied in intensity, for it is known that such variations take place with terrestrial volcanoes, according to the phase of the phenomena and the distance from the centre of eruption, and in a few deep-sea waters the Challenger found a great excess of carbonic acid.

It has been shown that large numbers of the nodules have two surfaces, separated externally by a median line; the superior surface is relatively smooth, and evidently projected above the clay or ooze, while the inferior one being much rougher and covered with asperities was without doubt plunged in the deposit. The layers of water resting on the deposit must be regarded as almost stationary, while we know that oozy deposits have but little consistence for the depth of at least 6 or 12 inches below the surface. There is a large body of evidence to show that it is in these conditions that the reactions resulting in the formation of manganese nodules have taken place.

In certain geological formations phenomena in every way similar to those taking place in the deep sea are observed; the concretionary substances are observed to have been eliminated from the mass of the rock, and to have accumulated in certain points in the form of nodules. The concentration of silica in the flints in limestones and chalk might be cited as an example. At Station 252 there is a parallel example in the deep sea; here there was a remarkable haul of manganese nodules containing between 20 and 30 per cent. of manganese peroxide, while the light coloured Red Clay in which they were imbedded contained only a trace of this substance, the oxide being entirely concentrated in the nodules. Where manganese nodules occur in greatest abundance, however, the clays are generally of a chocolate colour due to the presence of immense numbers of minute brown grains of manganese, which serve as a pigment to the deposit.

When we turn to a consideration of the remarkable localisation of the manganese in certain regions of the ocean, and of the altered volcanic materials which there accompany the nodules, facts are met with which throw a stronger light on their mode of formation as well as on the source of the manganese. Should it be admitted, for instance, that the manganese comes from the surface where the dissolved carbonates would be, by elimination of the carbonic acid, transformed into oxides and precipitated to the bottom of the sea there to accumulate, this gives no explanation of the geographical distribution, nor of the mineralogical associations of the nodules at the points where they are most abundant. We have repeatedly stated that the decomposition of volcanic products gives rise to clay, and these alterations should also give birth to the oxides of the manganese nodules, they being in a manner the complement to the formation of clay. These concretions are characteristic of the great oceanic depths, and especially of the red clay areas. Their peculiar form, their nuclei, their mineralogical and organic associations, distinguish them from the similar hydrated minerals of manganese and iron found in shallow water or on the continents, from which they differ also by the small quantity of barium they contain. It is with difficulty that traces of barium can be detected in these oceanic nodules, while it is well known that this is a frequent, sometimes abundant, constituent in terrestrial manganiferous minerals, and even in some nodules from terrigenous deposits.[1] The manganiferous minerals containing baryta must have been derived directly from the action of water on the ancient series of rocks, and this leads in another direction to the same conclusions as to the origin of the deep-sea nodules, for recent volcanic rocks contain little, if any, barium.[2]

In addition to the silicates, and in certain cases organic remains, some at least of the manganese nodules contain many relatively rare elements, such as nickel, cobalt, copper, zinc, lead, thallium, vanadium, as will be seen by reference to Dr Gibson's analysis. The source of these elements must be found in the volcanic rocks undergoing decomposition. They may exist originally either in the silicates or in the magnetic and titanic iron, and, after the alteration of these minerals, may be for the most part precipitated in the form of oxide in the presence of the alkaline sea-waters.

At first sight it may appear strange that these masses of manganese in the form of nodules should be derived from the decomposition of eruptive rocks and minerals, but care should be taken not to form an exaggerated idea of the quantity of manganese present in the deposit relatively to the other substances. In the nodules themselves the percentage of iron often exceeds that of manganese, and in the surrounding deposit the iron is in much greater abundance, indeed, there may be only a trace of manganese. Again, the quantity of clay, both in the nodules and in the deposit, is always very large, sometimes approaching to one-half of the whole.

It must not be forgotten that while the sea-water may dissolve a large number of other substances, and carry them away in solution, the higher oxides of these metals remain insoluble and accumulate in the deposits, for they do not enter in notable proportion into organic circulation; in consequence of their stability they do not undergo any alteration from the various solvents contained in the sea-water with which they are bathed.

Among the considerations which go to show that manganese nodules increase at a very slow rate, the following may be mentioned:—

[1] Commander A. Carpenter dredged off Colombo in the Indian Ocean, in 675 fathoms, small round nodules containing *Globigerina* shells, and 75 per cent. of sulphate of barium (see E. J. Jones, "On some Nodular Stones obtained by trawling off Colombo in 675 fathoms of water," *Journ. Asiatic Soc. of Bengal*, vol. lvi. pp. 209–212, 1887).

[2] But the reason of the absence or rarity of barium may not improbably be that the barium is converted by sea-water into sulphate, which would have no tendency to precipitate along with manganese.

1. The organisms which in many instances cover them continue to live even while the depositions are taking place. This shows evidently that in the ordinary progress of the phenomena only minute particles of the substance are deposited during the life-period of these animals.
2. All the pelagic deposits, in which these nodules are found in abundance, must increase much more slowly than the terrigenous deposits, and in all those pelagic deposits, like the Red Clays, where the calcareous organisms are wholly removed in solution, the rate of deposition must be exceedingly slow.
3. The highly-altered state of the basic and other fragments of volcanic glass shows that they must have lain a long time in the surface layers of the deposit exposed to the action of sea-water.
4. The greater abundance of sharks' teeth, bones of Cetaceans, crystals of phillipsite, cosmic spherules, in the areas where nodules are numerous, than in other deposits, points also to a slow rate of accumulation, for, *a priori*, there is no reason why these should be more abundant in these manganese regions except the fact that they are not covered over and masked by such an abundance of foreign materials as at other points of the deep sea. That some of the sharks' teeth, for instance, are covered by deep layers of manganese, while others lying alongside of them in the deposit have little or no manganese, indicates that some have lain on the bottom for a much longer time than others, and that there has been but little increase in the thickness of the deposit during the interval.
5. We have pointed out that nodules sometimes occur in Globigerina Oozes, as for instance at Station 297, but here they are not accompanied in the dredgings and trawlings by sharks' teeth, earbones of whales, zeolites, nor cosmic spherules, apparently from the more rapid accumulation due to the presence of the Foraminifera. In this and other deposits there are, however, many fragments of altered basic volcanic glass, which indicate proximity to submarine eruptions.

III. Glauconite.

Among the minerals of modern marine deposits, glauconite is one of the most interesting as well as one of the most widely distributed. This interest arises from the facts that it is one of the restricted number of silicates formed at the present day on the sea-bed, and that it is not universally distributed over the floor of the ocean, but is limited to the deposits forming along continental shores. The glauconitic grains found in marine deposits present, moreover, both in form and size, a complete analogy with those found at different horizons in the geological series of rocks, from the Cambrian period up to the most recent Tertiary layers. We are thus dealing with a mineral species that plays a very considerable role both in space and in time, concerning whose mode of formation there has been much controversy, without any very definite solution being arrived at. We propose, in the first instance, to point out its mode of occurrence in modern seas, its essential characters, its geographical and bathymetrical distribution, its organic and mineral associations, and thereafter to discuss the various hypotheses that have been advanced concerning its origin in modern seas and in geological formations.

Mode of Occurrence and Macroscopic Characters.—Among the collections made by the U.S.S. "Tuscarora" along the coast of California are several specimens of dark green or black sands composed almost entirely of grains of glauconite, a little less than a millimetre in diameter. There were a few Foraminifera and mineral particles other than glauconite, of about the same dimensions, mixed with these dark green grains. If the samples which we have examined were in the same condition as when procured from the bottom of the sea, the deposits along this coast in depths of from 100 to 300 fathoms are the purest glauconitic sands that have hitherto been discovered in existing seas. The Challenger collections, and other collections examined by us from different parts of the world, have not yielded glauconitic sands so free from admixture with other materials as those among the "Tuscarora" soundings. The most typical glauconitic sands of the Challenger collections contain from 40 to 50 per cent. of Foraminiferous and other carbonate of lime shells, together with the remains of siliceous organisms. As a rule the glauconitic particles in a sample of Green Sand or Mud are not very apparent till after all the carbonate of lime shells have been removed by means of dilute acid; the residue left after such treatment is usually of a mottled green or brown colour, and consists of numerous dark green grains of glauconite, together with the casts of Foraminifera and other calcareous organisms in a paler green, or even brown, colour. This appearance is represented in Pl. XXIV. fig. 1, in the residue of a Green Sand from 150 fathoms, off the Cape of Good Hope; and again in fig. 2 of the same plate, in the residue of a Green Mud from 410 fathoms, off the coast of Australia. In fig. 3 of the same plate, the residue of a Coral Sand is represented, from off the Great Barrier Reef of Australia, near Raine Island, and it will be observed that in this deposit the residue is for the most part made up of the brown-coloured casts of Foraminifera, only a few of them having a greenish tint, while typical glauconitic grains are absent.

The individual grains of glauconite that occur in marine deposits rarely if ever exceed 1 mm. in diameter, although they may occasionally be agglomerated into nodules cemented by a phosphatic substance several centimetres in diameter, as represented in Pl. XX. fig. 1. The typical grains are always rounded, often mammillated, hard, black or dark green, some of the grains being completely covered with a pale green pellicle; their surface is sometimes dull and sometimes shining. They have occasionally the vague form and appearance of Foraminifera and other organisms; mixed with the typical grains, however, as may be seen by reference to the figures on Pl. XXIV., are numerous pale green particles which bear distinctly the impress of the calcareous shells. Many, indeed, are internal casts reproducing with great distinctness and sharpness the form of the chambers in which the glauconite has been developed. Some of the casts have a brown colour presenting few of the characters of typical glauconite, and it will be seen that these pale-coloured or brownish casts predominate in the residue represented in Pl. XXIV. fig. 3. When the residue of a Green Sand is shaken up with abundance of water, it may be separated by decantation into three distinct portions, the one composed mostly of the dark green grains of typical glauconite,[1] the second in which the pale green casts predominate,[2] and the third consisting for the most part of the white, pale grey, yellow, and brownish casts.[3]

When a sample of a typical Green Mud is hardened and cut into a thin microscopic section, it will be observed that a large number of the chambers of the Foraminifera and the areolar spaces in Echinoderm spines and other calcareous structures are empty, while others are partially filled with a small quantity of a brownish semi-transparent substance. This brownish material may fill one or two of the chambers, or may simply coat their internal surface; in this way we may pass from shells only partially to those completely filled. It may frequently be observed that some of the smaller chambers have a distinctly green colour, while the larger ones are yellow or brownish; other shells, again, are filled with a dark green substance, which presents all the characters of typical glauconite. A transition may thus be traced from the pale brown substance lining some of the chambers of the Foraminifera to the pale green substance that forms a complete cast; this again passes into the dark green glauconitic grains. No external casts formed of matter deposited on the outside of the Foraminiferous shells have ever been observed, although exceptionally some shells presented a greenish coating of apparently glauconitic matter. Very frequently the reddish imperfect casts of the Foraminifera gave the reaction of phosphate of lime. In Pl. XXV. numerous particles of glauconite are represented as they appear within the shells and in an isolated condition; in many instances the shell appears to have been broken or thrown off by the continued growth of the internal glauconitic nucleus, the further growth eventually transforming the internal cast into an irregular glauconitic grain with a mammillated and furrowed surface; the figures on this plate show all the transitions between these phases in the formation of glauconite. In many samples of Green Muds and Sands are numerous minute particles about the same size as the glauconitic grains, and having the same furrowed and mammillated surface, of a brownish or green colour, but these from their internal structure are apparently highly altered grains of crystalline, schisto-crystalline, and other rocks (see Pl. XXV. figs. 2, 3). Finally, it may be added, there is often associated with the glauconite in the Green Muds from the shallower depths, an amorphous brownish green substance which either is,

[1] See Analyses 86 and 87. [2] See Analysis 85. [3] See Analysis 84.

or is associated with, organic matter, for on heating on a platinum plate it burns, becomes black, and finally assumes the brown colour of oxide of iron.

Microscopic Characters.—The thin slides of glauconite become transparent during the polishing process, and have a beautiful green tint; they present no special structure, being generally pretty homogeneous, except in the case of inclusions of foreign particles. Sometimes on the edges the colour is a little deeper, but this is an exception, and is possibly an indication of the commencement of alteration. The normal green tint may also, in cases of decomposition, pass into reddish or brownish, which is seen as a zone on the edges or even throughout the whole extent of the grain in section. We have never been able to observe in glauconite a sensible dicroscopism, and, as already stated, this homogeneous mass does not show any structure with ordinary light. In Pl. XXV. fig. 1 some sections of glauconite are represented as seen in polarised light. Between crossed nicols it presents a characteristic aspect; it never extinguishes at one time throughout the whole extent of the observed section. It shows aggregate polarisation, which presents itself in the following manner. The glauconitic particles have indefinite contours, and appear dotted with little points united the one to the other, and polarising with a bluish green tint. These deep-coloured points are detached from a base generally yellow or yellowish green in colour. The dotted parts of a bluish green colour more or less deep form a rather close network, which is very vague as to its contours; this network is seen in characteristic form in the two circular sections in Pl. XXV. fig. 1. The outlines of the sections of glauconite are not clearly defined, and the relief is feeble. Glauconite is never seen with a zonary structure, except in cases where alteration has commenced or where it shows, as previously mentioned, a border of a deeper colour following the external contours; nor does it present a fibro-radiate or a concretionary structure. Sometimes the microscope shows vaguely that around the grains there is a colourless zone of slight thickness, in which the arms of the cross of spherolithic concretions may be observed. Microscopic examination appears to show that the substance of glauconite itself is quite homogeneous. Sometimes, however, and especially when this mineral is enclosed in Foraminiferous shells, it includes, in the largest or terminal chamber, mineral particles similar to those in the sediment in which it is formed; among these particles the most frequent are quartz and magnetite, the latter of which may be extracted by the magnet. There may also be seen a darkish powder, the feeble yellowish reflections of which might well indicate pyrites. In some sections the form of some of the chambers of the shells of Foraminifera appears to be vaguely outlined. When the grains have undergone alteration, these sections not only show a brownish or reddish tint, from the presence of hydrate of iron, but this alteration is frequently accompanied by cracks traversing the glauconite in many directions. The sections of the glauconitic casts appear in the preparations with all the characteristic contours of the organisms in which they have been moulded, and the microscopic details apply equally to these, at least when they have taken on the characteristic green colour of glauconite.

Geographical and Bathymetrical Distribution.—Bailey in 1856 and subsequently Pourtalès, during an examination of samples procured off the Atlantic coast of North America, appear to have been the first to call attention to the occurrence of glauconite in modern marine deposits, Ehrenberg having previously pointed out its existence in the chambers of Foraminifera in many geological formations. During the last thirty years the examination of samples of marine deposits, from nearly all parts of the great ocean basins, has yielded a large amount of information with reference to the distribution of glauconite and glauconitic casts over the floor of the ocean. The Tables of Chapter II. show that in the Challenger samples, glauconite was almost exclusively limited to terrigenous deposits in more or less close proximity to the continental masses of land, while it was relatively rare or wholly absent from pelagic deposits situated towards the centres of the great ocean basins. It is characteristic of, and occasionally very abundant in, Green Muds and Sands, and is almost always present, though in smaller quantity, in Blue Muds. It is also present in samples of Globigerina Ooze situated at no great distance from the continents, in which the debris of continental land is relatively abundant. It may even be recognised in samples of Red Clay and other truly pelagic deposits, if these be in positions to which continental debris is transported by floating ice, or to which continental dusts are transported by winds. It is doubtful if any typical examples of glauconite have been discovered in the Volcanic Muds and Sands surrounding oceanic islands, although a few pale-coloured casts have been noticed in the muds off the Crozets and the New Hebrides. Glauconite is also absent from Coral Muds and Sands, except when these are formed off continental shores. Where the detrital matters from rivers are exceedingly abundant, and where there is apparently a rapid accumulation, glauconite, though present, is relatively rare; on the other hand, along high and bold coasts where no rivers enter the sea, and where accumulation is apparently less rapid, glauconite appears in its most typical form and greatest abundance.

The Challenger met with glauconite in greater or less abundance off the coast of Portugal, off the west coast of Africa, off the east coast of North America, the Cape of Good Hope, the Antarctic Continent, the coasts of Australia and New Zealand, the coasts of the Philippines, China, and Japan, and the west coast of South America. It has been found in the Mediterranean, off the north coast of Scotland, off the west coast of North America, off the east coast of Africa, and in many other regions, by other expeditions. During the cruise of the Challenger, glauconite was not recognised in any of the deposits after leaving the coast of Japan till the expedition neared the coast of Chili, thus presenting an excellent illustration, in the case of the Pacific, in support of the general statement that glauconite is not at the present time in process of formation in the central portions of the great ocean basins, while it is more or less characteristic of all the deposits now being laid down around continental shores.

With reference to its bathymetrical distribution, it appears to be most abundant about the lower limits of wave, tidal, and current action, or in other words, in the neighbourhood of what we have termed the mud-line surrounding continental shores. In the shallower depths beyond this line, that is to say, in depths of about 200 and 300 fathoms, the typical glauconitic grains are more abundant than in deeper water, but glauconitic casts may be met with in deposits in depths of over 2000 fathoms. No typical glauconitic sands have, so far as we know, been recorded in process of formation in the littoral or sub-littoral zones.

Organic and Mineral Associations.—From what has been said above as to the geographical and bathymetrical distribution of glauconite, it is at once evident that the mineral species associated with glauconite in marine deposits must be those which we have mentioned as more or less characteristic of terrigenous deposits, in contradistinction to those that are the chief mineral constituents of pelagic deposits. It is, further, associated with the minuter fragments of the rocks and minerals of continental land, for, as we have seen, its greatest development takes place just beyond the limit of wave and current action, or, in other words, where the fine muddy particles commence to make up a considerable portion of the deposits. It has, consequently, a restricted development in the shallow-water and littoral zones, where the coarser fragments prevail, and are continually subject to disintegration and transport by the mechanical forces of the sea. Glauconite is almost always accompanied by quartz, orthoclase often kaolinised, white mica, plagioclase, hornblende, magnetite, garnet, epidote, tourmaline, zircon, and fragments of ancient rocks, such as gneiss, mica-schists, chloritic rocks, granite, diabase, &c. In addition to these minerals there seems always to be associated with glauconite, in modern deposits, a considerable quantity of organic matter, often apparently of a vegetable nature. The glauconitic grains frequently contain traces of phosphate of lime, and make up a considerable part of some phosphatic nodules, so that phosphate of lime may be said to be one of its constant accompaniments. Volcanic rocks and minerals are, of course, frequently found in the same deposits as glauconite, for we have seen that they are universally distributed over the floor of the ocean; but as glauconite never occurs, or at least only exceptionally or doubtfully, in true Volcanic Muds and Sands, these minerals and rocks cannot be regarded as constant associates of glauconite.

From the fact that glauconite is almost always associated with Foraminifera and other calcareous organisms, and, indeed, originates in the hollow chambers and areolar spaces of these organic structures, these might be considered as essential to its occurrence, still it should be pointed out that there is not a trace of glauconite in many Coral Muds and Sands and in many Pteropod and Globigerina Oozes. When it is found in these calcareous deposits it is always possible to detect a considerable quantity of mineral particles belonging to the ancient or continental rocks in the residue after the removal of the carbonate of lime. In like manner, when glauconite is found in a Red Clay or Diatom Ooze, traces of continental debris can always be detected during the microscopical examination of the mineral constituents. The Red Clays, for instance, off the west coast of Africa and the coast of Australia, and towards the polar regions, contain apparently wind-borne or ice-borne particles of quartz, orthoclase, white mica, epidote, zircon, and fragments of gneissic and granitic rocks; and it may be urged either that the glauconite has been transported to these deposits at the same time or has been formed in consequence of the association with the above minerals. The view that it has been formed *in situ* is probably the correct one, for we have seen that it is thus formed in shallower water deposits like the Green Sands, where its associations are much more distinctly marked and its progressive development more easily traced. Finally, we may again point out that glauconite is now being formed in those marine deposits in more or less close proximity to continental shores, where the debris of ancient rocks makes up a large part of the deposit, and especially in those regions where this debris has been for a long time exposed to the action of sea-water, and has consequently undergone profound alteration.

When describing the Red Muds off the coast of Brazil, it was stated that glauconite and glauconitic casts appear to be completely absent from these deposits. These Red Muds differ from the vast majority of terrigenous deposits in the large quantity of ochreous materials borne to these regions by the rivers of South America. In the deposits in the Yellow Sea glauconite would also seem to be absent from similar Red Muds. In these positions all the conditions for the formation of glauconite are, so far as we can judge, present, with the exception that the iron is all in a higher state of oxidation than in the Green and Blue Muds; but in what way this can prevent the formation of glauconite is difficult to explain satisfactorily.

Geological Distribution.—The geographical and bathymetrical distribution, as well as the mineralogical associations of glauconite above pointed out, become especially interesting and instructive when we recall the analogies which they present to what has taken place in past geological times. It has already been stated that glauconite is one of the minerals most widely distributed in sedimentary rocks. It is found in the primary formations of Russia and Sweden among sands and gravels, in the Cambrian sandstone of North America, in the Quebec group of Canada, and in the coarse Silurian sands of Bohemia. In the secondary formations its presence is more pronounced—for example, in the Lias, and especially in the middle and upper layers of the Jurassic system in Russia, in Franconia, in Suabia, and in England. It has a still greater development in the sands, marls, and chalks of the Cretaceous formation; it will suffice to recall the glauconitic rocks of the Neocomian, of the Gault, and of the Cenomanian in various regions, such as the glauconitic marls of France, Germany, England, and several parts of

North America. This abundance of glauconite is continued into the Tertiary formations, from the lowest up to the highest horizons of the series.

From this rapid enumeration it will be seen that glauconite traverses the whole of the geological periods, and its formation is continued in modern deposits along many continental shores explored by the Challenger and other expeditions. A remarkable analogy is also found between the size of the grains now formed in marine deposits and that of the grains found in the geological series of rocks. It has been stated that some of the grains in the primary formations are of very large size—several centimetres in diameter. All the specimens of this kind, however, which we have been able to examine are found, on microscopic examination, to be made up of an agglomeration of grains rarely exceeding a few millimetres in diameter, and therefore closely resembling the glauconitic nodules or aggregations dredged by the Challenger on the Agulhas Bank off the Cape of Good Hope, in depths of 100 and 150 fathoms.

It is also important here to point out the association that exists in geological formations between glauconitic and sandy calcareous deposits, and the absence or rarity of glauconite in formations of pure chalk, or in nearly pure carbonate of lime deposits; glauconite may therefore be regarded as having been formed either in deep water not far from the coasts or in shallow water at parts of the coast where no large quantity of continental debris was deposited. This fact is significant, as it appears to prove the coast and subcoast character of these glauconitic deposits in past geological times, which consequently present a complete analogy with the glauconitic deposits of modern seas, both with respect to the conditions under which they were formed and their mineralogical composition. These analogies likewise prove the continuity of geological phenomena and the presence of nearly identical conditions in the sea during long periods in the history of the globe; they indicate that the presence of terrigenous matters, directly derived from the disintegration of continental land, is a necessary condition for the formation of glauconite, and this fact must be taken account of in any discussion bearing upon the origin of this mineral.

Chemical Composition and Mode of Formation.—While it must be admitted that we have arrived at certain definite and satisfactory conclusions as to the conditions under which glauconite is found in our present seas, as well as in geological formations, we are far from having at our disposal all the facts necessary for a complete explanation of its mode of origin. So many possible reactions may take place in the deposits being laid down in existing seas, that it is difficult to be certain that any one of them is necessarily the one which has been followed in the deposition of this silicate in the terrigenous deposits. The explanations that are given with reference to the formation of glauconite must then be more or less hypothetical; it is not to be wondered at that its origin has remained for a long time enigmatical, and that the researches of numerous mineralogists up to the present time have not led to any very definite results. The chemical analyses of glauconite have been very numerous; but, from the nature of the mineral and the peculiarities of its occurrence, it is impossible to be sure that the analyst has always been dealing with a pure substance; indeed, microscopic examination of samples that have been submitted to analysis shows that there is often an admixture of foreign mineral particles, and that the individual grains of glauconite in the sample do not always present uniform external characters; this in all probability accounts largely for the variable composition. The following analyses of glauconite formed in modern seas present in their principal features a great analogy with the composition of the same mineral in geological formations. Amongst the numerous analyses of glauconite that of a specimen of the chalk of New Jersey by Sterry Hunt[1] gives the closest approximation to the figures obtained in analysing what we consider typical modern glauconite (Station 164B, Nos. 86, 87). But a glance at the analyses shows how much this mineral may vary in composition, although the physical characters seem to be the same. These divergences are more marked when we compare the figures of the analyses of paler grains associated with the darker ones at the same station (No. 84 compared with Nos. 86 and 87). All that can be said is that the glauconite now forming on the bottom of the sea is, like the glauconite of geological formations, a hydrous silicate of potash and of ferric oxide, containing always variable quantities of alumina, ferrous oxide, magnesia, and often lime. If we compare the figures of the two analyses with the mean composition of glauconite given by Haushofer,[2] we see that all the percentages, except those of silica and perhaps water, differ greatly from the figures given in our analyses. The analysis No. 88 resembles that of decomposed glauconite, and the composition of this specimen may be compared with that of the altered glauconite of Kressenberg, given by Haushofer[3]; the high percentages of peroxide of iron and water point to a decomposition of this mineral which has been transformed into limonite, as is often the case in glauconite from the geological strata, with loss of silicic acid and of potash, but this interpretation can hardly be given for this specimen, which consisted of casts from a Coral Sand off the Great Barrier Reef of Australia. There can be no doubt that glauconite is a mixture, and this fact not only renders it difficult to fix its constitution, but also renders difficult any interpretation of the mode of formation.

We give here the analyses of some specimens of glauconite collected during the expedition. The substance used for Analysis No. 84 contained 65 per cent. of white, pale grey, and some yellow casts, 20 per cent. of pale green casts, 11 per cent. of dark green casts, along with 4 per cent. of mineral particles and siliceous organisms. The substance used for Analysis No. 85 contained 15 per cent. of white, pale grey, and yellow casts, 35 per cent. of pale green casts, 45 per cent. of dark green particles, together with 5 per cent. of mineral particles and siliceous organisms. The substance used for Analysis No. 86 contained 10 per cent. of white, pale grey, and yellow casts, 25 per cent. of pale

[1] Sterry Hunt, Mineral Physiology and Physiography, p. 198, Boston, 1886.

[2] Haushofer, *Journal f. prakt. Chemie*, Bd. xcvii. pp. 353–364, and Bd. xcix. pp. 237–8, 1866.

[3] Haushofer, *loc. cit.*, Bd. xcvii. p. 358.

green casts, 60 per cent. of dark green casts, along with 5 per cent. of mineral particles and siliceous organisms. The substance used for Analysis No. 87 contained 30 per cent. of white, pale grey, and yellow casts, 40 per cent. of pale green casts, 20 per cent. of dark green casts, together with 10 per cent. of mineral particles and siliceous organisms. The substance used for Analysis No. 88 contained about 10 per cent. of mineral particles similar to those mentioned in the description of the deposit (see p. 93), in spite of every care to obtain the red-coloured casts as pure as possible.

Station.	Depth in Fathoms.	No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	H_2O	Total.
164B	410	84	56·62	12·54	15·63	1·18	trace	1·69	2·49	2·52	0·90	6·84	100·41
164B	410	85	50·85	8·92	24·40	1·66	trace	1·26	3·13	4·21	0·25	5·55	100·23
164B	410	86	51·80	8·67	24·21	1·54	trace	1·27	3·04	3·86	0·25	5·68	100·32
164B	410	87	55·17	8·12	21·59	1·95	trace	1·34	2·83	3·36	0·27	5·76	100·39
185B	155	88	27·74	13·02	39·93	1·76	trace	1·19	4·62	0·95	0·62	10·85	100·68

While, then, there is a certain amount of agreement as to the chemical composition of glauconite, there is a wide divergence of opinion as to the immediate conditions which determine the formation of this mineral at the sea-bottom. Two principal opinions have been expressed.[1] Before the time of Ehrenberg attention had not been called to the remarkable fact that the grains of glauconite sometimes carried the impress of the calcareous organisms in whose cavities they were moulded. He concluded that this mineral was always formed through the activity of the creatures whose impress he had discovered.[2] This opinion was disputed in 1860 by Reuss,[3] who believed that the grains of glauconite might be concretions, not moulds, formed outside of the Foraminiferous and other shells, although he admits that some glauconitic grains are internal casts.

From all that we have already stated in this chapter, it appears certain that glauconite is principally developed in the interior of Foraminiferous shells and other calcareous structures, and that all the transitions can be observed from chambers filled with a yellowish brown mass to grains that have almost completely lost the impress of the organisms in which they were formed. From this fact, as well as from direct observations of the various constituents of the deposits, it is uncertain, and indeed little probable, that there are any minute grains of glauconite formed in a free state in the mud. We are therefore inclined to regard glauconite as having its initial formation in the cavities of calcareous organisms, although we have admitted above that some grains, which might be

[1] For the various hypotheses as to the mode of formation of glauconite see Gümbel, "Über die Natur und Bildungsweise des Glaukonits," *Sitzungsb. d. k. Akad. München*, Bd. xvi. Math. Phys. Kl., pp. 417–449, 1886.

[2] Ehrenberg, "Ueber den Grünsand und seine Erläuterung des organischen Lebens," *Abh. d. k. Akad. Wiss. Berlin*, 1855, Phys. Abh., pp. 85–176.

[3] Reuss, "Einige Bemerkungen über den Grünsand," *Sitzungsb. d. k. Akad. Wiss. Wien*, Bd. xl. Naturw. Kl., pp. 167–172, 1860.

regarded as glauconite, appear to be highly altered fragments of ancient rocks, or coatings of this mineral on these rock fragments. It appears that the shells are broken by the swelling out or the growth of the glauconite, and that subsequently the isolated cast becomes the centre upon which new additions of the same substance take place, the grain enlarging and becoming rounded in a more or less irregular manner,[1] as in the case of concretionary substances like silica, for example, which forms moulds of fossils. We have already referred to the size of certain alleged grains of glauconite found in geological formations; even if it be admitted that these large-sized grains are single individuals, and not agglomerations of smaller grains, their occurrence might be explained by supposing them to have been formed in Gasteropods and other calcareous organisms larger than Foraminifera.[2]

All the probabilities appear, then, to be in favour of the opinion that this silicate is formed originally in the cavities of organisms, whose remains are deposited in the sediments of the sub-littoral and deeper zones of the sea. In the cavities and veins of rocks in process of decomposition, green substances are frequently deposited, which for a long time were confounded with glauconite. But chlorite and green earth, for example, which are formed in this way, are minerals widely different from glauconite, and their formation may be easily explained by taking into account the mineralogical and chemical changes going on in these rocks. The initial stages of the formation of glauconite in these shells are, in all probability, due to the action of organic matter, which incontestably influences the precipitation of some mineral substances. In this case it must be admitted that the organic matters, or the sarcode elements of the organisms fallen from the surface or living on the bottom, ought to remain in the interior of the shells, at least temporarily. After the death of the organisms their shells are slowly filled with the fine mud in which they are deposited. The existence of this organic matter in these cavities, and the absence of all other causes which might there induce the deposition of the silicates, in fact, the

[1] The increase by new additions of glauconitic material is indicated by the fact that in rare cases the glauconitic casts of Foraminifera shells are found entirely enveloped by subsequent depositions of that mineral. In such a case it must be admitted that after the glauconite has broken the chambers of the Foraminifera it has continued to play the role of centre of attraction, and that the same matter has been continually deposited around this nucleus, thus causing the primitive form of the cast to disappear.

[2] Gümbel, who does not admit that certain grains of glauconite have been moulds in organisms, because of their large size and regular form, without trace of organic impress, suggests the following interpretation:—He compares them with entooliths, and maintains that the gases disengaged by the decomposition of organic matters, contained in the sediments where glauconite is formed, play a role in the formation of these glauconitic granules. These gases are the hydrocarbons, carbonic acid, and hydrosulphuric acid, which form bubbles of different dimensions that remain a long time in the muddy deposits and attach themselves to the grains of sand or aggregates of the mud, grouping themselves in a varied manner. At the surface of these bubbles reactions take place, provoked by the action of the gas upon the bodies held in solution in the sea-water, and a deposit of these bodies takes place there; it is usually carbonate of lime and silica that are thus deposited, and in this case glauconite would form the crust around the bubble. If this crust be formed it will be filled by intussusception in the same solution that has given birth to the primordial glauconitic sphere. If they were bubbles of sulphuretted hydrogen, pyrites would be formed in them at the same time as the glauconite; if at the same time there were disengagement of hydrocarbons there would be formed in the presence of iron, magnetite (by reduction) similar to that found enclosed in the grains of glauconite (*loc. cit.*, pp. 435–439). We felt bound to notice these views, but everything connected with them appears very hypothetical.

constant association of these phenomena, appear to demonstrate the existence of a relation of cause and effect. Formerly the role of organic matter in the formation of glauconite was specified by saying that it determined a reduction of the iron to the state of protoxide, but this interpretation is not admissible at the present time, for we have seen by the analyses that iron exists in glauconite in the state of peroxide. It may be urged that an infiltration pure and simple of the solution which forms glauconite into the cavities of the organisms takes place, the same as in a geode. This solution, being attracted by the organic matter, may act upon the solid matters derived from the mud already enclosed in the cavities of the organisms. This, however, does not appear to be the most probable interpretation. In describing the microstructure of the glauconitic grains, it was pointed out that inclusions of mud, of quartziferous particles, grains of magnetite and other minerals, were sometimes observed, and that these probably pre-existed in the shells before the development of the glauconite. It would appear that these enclosed materials must have undergone with time a molecular modification, whose final term is seen in the typical dark green granules, presenting feeble double refraction and aggregate polarisation, and possessed of a greater hardness than the lighter coloured glauconitic casts of organisms, in which a more earthy nature may be observed. It is certain that very fine mud is washed into the *Globigerina* shells, and may penetrate through the foramina. If we admit that the organic matter enclosed in the shell, and in the mud itself, transforms the iron in the mud into sulphide, which may be oxidised into hydrate, sulphur being at the same time liberated, this sulphur would become oxidised into sulphuric acid, which would decompose the fine clay, setting free colloid silica, alumina being removed in solution; thus we have colloid silica and hydrated oxide of iron in a condition most suitable for their combination. To explain the presence of potash in this mineral, we must remember that, as we have shown when speaking of the formation of palagonite under the action of sea-water, there is always a tendency for potash to accumulate in the hydrated silicate formed in this way, and, as we have stated before, this potash must have been derived from the sea-water.

If we recall the observations with reference to the geographical distribution and mineralogical and lithological associations, it seems possible to suggest, with a considerable degree of certainty, the relative abundance of potash in the deposits where glauconite is forming. It was pointed out that glauconite was always associated with terrigenous minerals, and in particular with orthoclase more or less kaolinised and white mica, and with the debris of granite, gneiss, mica-schists, and other ancient rocks. We cannot fail to be struck with these relations, for it is just those minerals and rocks that must give birth by their decomposition to potassium, derived from the orthoclase and the white mica of the gneisses and the granites.[1] The minute particles of these rocks

[1] It has been shown in fact, by Guignet and Telles, that the water of the Bay of Rio Janeiro contains a large amount of potassium salts evidently due to the presence of ancient rocks in this bay (see *Comptes Rendus*, tom. lxxxiii. p. 919, 1876).

and minerals, which make up a large part of the muddy matters settling on the bottom beyond the mud-line around continental shores, would readily yield under the action of sea-water the chemical elements that are deposited in the form of glauconite in the chambers of Foraminifera and other calcareous organisms.

Other Casts of Foraminifera.—In the Tables of Chapter II. it will be observed that imperfect casts of Foraminifera are very frequently recorded in the residues after the removal of the Foraminifera by dilute acid. In the great majority of instances these are of a reddish or brownish colour, and appear to be formed of a substance which lined with a thin coating the internal chambers of the shells. They hold together with some tenacity in water, but immediately collapse when dried upon a platinum foil, and sometimes they become black or burn, leaving a small reddish residue. At other times phosphates can be detected in these imperfect casts. As a general rule, a few red-coloured more or less imperfect casts of the internal chambers of Foraminifera may be found in nearly all calcareous deposits, but internal casts are only present in abundance in those regions where glauconite is in process of formation, and have been fully referred to above.

At Station 176 in the South Pacific, large numbers of peculiar casts were observed in a Globigerina Ooze from 1450 fathoms, which are markedly different from the glauconitic casts. The Foraminifera, in the deposit from this station, presented a very mottled aspect under the microscope, some of them being white or rose-coloured, as is usually the case in a Globigerina Ooze, while others were brown or black, from a deposit of the peroxides of iron and manganese on their outer surfaces. When a section is made through these black or brown-coloured specimens, three zones can be distinguished: at the centre an internal cast of the shell, then the white carbonate of lime shell itself, and outside this an external cast of the same nature and aspect as the internal one, to which it is connected by little pillars filling up the foramina of the shell (see Pl. XI. fig. 1). When the carbonate of lime is removed from such specimens, it is seen that the external cast is in general not thicker than the hollow space left by the removal of the shell, and that this external cast can be partially separated from the internal one by the use of a little force. The general appearance of these external and internal casts is represented in Pl. XXIV. fig. 4, and it will be observed that they differ, owing to the presence of the external casts united to internal casts by little pillars, from the specimens represented in the other figures on the same plate, where we observe only internal glauconitic casts. The red-coloured casts from this station offer considerable resistance to the action of acids and mechanical effort, which seems to show at once that we are not dealing with a cast made up merely by a simple filling of the shell with fine mud or clay. The red casts, when examined in thin sections by transmitted light, are yellow or brown, scattered over by a fine granulation, which is not affected between crossed nicols. When treated with warm hydrochloric acid we obtain, by elimination of the iron, colourless globules that appear to have almost completely resisted the action of the acid, and are in all likelihood composed principally of silica. When treated with alkaline carbonates, we have found that these casts contain silica, alumina, lime and magnesia; traces of alkalies were also detected. They are evidently composed of a substance differing completely from glauconite, and due to some special conditions in the immediate surroundings, for in this deposit there were none of the conditions which are usually present in glauconitic deposits as regards mineral and lithological associations and geographical position, the deposit at this station being a Globigerina Ooze containing 61 per cent. of carbonate of lime, a few Radiolarians and Diatoms, and a great abundance of volcanic debris.

IV. Phosphatic Concretions.

In the foregoing chapters of this work reference has frequently been made to the presence of phosphate of lime in marine deposits. The bones and teeth from the central parts of the Pacific, and the manganese nodules which have been formed around organic centres, frequently yield considerable quantities of phosphate of lime. In the Globigerina and other organic oozes, there is always a small quantity, usually less than 1 per cent., of phosphate of lime, while in the shallower water deposits around continental shores there is usually a much larger percentage of phosphates. When describing the glauconitic material of the Green Sands and Blue Muds, it was pointed out that this substance was frequently associated with phosphate of lime in the interior of the Foraminifera shells. We now propose to describe in detail certain phosphatic concretions found in marine deposits, especially in those deposits in more or less close proximity to continental shores, which present in many instances a most complete analogy with similar concretions in geological formations. In these descriptions we will deal especially with the nodules dredged at Station 141, 98 fathoms, Station 142, 150 fathoms, and Station 143, 1900 fathoms, for at these points the most typical examples were procured; the two former stations are situated on the outer edge of the Agulhas Bank, south of the Cape of Good Hope, and the last in the deep water nearly 100 miles south-east of the Bank.

Macroscopic Characters.—The concretions vary from 1 to 3 cm. in greatest diameter; exceptionally they may attain from 4 to 6 cm. in diameter. They are surmounted by protuberances, penetrated by more or less profound perforations, and have, on the whole, a capricious form, being sometimes mammillated, with rounded contours, and at other times angular. Their surface has generally a glazed appearance, and is usually covered by a thin dirty brown coating, a discolouration due to the oxides of iron and manganese. This coating, which covers all parts of the concretions, usually veils the mineralogical nature and aggregate structure. When they are regarded more closely, the irregularities of the surface are frequently observed to be due to heterogeneous fragments applied the one against the other, cemented by phosphatic material which, as will be presently pointed out, forms the principal mass of most of these little nodules. When examined on a fresh fracture, the greater part is seen to be formed of a brownish yellow, slightly shining, compact matter, in which are embedded black-brown granules of glauconite, that stand out on the broken surface, together with other mineral grains and remains of microscopic organisms. These concretions are hard and tenacious, the fundamental mass, in spite of its earthy aspect, being compact, and having a hardness that does not exceed 5. The fracture is plane or irregular and slightly granular. The matter forming the matrix presents the pyrognostic reactions of phosphate of lime; it is fusible with difficulty on the edges of the splinters; moistened with sulphuric acid it colours the blow-pipe flame with green; it is soluble in hydrochloric acid. It may be added that the concretions from the shallower depths were larger, contained much more glauconite, and presented a green-coloured external appearance, while those from 1900 fathoms were of a light brown colour.

Chemical Composition.—The determination arrived at from the above-mentioned characters as to the phosphatic nature of the substance making up these nodules is confirmed by the following analyses:—

STATION 142, 150 FATHOMS, No. 72.

		Ratio of Equivalents.	
P_2O_5,	19·96	0·422	0·713
CO_2,	12·05	0·274	
SO_3,	1·37	0·017	
SiO_2,	1·36		
CaO,	39·41	0·704	0·721
MgO,	0·67	0·017	
Fe_2O_3,	2·54		
Al_2O_3,	1·19		
Loss,[1]	...		
Insoluble residue,	17·34		
	95·89		

STATION 143, 1900 FATHOMS, No. 73.

		Ratio of Equivalents.	
P_2O_5,	23·54	0·498	0·757
CO_2,	10·64	0·242	
SO_3,	1·39	0·017	
SiO_2,	2·56		
CaO,	40·95	0·731	0·752
MgO,	0·83	0·021	
Fe_2O_3,	2·79		
Al_2O_3,	1·43		
Loss,	3·65		
Insoluble residue,	11·93		
	99·71		

Analysis of Insoluble Residue, No. 72.

SiO_2,	77·43
Al_2O_3,	12·40
Fe_2O_3,	7·91
CaO,	1·07
MgO,	1·02
	99·83

Analysis of Insoluble Residue, No. 73.

SiO_2,	76·58
Al_2O_3,	13·85
Fe_2O_3,	7·93
CaO,	1·27
MgO,	1·18
	100·81

[1] An accident in the operation prevented the determination of the Loss.

				Portion Soluble in HCl.										Portion Insoluble in HCl.					
Station.	Depth.	No.	Loss on Ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCO_3$	$CaSO_4$	$Ca_3 2PO_4$	$MgCO_3$	Cu	Total.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total.
143	1900	74	4·10	6·00	3·00	5·80	2·70	16·07	2·62	49·57	0·98	tr.	86·74	8·40	0·60		0·16	tr.	9·16

Microscopic Characters.—The microscopic examination of thin sections of the phosphatic nodules shows that they present special peculiarities, depending on the nature of the deposit in which they have been formed. The phosphate of lime is the principal constituent, and presents the same characters in every one of the concretions examined, but the nodules differ in the nature and abundance of the heterogeneous particles cemented by the phosphate. These particles, whether of organic or mineral origin, are seen to be the same as those in the deposits containing the concretions; for instance, the nodules from Station 142, where the deposit is a Green Sand, are principally composed (to the extent of two-thirds) of glauconitic particles, quartz, and silicates (see Pl. XX. fig. 1), while in those from Station 143, Globigerina Ooze, the remains of Foraminifera predominate (see Pl. XX. figs. 2–4). In the first case, where the aggregations are formed of glauconitic and sandy particles, the phosphate plays simply the role of a cement interposed between the mineral grains. In the second case the phosphatic matter is more abundant, not only cementing the particles but penetrating through the cavities of the shells; it fills up the spaces between the sections of the Foraminifera, and plays in a manner the role of a fundamental mass, pseudomorphosing, sometimes entirely, all the carbonate of lime of these organic remains.

The phosphatic concretions from the above-mentioned Green Sand show under the microscope an agglutination of angular (rarely rounded) quartz grains, along with rounded glauconitic grains, all of which are abundant in the deposit; there is neither pseudomorphism nor penetration of phosphate into the interior of the mineral particles; the phosphate plays only a relatively subordinate part, binding together the mineral particles of the deposit (see Pl. XX. fig. 1). It is distinguished by a brownish yellow tint, and is seen interposed between the minerals as a network of phosphatic matter. In the microscopic preparations isolated patches of phosphate, scarcely exceeding 0·1 mm. in diameter, are occasionally to be seen; one may observe upon these larger patches that the substance is concretionary; they do not extinguish uniformly between crossed nicols, but spots with indefinite contours and vague tints of polarisation appear, like those presented by very closely aggregated geodic minerals, chalcedony for example, or, better still, certain zeolites.

The phosphatic concretions from the Globigerina Ooze in deeper water, 1900 fathoms (see Pl. XX. figs. 2–4), present considerable differences from those dredged in the Green Sand from 100 and 150 fathoms. In the deep-water specimens there is an abundance of calcareous organic remains, especially Rhizopods, a diminution of mineral particles, and a great preponderance of phosphatic matter. The phosphate penetrates the shells in every part, and pseudomorphoses them in a more or less complete manner. It also forms large patches, enclosing organisms and minute mineral particles, which do not show structure, properly speaking; they are slightly brownish with transmitted light, and appear to occupy the place of the muddy calcareous matter usually found between the Foraminiferous shells in a Globigerina Ooze. These phosphatic patches are characterised by a certain opacity due to the inclusion of a crowd of infinitesimal heterogeneous particles. It might be said that the phosphatic matter, when infiltrating into the mud, had embraced and cemented all the immediately surrounding impurities. Although, as already stated, these patches present no structure, they are lined by a zone which resembles in character concretionary phosphate of lime (see Pl. XX. fig. 4). It might be suggested that the fundamental mass in solidifying had concentrated the organic and mineral matters of the deposit, and in so doing had left behind microscopical empty spaces, which had subsequently been filled by infiltrations of a more homogeneous phosphate of lime, and that this was deposited in these cavities in a manner resembling substances coating some geodes. These later additions of phosphate of lime, being of purer matter, more transparent, slightly yellowish, have solidified with the curvilinear contours and fibro-radiate structure of some concretionary coatings. Between crossed nicols the fundamental mass of these sections can be seen to remain without sensible action on polarised light, while the zone surrounding the borders reacts in giving a rather vivid tint. In the same way the external parts of the concretions offer in thin sections a border of transparent phosphate without inclusions, and with concretionary structure, as if the later depositions had been formed of a more homogeneous material (see Pl. XX. figs. 3 and 4). The same observation is applicable likewise to the infiltrations into the hollow spaces of the microscopic Foraminifera shells.

In these thin sections the Foraminifera that have been aggregated by the phosphate are sharply distinguished from it by the colourless calcareous matter of their shells. The interior formerly occupied by the sarcode is filled by a honey-coloured phosphate, the phosphate infiltrated by the foramina of the Rhizopods being much purer than that cementing the particles of the deposit; but this deposition of phosphate in the interior of the calcareous shells has sometimes been accompanied by brownish pigmentary matters, which are evidently hydrated oxide of iron associated with organic matters (see Pl. XX. fig. 2). The interiors of the Rhizopods in this way appear generally like yellowish, or in some cases like little black, masses limited by the calcareous envelope of the shell.

The infiltration of phosphate is not always limited to the filling up of the cavities of Foraminifera and other organisms; a pseudomorphic substitution of the carbonate of lime of the shell is often observed. According to the structure or thickness of the calcareous partitions, this substitution is more or less advanced; sometimes the structure of the shell is more or less well preserved, but frequently it is quite effaced. When the phosphate has invaded the interior of the Foraminifera, and the calcareous partitions have not been touched by the pseudomorphism, the sections of the partitions stand out pure and colourless, showing that the infiltrated matter has penetrated by the foramina; at other times the shell assumes a yellow appearance, showing the first step towards phosphatisation (see Pl. XX. fig. 3). When the filling up of a Foraminifer, for example, and the pseudomorphism of its shell are complete, the phosphate, attracted around this little centre, continues to be added at the surface, and thus a phosphatic granule is formed whose external appearance no longer recalls that of the organism around which the phosphate has grouped itself. This observation is not without importance in the interpretation of the origin of the phosphatic grains. The study of microscopic sections of these Foraminifera confirms a fact often brought out in descriptions of phosphatic fossils, viz., that the infiltration of the phosphate has a direct relation, so to speak, to the fineness of the openings by which this matter must be introduced. Thus a large number of the Foraminifera may be seen to be filled with phosphate, while very often in the fundamental mass at the mouth of the shell there are points where the phosphatisation has not taken place, being still dotted with particles of carbonate of lime showing clearly the optic phenomena of that mineral. It may be said that when the sections of shells of Foraminifera no longer exhibit the black cross between crossed nicols, they are transformed into phosphate.

Sometimes the phosphate of lime takes on an ochreous or brownish tint, showing that it is mixed, as already indicated, with manganiferous and ferruginous matters —its usual accompaniments in marine sediments—or with organic matters. Although the yellowish tint is characteristic, it may also be replaced by a greenish coloration, when it is sometimes difficult to distinguish phosphate of lime from glauconite. Means of distinction, however, may be found in the concretionary forms of the phosphate, giving it a zonary structure, even recalling by its capricious lines an osseous structure at first sight, while, on the other hand, the aggregate polarisation of glauconite affords a means of differentiation, which, after a little practice, may be applied with certainty. In doubtful cases it is well to have recourse to microchemical reaction, when, with the aid of molybdate of ammonia, the question may be decided in a sure and rapid manner.

Distribution and Mineral Associations.—Having described in detail these phosphatic concretions, we may now consider the conditions under which they have been formed. It has already been stated that these nodules were dredged by the Challenger at Stations 141, 142, and 143, after leaving the Cape of Good Hope for the southern cruise. The two former are situated on the Agulhas Bank, on the submarine edge of the continental shelf, the deposit in each case being a Green Sand, in depths of 98 and 150 fathoms, while the third station is situated in the deep water to the south of the Bank, in 1900 fathoms, the deposit being a Globigerina Ooze.

The mineralogical elements of the Green Sand (Stations 141 and 142) may be considered as derived from the neighbouring land, consisting of quartz, garnet, green hornblende, black mica, &c., and the coast character of the deposit is still further indicated by the large quantity of mineral particles left in the residue after treatment with acid, and also by the presence in abundance of typical grains of glauconite, a mineral never found, we may say, in truly pelagic deposits. The analogy between this sediment and the greensands of geological formations cannot be misconstrued, and the conditions under which they have both been formed must be nearly identical. As the distance from land and the depth of the sea increase, the deposit assumes a more pelagic character, and consequently at Station 143 the mineral particles are for the most part those found in the open ocean, being mostly of volcanic origin; this Globigerina Ooze, however, being formed at a point not very far removed from land, is not purely pelagic and still contains particles of quartz, indicating with considerable certainty the proximity of land. This deposit may be compared with the white chalk of geological formations, but in this case the Rhizopod shells, constituting the mass of the sediment, are preserved entire, and belong to pelagic species, while in the chalk the Foraminifera are chiefly bottom-living forms, and have generally been broken or reduced to powder by agencies posterior to sedimentation.

During the Challenger Expedition, phosphate of lime was procured at many of the shallower stations around continental shores, but never in such abundance or such typical development as at these stations to the south of the Cape of Good Hope.[1]

Mr Murray has described similar phosphatic concretions from the dredgings of the U.S.S. "Blake," along the Atlantic coasts of North America.[2] In one instance the nucleus of the concretion consisted of a fragment of a manatee bone, but in the majority of cases the nodules consisted of an aggregation of calcareous organisms cemented by a brownish yellow phosphatic matter, often showing concentric rings, after the manner of agates, thus indicating deposition from solution.

It may be pointed out that phosphatic nodules are apparently more abundant in the deposits along coasts where there are great and rapid changes of temperature, arising from the meeting of cold and warm currents, as, for instance, off the Cape of Good Hope and off the eastern coast of North America. It seems highly probable that in these places large numbers of pelagic organisms are frequently killed by these changes

[1] In the material dredged by the German ship "Gazelle" on the Agulhas Bank, which Mr Murray was permitted to examine at Berlin, there were numerous phosphatic and glauconitic nodules identical with those procured by the Challenger.

[2] *Bull. Mus. Comp. Zoöl.*, vol. xii. pp. 42, 43, 52, 53, 1885.

of temperature, and may in some instances form a considerable layer of decomposing matter on the bottom of the ocean. It is also well known that large numbers of pelagic creatures are in like manner destroyed where there is a mixture of waters of different salinities, for instance, where polar and equatorial currents mingle, or where large quantities of fresh water are thrown into the ocean from floods in great rivers.[1] By taking account of phenomena such as these, which would result in the destruction of large numbers of pelagic animals at one time, thus covering the deposit in process of formation with a vast layer consisting of the dead bodies of marine animals, it is believed that the origin of the thin bands of phosphatic nodules, so frequent in geological formations, may be accounted for.

The phosphatic nodules observed in existing deposits belong then to the coast zone. They may be found in all terrigenous deposits, and also along the edge of the abyssal zone in deposits of a pelagic type, which, however, from their nearness to land, still contain terrigenous elements. The resemblance of these deposits to those of geological formations containing phosphorites in greatest abundance—the greensands, glauconitic chalks, and pure chalks—is so evident that it is unnecessary to insist on it. The mode of formation of the one must have been almost identical with that of the other, and the interpretation of the origin of the phosphatic concretions of existing seas should be equally applicable to those of the Cretaceous and Tertiary formations, for example.[2] Reference has already been made to the analogies between the phosphatic nodules of modern sediments and those of a great number of nodular phosphates of the chalk and greensand formations, so much so that it might even be asked whether the concretions described in this chapter might not be derived from ancient formations cropping out at the bottom of the sea. This doubt is at once removed when account is taken of the fact, already pointed out in treating of the microstructure of these concretions, that they contain, cemented and enclosed by phosphates, the remains of organisms and mineral particles identical with those constituting the actual sediments in which the concretions are found. These phosphatic concretions must therefore be regarded as having been formed *in situ*.

Mode of Formation.—If we ask whence the phosphate of lime found in these nodules is immediately derived, we may set aside in the first place the hypothesis of a direct derivation from the interior of the globe, for although it is evident that in certain cases a small percentage of phosphate of lime in deep-sea muds might be attributed to apatite coming from volcanic rocks, still even at the highest estimate the amount of phosphate of lime coming from this source must be very subordinate relative to that derived, for instance, from organic remains. Nor is there any reason in the conditions under which they have been formed for supposing that the phosphate of lime could have been derived from submarine springs. Again, we find nothing in the surroundings to induce us to

[1] Murray, *Scot. Geogr. Mag.*, vol. vi. pp. 481, 482, 1890.

[2] Murray, *loc. cit.*, pp. 464, 465.

regard the phosphate of lime of these nodules as being a direct deposit from the waters of the ocean without the previous intervention of organisms; the small quantities of this substance found in analyses of sea-water prevents us in the actual state of our knowledge from having recourse to this interpretation. But if phosphates are not deposited directly from the waters of the ocean, it is incontestable that by the action in the first instance of vegetable organisms phosphates are without cessation removed from these waters during vital processes, and a notable proportion is fixed in the hard parts of certain groups of organisms.

Organic remains must sometimes accumulate in vast numbers on the sea-bed, and sometimes be buried in the sediments; it seems to us that the decomposition of such organic remains is the immediate source of the phosphates in the concretions here described. We know that *Lingulæ* have secreted this substance since the Cambrian Period, and indeed this process has been going on from geological periods of the most ancient date, ever since the conditions had become favourable to the existence of organisms in the bosom of the ocean. It is evident that the phosphates thus elaborated by organisms ought, when life abandons the organic structures, to accumulate along with sedimentary matters upon the bed of the ocean. The deposits there forming are the seat of many chemical reactions under the joint influence of decomposing organic matter and sea-water. All the mineral substances here described under the name of chemical deposits are the very best proof of these reactions, and although not energetic, they are not the less considerable as to their effect, granted the duration of the action and the mass of substances present. In that pulp formed by the calcareous and siliceous organic envelopes, by the fragments of rocks and minerals reduced to the state of muddy matter, and albuminoid and other matters derived from higher organisms, the phosphates are re-arranged, with the result that phosphate of lime in a nodular form is in some places found in considerable abundance. It may be supposed that this phosphatic matter dissolved in the sea-water impregnating the mud is endowed with the properties of colloidal bodies, for we know that phosphate of lime presents incontestable analogies with certain colloids, for example, with hydrated silica. By admitting that phosphate of lime can effect this colloidal state, it is sufficient that a centre of concretion should arise to initiate precipitation, and the nucleus once formed would subsequently enlarge by successive additions.[1]

Many substances may have played, with respect to the phosphate, the role of centre of attraction. It may have originated in the first instance, as we have shown, in the filling up of the hollow spaces of a *Globigerina* shell; afterwards it may be deposited around this shell and agglutinate the surrounding portions of the deposit into a more or less com-

[1] The phosphate of lime may be held to be directly derived from the products of decaying bones of dead animals, upon which carbonic acid exerts a powerful solvent action. At the same time the organic nitrogenous matter of the bones is decomposed into ammoniacal salts, which would readily dissolve in water containing free carbonic acid, and form a solution exceedingly prone to re-deposit the phosphate of lime held in solution on any nucleus or in any cavities or shells.

pact mass. The organic remains on the bottom of the sea often retain for a long time some of their sarcodic substance, and we are inclined to think that this exercises upon the phosphate an attraction which might be considered as a feeble echo of that exercised by living matter. This view might be supported by recalling the frequent incrustations of phosphates and its concretionary development upon the remains of plants and animals; at the same time it must be pointed out that phosphate of lime is sometimes formed around inert matters to which no affinity would appear to carry it. A solid body of any kind appears to serve as a nucleus, though phosphatic nodules are by preference formed around organic centres, but whatever the nature of the nucleus, once the first layer of the concretionary substance is deposited it no longer remains inert, acting in its turn as a centre of attraction and grouping round it, just as the solvents furnish material, all the molecules of the same nature which are found within its radius of attraction.

Recalling now the various particulars stated in the preceding general descriptions, we may give a resumé of the facts upon which we rely for the interpretation of the mode of formation of the phosphatic nodules dredged to the south of the Cape of Good Hope. It may be said that the phosphate of lime accumulates in marine muds in the form of remains of organisms which secreted this body during life, the analyses of oceanic deposits usually showing the presence of a notable quantity of phosphate of lime. It is upon the debris of organisms that the solvent action of the sea-water impregnating the sedimentary pulp is exercised; we know that nearly all the bones of fishes, Crustacean carapaces, and other organic structures containing phosphates, have been removed in solution. After having been dissolved, the phosphate, existing in a state analogous to that of colloidal bodies, is deposited at first in the interiors of Rhizopod shells lying isolated in the muddy matter and still lined with organic material. This filling up of the Foraminifera shells is seen perfectly in microscopic sections of the nodules, which show also that the concretionary substance, having filled the empty spaces, continues to be attracted around these centres and infiltrates into the muddy mass, enclosing all the impurities and binding together several centres whose agglomeration forms the nodule. This concretionary process is accompanied by an after-growth more or less complete of phosphate upon the calcite. In other cases mineral particles are taken as a centre of concretion, as shown in the nodules from the Green Sand; in this case organic matter does not apparently play the same role in determining the formation of the nodule.[1] On the decay of fish bones, and indeed of all animal structures, ammoniacal salts are formed, and at the same time phosphoric acid in combination with lime is dissolved in sea-water, the natural result being the formation of ammoniacal or alkaline phosphates, which react upon any structural form of carbonate of lime, such as shells, Corals, &c., the phosphoric acid in combination with the alkaline bodies combining with the lime of the Coral or shell to form phosphate of

[1] See Irvine and Anderson, "On the Action of Metallic (and other) Salts on Carbonate of Lime," *Proc. Roy. Soc. Edin.*, vol. xvii. pp. 52–54, 1891.

lime, thus producing pseudomorphism.[1] But whatever may be the nature of the substance serving as a first centre for these concretions, we are led to believe that the phosphate of which they are constituted has passed through living matter. Its cycle may be traced by saying that, after having been concentrated by living beings, it is rendered to the mineral world again, after solution by sea-water, in a concretionary form, and is thus placed in a more stable form in reserve for the future wants of life.

V. Crystals of Phillipsite in Marine Deposits.

It has been pointed out that glauconite is a hydrated silicate now forming in considerable abundance in marine deposits; it has been shown that it never presents itself in a crystalline condition, and does not occur in a free state, but originates in the hollow spaces of calcareous organisms. It is limited to terrigenous deposits, and is always associated with ancient volcanic rocks or crystalline schists, from whose alteration in all probability its chemical constituents are derived. The hydrated silicate, phillipsite, to which we now propose to direct attention, is, on the other hand, always present in a crystalline form, and is found in a free or isolated condition in the deposits. It is limited to purely pelagic clays or oozes, and is associated with recent volcanic rocks, and the materials derived from their alteration. We hope to be able to show that these zeolitic crystals arise from the decomposition of such volcanic rocks.

Crystals of phillipsite were first discovered in deep-sea deposits during the cruise of the Challenger between the Sandwich and Society Islands, where they were found to make up 20 or 30 per cent. of some samples of Red Clay. A fact which proves that they must have been in considerable abundance at many points is that the shells of some arenaceous Foraminifera were entirely made up of these little crystals. They have been found distributed over wide spaces in the central regions of the Pacific, and have subsequently been discovered in the deep water of the Central Indian Ocean. Although found in the various kinds of deposits in the deep water of the Central Pacific and Indian Oceans far removed from land, they cannot be regarded as characteristic of any type of deep-sea deposit, although most widely distributed and abundant in some red clay areas. The presence of these microscopic crystals in enormous numbers and in a free state in the pelagic deposits possesses a high interest, viewed with respect to the chemical reactions taking place during the present period upon the floor of the great ocean basins. Zeolitic minerals, and phillipsite in particular, are known to occur in the vacuoles, fissures, and empty spaces of certain crystalline masses or tufaceous rocks of volcanic origin.

[1] Irvine and Anderson found that a porous variety of Coral had, in the course of six months, abstracted from a solution of phosphate of ammonia, phosphoric acid sufficient to replace about 60 per cent. of the carbonate of lime present.

Daubrée has shown that zeolites are even in process of formation in the Roman bricks and concretes of the springs at Plombières, and around the edges of other thermal wells.[1] But, as far as we know, they have never before been found in an isolated condition—as simple or twinned crystals, or free radiated aggregates—as we find them in the deposits of the Pacific and Indian Oceans. The deposits containing these zeolitic crystals present in these regions a totality of phenomena that appears never to have been realised on the same scale in the sedimentary formations of any geological period, unless, indeed, it be admitted that all traces of them have been effaced by posterior changes.

Physical Characters.—On examining the deposits, from the regions in which these zeolitic crystals occur, under the higher powers of the microscope, there is seen, in the midst of mineral and argillaceous matters and volcanic debris, an infinity of small prisms of sharply cut form generally covered with a yellowish deposit. These microliths appear to be as numerous in the clay as the little crystals of rutile in certain slates, for example. They are generally simple and isolated, though in some cases they form aggregates or are twinned; there are also spherolithic groups in which several of these zeolitic crystals are entangled together so as to form crystalline globules of sufficient size to be distinguished by the naked eye, giving a certain grain to the deposit. We will describe first the isolated crystals of minute dimensions, which are carried away along with the argillaceous matters of the deposit in the process of decantation. These microliths are coated with a thin layer of hydrates of iron and manganese, which gives them, and in fact the whole deposit, a brown or fawn colour. Their form is better observed after treating them with very weak acid, which frees them more or less perfectly from the accidental coating substances. Thus cleaned the smallest crystals are seen to be colourless or slightly milky; a large number of micrometric measurements gives them a mean diameter of 0·027 mm. in length, and 0·005 mm. in breadth. They have a pronounced prismatic, very simple, form; the elongated faces, which may be taken for the faces of the prismatic zone, form between them a right angle. They are terminated at the two extremities by two faces resembling a dome, inclined the one to the other at an angle approaching 120°. It is rather difficult to see other faces clearly; those just indicated are observed with certainty, but it may be that the smallest crystals of phillipsite, or at least certain of them, are terminated by four faces instead of two at each extremity. At the two ends of the crystals traces of two other faces which appear as dwarfed may be seen, but they are too ill-defined to allow of their existence being definitely made out. As a matter of fact, however, these four faces do exist in larger individuals, as will be presently pointed out. Their form indicates that they are single individuals of the monoclinic system presenting the faces 0P(c), ∞P̶∞ (b), ∞P(m), elongated following the edge c/b (see Pl. XXII. fig. 1), an elongation which determines the prismatic form of the crystals. The faces having the appearance of forming a dome are those of the prism (m); the angle formed by the two

[1] A. Daubrée, Études synthétiques de Géologie expérimentale, pp. 180 *et seq.*, Paris, 1879.

faces *m*/*m* answers within several minutes to the angle of the same faces in phillipsite. Here then we are dealing with the fundamental forms of this mineral, and, at least in the case of the smallest of these microliths, with non-twinned crystals, which have not hitherto been pointed out in specimens of this species found in fissures and geodes of volcanic rocks. In spite of their extreme tenuity, the faces *c* and *b* can each give good reflections, thus showing that these crystals are not lamellar, as might be supposed at first sight, but that they possess a development almost equal for these faces. The attempts to determine their optical properties, difficult even in the case of large crystals, have not given any definite results. The optical properties of phillipsite are very variable, and, as with the majority of minerals belonging to the group of zeolites, the tints of chromatic polarisation are of low order, and in this case the difficulty is increased owing to the great absorption of light by the optic apparatus when studying between crossed nicols with high magnifying powers. In fine, the angle of extinction of phillipsite is relatively small, and as the edges are only a few hundredths of a millimetre in length it is difficult to measure this angle under the microscope. When the crystals are larger, there may sometimes be observed at the two extremities four lozenge-shaped faces reposing upon the edge $\infty \mathrm{P}\infty / 0\mathrm{P}$, having then the aspect of orthorhombic prisms terminated by the faces of a pyramid. What has been said as to the determination of the faces shows that we are dealing in this case with one of the ordinary twins of phillipsite, the plane of twinning and the plane of composition being the face $0\mathrm{P}$. It may be added that this twinned form has not up to the present time been observed in an isolated condition, except in the case of small crystals of phillipsite from Plombières, where Des Cloizeaux has found forms identical with those here indicated.

The small crystals are seen to pass through all the transitions of size to the larger simple or twinned individuals, which show a tendency to group themselves irregularly or according to a crystallographic law. Even the smallest microliths that pass off with the first decantation are superposed, grown together, and interlaced. In certain cases the groups are regular; they are crossed twins, recalling perfectly the well-known twin form of harmotone and of phillipsite. The annexed woodcut (Fig. 36) represents one of these twinned crystals from the South Pacific, Station 276, 2350 fathoms; it is from this station that all the figured specimens of zeolites from the Pacific have been selected. This cruciform twinning is repeated so frequently and is so characteristic that it might almost of itself serve to identify these little crystals as belonging to the one or the other of these zeolitic species.

Fig. 36.—Crossed Twin Crystal of Phillipsite. Station 276, 2350 fathoms, South Pacific.

Although the twinning is not rare, the crystals are more frequently observed forming irregular groups, as shown in Pl. XXII. fig. 4, where these crystals are grouped as they appear after isolation from the mud by decantation. The grouped microliths are covered by a coating of manganese and iron, which is generally arranged around the centre of the group. In this figure only one crossed twin is seen; the other groups are formed sometimes by two microliths crossing each other at variable angles or juxtaposed, sometimes by three or four little crystals superposed one above the other, while in certain groups there is a tendency to affect a spherolithic or radiated disposition around a centre. Finally in some cases the spherolithic structure is more perfect, as will presently be pointed out when describing the spherolithic globules formed by radiate crystals of phillipsite, which are very frequent in the deep-sea deposits already indicated.

We may recall the fact that this globular or spherolithic disposition is to a certain extent characteristic of several species belonging to the group of zeolites; mention may be made of the crystalline botryoidal masses lining the hollow cavities of certain altered volcanic rocks. In this case the crystals are supported on the rock, while in the case of the globules of phillipsite the little groups of radiated crystals are formed in a free state in the mud. In the aggregate of crystals represented in Pl. XXIII. fig. 6 the grouped microliths are seen pressed the one against the other, as if they came from a geode. A cosmic spherule, on falling upon the bed of the sea, has been enclosed in this agglomeration of little prisms, and has been entangled among zeolitic crystals.

The spherules now to be described are of the same mineral nature as the isolated microliths, twins, or groups previously spoken of, but they are larger, being distinguishable by the naked eye or with the aid of a lens. When the various elements of the mud are separated by decantation or by means of dense liquids, such as the iodide of mercury and potassium, the most numerous particles observed are grains resembling a ferruginous sand. These grains are often spherical, and with the aid of a good hand-glass they are seen to be terminated at the surface by slightly-reflecting crystalline facets. They are always soiled by argillaceous mud and coatings of iron and manganese. The mean diameter of these spheroliths is about 0·5 mm., though in some cases they may attain a diameter of 2 mm. In reflected light under the microscope the facets, at the surface of the globules, are seen to be those answering to the two prismatic faces ∞P of simple individuals, or to the four faces of individuals twinned following the law already referred to. Pl. XXIII. fig. 3 represents one of these spheroliths, magnified 20 diameters, as seen by reflected light. Mounted in Canada balsam or copal, the spherules can be rubbed down, and become sufficiently transparent to be submitted to microscopic examination by transmitted light, when it is seen that they are made up of little radiating microliths of phillipsite. Pl. XXII. fig. 3 represents a spherule cut approximately through the centre, showing precisely the internal structure of these zeolitic balls. It is surrounded by a deep brown or red-brown coating of manganese, while all round the figure are agglomerated mineral particles of the deposit traversed by dendrites of manganese. Among these particles are little irregular colourless fragments of minerals of volcanic origin or debris of organisms. The crystals composing these spheroliths become thin towards the centres of the globules, and there terminate in an acute angle following the edge *c/b*. They advance more or less regularly following the radii, growing gradually larger as they approach the periphery; this structure, however, is not quite what is denominated fibro-radiate. The individuality of each crystal is too well marked; properly speaking, it is a radiate structure. The section cuts some of the crystals more or less parallel to the axis of elongation, and the extremity is then seen to be terminated by the faces *m/m*. Zones of growth may be observed upon these microliths, indicated by inclusions of the limonitic and manganiferous mud; in many cases these zones do not present a well-marked direction, but sometimes the inclusions are arranged and disposed *en chevron*, which might answer to the arrangement of the hemitropic lamellæ observed upon the face *b* of crystals of phillipsite. Even in these pretty large crystals of the spheroliths it is very difficult to discern the optical properties exactly, and this difficulty is increased by reason of the wedge-shaped form affected by each of the individuals; in the spheroliths the properties of the individual crystals, as in the case of a twin, lose all regularity. Pl. XXII. fig. 2 shows one of the spherules cut nearer to the surface, consequently the section cuts the radial crystals near their external extremity. Sometimes the form of the sections is a parallelogram more or less elongated, or approaches to a square, according as they are cut more or less normally to the edge *c/b*; this is what the crystals of phillipsite should give when cut across in such a section. Sometimes sections with re-entrant angles are also observed, and are the traces of crossed twins; two or three such sections are seen in the spherule figured, at the upper right-hand side of the figure.

Chemical Composition.—From the physical characters just described, it is evident that these crystals belong to the species phillipsite, and the results of the following analyses confirm this determination. The material chosen for the analyses was as pure as it could be obtained by decantation, or by the aid of dense liquids, without being cleaned with acid.[1]

Station.	Depth.	No.	Loss on ignition.	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	H_2O	Total.
275	2610	89	7·59	47·60	17·09	5·92	0·43	3·20	1·24	4·81	4·08	9·15	101·11
275	2610	90	7·35	49·88	16·52	5·54	0·44	1·38	1·20	5·10	4·59	9·33	101·33
275	2610	91	9·47	48·70	17·58	6·17	...	1·70	1·02	4·83	3·75	7·95	101·17

The presence of iron and manganese must be placed against the coatings and inclusions of the crystals. Apart from these foreign matters, the composition shown by the analyses corresponds closely with the average composition of phillipsite, except in the case of the alumina, the percentage of which is rather below the average; this deviation

[1] In Appendix III. will be found three additional Analyses (Nos. 20, 21, and 92), which were made from impure material or are incomplete, and need not be specially referred to here.

may be accounted for when we remember that the substance is not homogeneous, and is so fine in the grain that perfect separation is impossible even under the microscope. It may be added that, like other zeolites, these crystals are attacked by hydrochloric acid, leaving a siliceous skeleton.

Geographical and Bathymetrical Distribution and Mineralogical Associations.—We have seen that phillipsite is present in nearly all the deposits collected by the Challenger in her voyage through the Central Pacific, from the Sandwich Islands to near the island of Juan Fernandez. It has also been detected in some of the deep-sea clays collected by the U.S.S. "Tuscarora" in the Central Pacific, and in the deposits collected by H.M.S. "Egeria" in the Central Indian Ocean. It always occurs in the deeper deposits, as will be seen by reference to the Tables of Chapter II., most abundantly in Red Clays, more rarely in Radiolarian Oozes, and still more rarely in Globigerina Oozes.

By reference to what has been said as to the distribution of basic volcanic glasses and basaltic lapilli, it will be seen that the distribution of these substances coincides with the distribution of the crystals of phillipsite. If the sounding tube has not demonstrated that the basin of the Pacific is covered at many points by flows of lava, it is because this apparatus cannot, any more than the dredge, penetrate below the surface of the sediment, and these superficial layers are always formed, as might be expected, of fragmental matters. But granted the accumulation of lapilli and volcanic ashes and sand that are found there, everything points to the conclusion that, beneath the deposits of mud, the bottom is constituted over considerable areas by veritable volcanic flows. Whether this supposition be correct or not, it is incontestable that, at those points far removed from continental land, and situated beyond the influence of transport by rivers, waves, tides, and currents, the elements most widely spread in the oceanic sediments are of volcanic nature, or result from the decomposition of eruptive products. It may be pointed out also that the volcanic matters predominating among these products of submarine eruption and scattered over this region of the ocean are from their nature essentially alterable, being mostly basic glasses. The basic nature, and at the same time vitreous condition, of these fragments is a certain index of alterability and of the facility with which sea-water can attack and transform them. These points will be referred to presently, for they give the key to the mode of formation of zeolites in the deposits.

Mode of Formation.—If we consider, in the first place, the subaerial rocks where zeolites are located, it will be seen that they are of the same nature as the volcanic fragments dredged from pelagic sediments, and that the conditions under which the zeolites are formed in both cases are analogous. It is a well-established fact that zeolites are never met with in fresh and unaltered rocks, neither are they ever observed as direct products of crystallisation in a magma nor as products of sublimation. They are specially developed as secondary minerals in the hollow cavities, the vesicles, the fissures, of some older or recent eruptive masses and in their tufas; they are sometimes also seen pseudomorphosed on anhydrous silicates. An intimate bond unites the zeolites with the matters upon which they are implanted or with which they are associated. It might be said that these hydrated silicates are nothing else than the volcanic minerals transformed under the action of water and in a manner regenerated; as soon as these crystalline rocks or their tufas are exposed to the action of water that penetrates them their pores are seen to be lined with zeolitic minerals. This filling up is in direct relation with the degree of alteration of the rocks; in short, these veins and geodes have been lined by zeolitic minerals by an exudation, so to speak, of the rock containing them. It is especially in the geodes of basalts, of phonoliths, of diabases, or in the respective tufas, that they are met with. The submarine volcanic matters of the regions already indicated are precisely those that might be considered as the tufas of basaltic rocks.

The study of the crystals and zeolitic coatings lining the cavities of products of subaerial eruption indicates clearly that these secondary minerals have been formed by waters, which have taken from the very rocks through which they have passed the constituent elements of the zeolites. We may even follow in the various zones of the geodes the gradual series of alterations that the rocks have undergone under the influence of the infiltrating water; it has deposited in the hollow cavities matters with which it has been gradually charged during its passage through the capillary canals traversing these eruptive masses. Amygdaloid rocks of the basic series of all geological formations exhibit the conditions here recalled; it has even been shown that, in lavas so recent as those of the Puy-de-Dôme and of Gravenoire, these zeolites are present. In a word, wherever basic volcanic rocks are exposed we are sure to observe minerals belonging to the group of zeolites, always formed by the solvent action of waters upon the volcanic masses containing them. This is the case in Auvergne, in Bohemia, in the Siebengebirge, in the rocks in the neighbourhood of Idar, in Iceland, in the Deccan, in the eruptive masses in the Trias of Scotland, &c.

It is only in exceptional circumstances that the zeolites are observed in sedimentary layers. The solutions depositing them may then have taken the elements from the neighbouring eruptive rocks, or these sedimentary layers may have originated from tufaceous matters more or less closely resembling those found at the present time on the bed of the Pacific. It is very probably in these conditions that zeolites occur in the argillaceous schists at Andreasberg and Eule, in the limestones at Chappel, Fife, where apophyllite with opal is observed filling *Strophonemas*, and in the sandstones of the Upper Tertiary at Crevacuore. But whatever their position, or the nature of the rock in which they are formed, these silicates always present characters indicating hydrochemical origin. It may also be stated, as the result of a considerable number of observations, that the mineral masses in which they are localised belong especially to amygdaloid rocks or to the basic series.

Another very significant fact may be here noticed, viz., that whereas zeolites abound in basic volcanic rocks they have no such great development in other crystalline rocks. Thus the paste of granites and porphyries, richer in silicic acid than the rocks just mentioned, do not contain zeolites, which are replaced by siliceous concretions, by quartz, chalcedony, and opal. All this demonstrates in a conclusive manner that the waters infiltrated in volcanic masses do not deposit there matters other than those taken up from these very rocks, and that the products of the alteration of these rocks furnish the elements entering into the constitution of the zeolites or other secondary minerals. Water is, then, only an instrument in this regeneration of minerals. At the moment of its infiltration it may not have been charged with any of the elements constituting the secondary products about to be deposited from it; these elements are found ready in the eruptive masses from which the waters take them to abandon them almost immediately in the form of crystals or of amorphous coatings.

The study of contemporaneous phenomena supports the preceding deductions drawn from the observation of eruptive rocks of past geological periods. Daubrée has proved that at Plombières water but slightly mineralised has infiltrated into the concrete and masonry by whose aid the Romans had retained the spring, and has there determined the formation of zeolites, among which he has observed crystallised phillipsite. In the vesicles of the bricks and in the cement, the infiltrating water has deposited minerals identical in every respect with those observed in the vesicular rocks of the basaltic series. At Plombières better than anywhere else the conditions under which zeolites may be formed are easily observed, and it may be there demonstrated with certainty that the waters depositing the zeolites take the elements from the surrounding medium. There are no traces of zeolites nor of other contemporary minerals in the sandy gravel traversed by the waters before reaching the concrete and masonry, and these formations are absent also in the friable granite found at Plombières although submitted to identical conditions as the cement and Roman bricks. We must conclude from these facts, and especially from this localisation, that the very material in which the crystals are deposited furnishes to the water the constituent elements of zeolites, and it is evidently according to the composition or alterability of mineral matters traversed by water that zeolitic matters are extracted, deposited, and crystallised. Granite and gravel, richer in silica, offer more resistance to the solvent action; the water cannot take anything away nor depose anything there. These modern phenomena then present an exact repetition of those revealed by the study of crystalline rocks of geological formations.

We have given these details of Daubrée's observations at Plombières, which he has found to be confirmed at several other thermal springs, because these phenomena present points of comparison which permit us to determine with great probability the origin of the submarine zeolites. Keeping in mind the whole range of facts furnished by the study of zeolitic rocks, and of the formation of contemporary zeolites, we may proceed to consider the origin of the little crystals of phillipsite from the clays of the Pacific. The dredgings and soundings in these zeolitic regions show an exceptional abundance of fragments or of lapilli of vesicular basalt, often with a highly-developed vitreous base. Almost all these rocks belong to the basic series, and among them are found types of the eruptive series poorest in silica. With these lapilli, which are always observed in a state of hydration and more or less advanced disaggregation, are associated, with remarkable constancy, fragments of palagonite representing one of the last phases in the hydration of basaltic volcanic glasses. Microscopic particles also observed in these clays must have been projected as volcanic ashes from submarine or subaerial eruptions, and have apparently come from eruptions that have covered the bottom of the sea with eminently alterable lapilli, similar to those just referred to. These particles are also generally of a basaltic nature, and their state of extreme division must render them in an exceptional degree favourable for attack by sea-water.

It is seen, then, not only that the rocks just enumerated are those in which, in geological formations, zeolites have been developed in a marked degree, but that they are especially represented by the vitreous varieties. Moreover, it is known, from observations of geological formations, and from experiments in the laboratory, that these vitreous varieties are precisely those which, as might be expected, offer the least resistance to the action of water, and that water transforms them, in part at least, with great facility into matters of a zeolitic nature. What may be expected to be the result of the action of water upon the rocks and minerals found on the bed of the Pacific? Evidently the same at the bottom of the sea as that observed in analogous rocks on the dry land, where we are able to follow the modifications there taking place. As we have already remarked, the minerals constituting the basalts and basaltic rocks in general undergo, under the influence of waters that attack them, a series of transformations produced with constancy in nature, which may be thus summarised. During the decomposition of these rocks the waters take away from the alkaline silicates almost all they contain of potash and soda, silica being at the same time liberated; in silicates with a base of lime, magnesia, iron, and manganese, almost the whole of the lime and of the iron is separated with a notable quantity of silica. These various elements tend to disappear from the primitive mass, being taken away by the waters, but sometimes the iron and the manganese remain in the residue of the decomposition in a high state of oxidation. As to the alumina entering into the composition of these silicates, a fraction of it is eliminated, but the greater part is concentrated in the residue, in retaining a certain portion of the silica, and in fixing a certain quantity of the water. The final product of this decomposition approaches more and more to a hydrated silicate of alumina, which constitutes an argillaceous mass containing always traces of alkalies, especially of potash, and mixed with iron and manganese. The waters may deposit the elements thus taken up from the rocks upon the immediate borders of the points from which they have been extracted, or they may be carried further away, according as the liquid is at rest or in more or less rapid motion.

We will now show that phenomena analogous to these take place at the bottom of the Pacific; the differences observed are non-essential, and are explicable when the location and special conditions are taken into account. Remembering the nature of the rocks found to be present on the bottom in the central regions of the great ocean basins, we would expect to observe there the formation of zeolites bearing characters depending upon the medium in which they have been developed; they would be found, not only in the vesicles of the volcanic fragments in the form of definite crystallographic individuals or in aggregates, but also in a free state, and not enclosed. The sea-water acting upon basaltic volcanic material will be charged with elements to be afterwards deposited as zeolites, the residue being transformed into an argillaceous mass, in which manganese and iron are concreted in nodules of hydrated peroxide. In this argillaceous ooze the zeolitic crystals will be deposited, granted that the movement of the water is almost insensible; the solutions could not be carried very far, as is often the case in clays derived from the decomposition of subaerial basalts. These crystals cannot be placed in positions similar to those upon the solid partitions of crystalline rocks, hence their special characteristics; they are terminated on all sides by crystalline faces or form aggregates and spherolithic globules, the surfaces of which bristle with facets. These are, indeed, the peculiar characteristics of crystals formed in muddy matters, viz., the crystals of gypsum and the radiate groups of sulphide of iron formed under conditions fundamentally resembling those under which these microscopic crystals of phillipsite are found. Thus the presence of eruptive materials whose decomposition under the action of water gives origin to zeolites, the co-existence of these with the normal residue of the alteration of basaltic rocks—clay and ferro-manganiferous concretions, the special characters of these zeolitic microliths, indeed the whole range of facts observed on the bed of the Pacific, contribute to the support of the interpretation here proposed, which appears to give an adequate explanation of the origin of these crystals of phillipsite.

Some points upon which we have not insisted may, however, be raised against the view here adopted, and in terminating this discussion we may examine some doubts that naturally enough present themselves. It may be asked, in the first place, whether the substances extracted by sea-water from silicates of volcanic rocks ought not to be spread by diffusion throughout the oceanic mass and be lost in this immense reservoir. To remove this objection, it will be sufficient to recall a fact placed beyond doubt by recent oceanographical researches, viz., that in great depths the water is not subjected in a sensible manner to the influence of superficial movements—waves, tides, and currents—but that there is only a massive movement of extreme slowness, in striking contrast with the agitation of the surface water. As already stated, it is sufficient for the formation of zeolites to have a very slow renewal of the water, and we have at the bottom of the Pacific this condition, which is observed in the waters infiltrating into the subaerial rocks and there depositing hydrated silicates. In consequence of the greater or less stability of the masses of water in contact with or imbibed by the sedimentary ooze and volcanic debris, diffusion, if not altogether suspended, operates only in a very slow manner in the deeper layers of the sea, and thus permits the dissolved elements to be deposited, in part at least, at the points not far removed from where they have been extracted. One of the conditions desired for the formation of zeolites—the slow renewal of the water—is then realised at the bottom of the sea, and especially in the muds saturated with water.

Another objection arises from the low temperature of the water at great depths, which oscillates between 2° to 3° C. above and below zero; it may be thought that these thermal conditions are incompatible with the formation of zeolitic crystals. It has generally been admitted that these minerals require for their formation waters of a high temperature, but that they can be produced without demanding a great heat is proved by the zeolites of Plombières, for, as already stated, they are there developed almost at the surface of the ground under the action of waters, thermal, it is true, but whose temperature scarcely rises to over 40° C. This is very far from the high temperature which has been hypothetically invoked to explain the deposit of all zeolitic matters. To judge from the effects produced at Plombières by waters of a comparatively low temperature during the relatively short time separating us from the Roman period, it is reasonable to suppose that even very much lower temperatures may produce analogous phenomena, if account be taken of the great alterability of basaltic silicates and the state of fine division in which they occur at the bottom of the sea. That which cool or tepid waters, like those of springs, can produce, will be realised in sea-water in a certain measure, especially if it has time to act, for time is a great factor in these reactions; the ultimate result will be the formation of crystals scarcely exceeding a fraction of a millimetre in diameter. It would be easy to prove, it may be added, that the decomposition of a great number of rocks, and the deposition of zeolites under the influence of water, could only take place at a relatively low temperature. It is scarcely necessary to remark that if a water but little mineralised, like that of Plombières, is sufficient to attack the substance of bricks and concrete, and there provoke the formation of zeolites and other species—chalcedony, opal, &c., the water of the sea is able to exercise an analogous action upon the natural silicates bathed by it. If it be admitted that pure water suffices to decompose rocks, with all the more reason may we conclude that sea-water charged with salts is able to attack the mineral matters which it penetrates. It is well known that water in contact with finely-pulverised silicates gives at once an alkaline reaction, and that afterwards it may act in consequence of the contained alkali. To this action of water may also be added the much more energetic, though more localised, phenomena,* arising from acid exhalations, carbonic acid in particular, which form a habitual accompaniment of volcanic manifestations, and of which the submarine regions of the Pacific must often have been the theatre.

Relation of Secondary Chemical Products to Rate of Deposition in Deposits.—It must be admitted that at the present time we have no definite knowledge as to the absolute rate of accumulation of any deep-sea deposit, although we have some information and some indications as to the relative rate of accumulation of the different types of deposits among themselves. The most rapid accumulation appears to take place in the Terrigenous Deposits, and especially in the Blue Muds not far removed from the embouchures of large rivers. Here no great time would seem to have elapsed since the deposit was formed, so far at least as the materials collected by the dredge, trawl, and sounding tube are concerned. The various constituents of the mud are little altered, and if great chemical changes have taken place in the deep layers beyond the reach of our instruments, these are not apparent in the more superficial layers to which our direct knowledge is at present limited.

In glauconitic deposits, along high and bold coasts, where few rivers enter the ocean, a large number of the mineral particles have undergone profound alteration, there is a large admixture of *Globigerinæ* and other pelagic shells, and the glauconite with which many of these are filled, as well as the presence of phosphatic, calcareous, and barium nodules or concretions, all indicate that there has been an extensive formation of secondary products. All the constituents in the superficial layers of these deposits appear to have been for a long time exposed to the action of sea-water, and for the reasons here stated we must assume that the Green Muds and Sands have therefore accumulated at a much slower rate than the Blue Muds.

The majority of Volcanic Muds and Sands appear to accumulate at a relatively slow rate, judging from the large number of pelagic shells frequently present in them, and the depositions of manganese peroxide on many of the particles making up the deposits. Near some active volcanoes, however, there has evidently been a more rapid accumulation, as nearly all the mineral particles are fresh and unaltered, and there is but a slight admixture of pelagic organisms.

Around some coral reefs the accumulation must be rapid, for, although pelagic species with calcareous shells may be numerous in the surface waters, it is often impossible to detect more than an occasional pelagic shell among the other calcareous debris of the deposits.

The Pelagic Deposits as a whole, having regard to the nature and condition of their organic and mineralogical constituents, evidently accumulate at a much slower rate than

* See R. Bunsen in Taylor's Scientific Memoirs, Nat. Phil., vol. i. p. 69, 1852

the terrigenous deposits, in which the materials washed down from the land play so large a part. The Pteropod and Globigerina Oozes of the tropical regions, being chiefly made up of the calcareous shells of a much larger number of tropical species, must necessarily accumulate at a greater rate than the Globigerina Oozes in extra-tropical areas or other organic oozes. Diatom Ooze, being composed of both calcareous and siliceous organisms, has, again, a more rapid rate of deposition than the Radiolarian Ooze, while in a Red Clay there is a minimum rate of growth.

It has already been stated that cosmic spherules, sharks' teeth, the earbones and other bones of Cetaceans, are much more numerous in a Red Clay than in any other deposit, and it has been urged that the greater or less abundance of these might be taken as a measure of the rate of deposition. These spherules, teeth, and bones are abundant in the Red Clays, because few other substances there fall to the bottom to cover them up, and they thus form an appreciable part of the whole deposit. In the organic oozes and terrigenous deposits, however, a large number of additional substances contribute to form the bulk of the mud or ooze, and the chance of cosmic spherules, sharks' teeth, or earbones being dredged from these deposits is proportionally small, and as a matter of fact only a few have been obtained in these deposits.

The volcanic materials in a Red Clay having, because of the slow accumulation, been for a long time exposed to the action of sea-water, are profoundly altered, the decomposition being accompanied by the formation of clay, massive manganese-iron nodules, and zeolitic crystals, just as the formation of glauconite, phosphatic, calcareous, and barium nodules accompany the decomposition of terrigenous rocks and minerals in deposits nearer continental shores.

It has been argued by Dieulafait and others that the manganese of the manganese nodules has fallen from the surface and has accumulated in the red clay areas owing to the non-deposition of other substances. In opposition to this view it must be pointed out that some of the Challenger's largest hauls of manganese nodules were not in the red clay areas, but in Pteropod and Globigerina Oozes, or near volcanic cones. These Pteropod and Globigerina Oozes always contained a large quantity of volcanic glass, in a fine state of sub-division, and many minute particles of palagonite. In other Globigerina Oozes, where the rate of deposition must have been about the same or less, and where the volcanic particles were absent or relatively rare, only traces of manganese peroxide could be detected. For these reasons the abundance of manganese in a deposit cannot be looked upon as an index of the rate of deposition. The conditions in which manganese nodules and zeolitic crystals occur, frequently suggest the proximity of volcanic phenomena at the bottom of the sea, and no more instructive work could be undertaken than the exhaustive examination of one of these areas, that in the South Indian Ocean for example, where the surroundings suggest that the carbonate of lime shells have been removed from the deposit some time after deposition as a result of submarine volcanic action.

APPENDIX I.

EXPLANATION OF CHARTS AND DIAGRAMS.

CHARTS.

Chart 1 shows the distribution of Marine Deposits by means of Colours, and is compiled from the latest available information (see pages 247 and 248); the depths are represented by means of cross-ruling, and the track of the Challenger is indicated by a dotted line with arrows.

Charts 2 to 43 show the positions of the Sounding and Dredging Stations, nature of the Deposits, direction and force of the Wind and Surface Current, the following abbreviations and symbols being made use of:—

Figures enclosed thus, (37), indicate the position and distinguishing number of a Sounding, Dredging, or Trawling Station. Figures in block letter, thus, **2650**, indicate the depth in Fathoms.

The letters under the depth indicate the nature of the Deposit at the bottom:—

gl. oz.	signifying	Globigerina Ooze.	r. m.	signifying	Red Mud.
pt. oz.	,,	Pteropod Ooze.	bl. m.	,,	Blue Mud.
di. oz.	,,	Diatom Ooze.	calc.	,,	calcareous.
rad. oz.	,,	Radiolarian Ooze.	s.	,,	sand.
r. cl.	,,	Red Clay.	m.	,,	mud.
crl. m.	,,	Coral Mud.	st.	,,	stones.
crl. s.	,,	Coral Sand.	sh.	,,	shells.
volc. m.	,,	Volcanic Mud.	g.	,,	gravel.
volc. s.	,,	Volcanic Sand.	crl.	,,	Coral.
gr. m.	,,	Green Mud.	h. g.	,,	hard ground.
gr. s.	,,	Green Sand.			

Arrows thus, ↙, indicate the mean direction of the Wind, the number at the base giving the mean Force (in Beaufort's Scale). Arrows thus, ↙ 24, indicate the direction of the Surface Current, the numbers at the base giving the rate in miles per 24 hours.

The position of the Ship each day at Noon is indicated by a black dot. When the position at noon corresponds with a Sounding Station the black dot is replaced by the number of the Station. The day of the month is noted in hair line, thus, 25, and occasionally the month and year are also given, the month being shown in Roman figures, thus, 1. V. 74.

Chart

2. From England to the Canary Islands; also from Cape Verde Islands towards England.
3. In the vicinity of Lisbon.
4. In the vicinity of Madeira.
5. In the vicinity of the Canary Islands.
6. From Canary Islands to St. Thomas, St. Thomas to Bermuda, Bermuda to the Azores, Azores to Madeira, Madeira to Cape Verde Islands; also from Cape Verde Islands towards England.
7. In the vicinity of the Virgin Islands.
8. In the vicinity of Bermuda.
9. From Bermuda to Halifax, and Halifax to Bermuda.
10. In the vicinity of the Azores.
11. In the vicinity of the Cape Verde Islands.
12. From Cape Verde Islands to Bahia; also from Ascension to Cape Verde Islands.
13. In the vicinity of St. Paul's Rocks.
14. In the vicinity of Fernando Noronha.
15. In the vicinity of the Coast of Brazil.
16. From Bahia to the Cape of Good Hope; also from Monte Video to Ascension.
17. In the vicinity of the Tristan da Cunha Islands.
18. From the Cape of Good Hope to the parallel of 60° S.
19. In the vicinity of Prince Edward and Marion Islands.
20. In the vicinity of the Crozet Islands.
21. In the vicinity of Kerguelen Island.
22. In the vicinity of Heard Island.
23. In the neighbourhood of the Antarctic Circle, between the meridians of 78° and 98° E.
24. From a position in lat. 59° 56′ S., long. 99° 14′ E., to Melbourne.
25. From Melbourne to Sydney.
26. In the vicinity of Sydney.
27. From Sydney to Wellington, Wellington to the Fiji Islands, Fiji Islands to Cape York.
28. In the vicinity of Tongatabu.
29. In the vicinity of Matuku Island.
30. In the vicinity of Ngaloa Harbour, Fijis.
31. From Cape York to Hong Kong, Hong Kong to Yokohama.
32. In the vicinity of the Arrou and Ki Islands.
33. In the vicinity of the Banda Islands.
34. In the vicinity of Nares Harbour, Admiralty Islands.
35. In the vicinity of Japan.
36. From Yokohama to the Sandwich Islands.
37. In the vicinity of the Sandwich Islands.
38. From the Sandwich Islands to Tahiti, Tahiti to Valparaiso.
39. In the vicinity of Tahiti.
40. From Valparaiso to Port Otway.
41. From Port Otway through Magellan Strait.
42. From Magellan Strait to Falkland Islands, Falkland Islands to Monte Video.
43. In the vicinity of Ascension.

DIAGRAMS.

Diagrams 1 to 22 show the vertical distribution of Temperature, the relief of the Bottom of the Sea, the nature of the Deposits, and the percentages of Carbonate of Lime. In these Diagrams horizontal lengths or distances from Station to Station are on a scale of 200 miles to the inch, and the depths are on a scale of 500 fathoms to the inch, so that depths or heights, as compared with horizontal distances, are exaggerated in the proportion of 400 to 1. In looking, therefore, at the Plan as one of the bed of the area, it must be remembered that the inclines as observed were 400 times less steep than they are represented. The Diagrams show the isotherms for every five degrees, which were obtained by plotting the temperature observations on paper of equal squares and drawing the curves (the observations and curves are published as Part III. of the Physics and Chemistry of the Expedition).

In the Diagrams the thick *Horizontal lines* represent lines of equal temperature in Fahrenheit Scale. The figures above each *Vertical line*, thus, (87) 2650·68°, indicate, (87), the number of the Station, 68°, the Surface Temperature, and, 2650, the Depth in fathoms. The figures below each *Vertical line* indicate the temperature at the Bottom, the type of Deposit being given with the percentage of Carbonate of Lime underneath.

Diagram

1. Longitudinal section from Tenerife to Sombrero.
2. Diagonal section from Bermuda towards New York; also Meridional section from Halifax to St. Thomas.
3. Longitudinal section from Bermuda to the Azores and Madeira.
4. Longitudinal section from a position in lat. 3° 8′ N., long. 14° 39′ W., to Pernambuco.
5. Diagonal section from Abrolhos Island to Tristan da Cunha Islands.
6. Longitudinal section from Rio de la Plata to Tristan da Cunha Islands and the Cape of Good Hope.
7. Meridional section from the Azores to Tristan da Cunha Islands.
8. Meridional section from the Cape of Good Hope to the parallel of 46° S. lat.
9. Meridional section between the parallels of 50° and 65° S. lat.
10. Diagonal section from a position in lat. 53° 55′ S., long. 108° 35′ E., to Cape Otway.
11. Longitudinal section from Sydney to Porirua, Cook Strait, New Zealand.
12. Meridional section from Kandavu Island to Cape Palliser, New Zealand.
13. Longitudinal section from the Fiji Islands to the Barrier Reef, Australia.
14. Enclosed seas of the Eastern Archipelago.
15. Longitudinal section from Meangis Island to the Admiralty Islands.
16. Meridional section from the Admiralty Islands to Japan.
17. Longitudinal section from Japan to a position in lat. 35° 49′ N., long. 180° W.
18. Longitudinal section from a position in lat. 35° 49′ N., long. 180° W., to a position in lat. 38° 9′ N., long. 156° 25′ W.
19. Meridional section from the parallel of 38° N. to the parallel of 40° S. lat.
20. Longitudinal section from a position in lat. 40° 3′ S., long. 132° 58′ W., towards Mocha Island.
21. Meridional section from the parallel of 33° S. to the parallel of 46° S. lat., off the west coast of South America.
22. Meridional section from the Falkland Islands to the parallel of 35° 40′ S.

This Page is Blank

APPENDIX II.

REPORT on an ANALYTICAL EXAMINATION OF MANGANESE NODULES, with special reference to the PRESENCE or ABSENCE of the RARER ELEMENTS. By JOHN GIBSON, Ph.D., F.R.S.E.

The material subjected to analysis consisted of small and characteristically-shaped nodules, varying in size from about ¼ to ¾ inch in diameter. They were received from Mr Murray, labelled as follows:—

MANGANESE NODULES (medium size).

Station 285. 14th October 1875.
Lat. 32° 36′ S.; long. 137° 43′ W.
2375 fathoms.

A preliminary examination showed that these nodules consisted chiefly of hydrated oxides of manganese, iron, and aluminium, soluble in hydrochloric acid, together with a highly siliceous insoluble residue. No rare element was found in large quantity, so that it was obviously necessary for the purposes of this examination to operate upon a large quantity of the material. In carrying out the analyses special care was taken that the necessarily large quantities of the reagents employed should be minimised as far as possible, and every positive result was supplemented by cross tests, so as to ensure that the traces of the different elements found were really originally present in the nodules, and not derived from the reagents themselves, or from the vessels in which the various operations were carried out. In every case the possibility of such sources of error was made the subject of careful investigation, and from the outset the analytical methods adopted were chosen with special reference to this difficulty. The reagents used were rigorously tested, and in many cases specially prepared.

Spectroscopic Examination.

At first sight it might be supposed that a direct spectroscopic examination of the original material, or of its concentrated hydrochloric acid extract, would have gone far towards deciding as to the presence or absence of those elements at least which give characteristic spectra. The extreme delicacy of spectroscopic tests, when applied to relatively simple substances, is not unfrequently referred to in a manner which would lead one to suppose that qualitative analysis might, in the hands of a good spectroscopist, be reduced to the simple measurement of the lines present in the spectra of the substance to be analysed. Unfortunately it is not so. Repeated measurements of the lines in the very complex spectra produced by the original substance and its concentrated hydrochloric acid extracts when volatilised in a powerful electric spark, with and without the use of a condenser, and also in the electric arc, failed to give conclusive evidence, and in many cases even any indication of the presence of elements which subsequent analysis proved to be present. The various products of the preliminary examination were of course examined spectroscopically, and by the accurate measurement of the various characteristic lines, positive proof was obtained of the presence of a number of elements, which were present in so small quantity that their identification at that stage by other analytical methods would have been very difficult if not impossible. Amongst these may be mentioned—Lithium, Potassium, Barium, Strontium, Zinc, Thallium, and Titanium. Throughout the course of the final analyses spectroscopic measurements were made whenever practicable. The measurements were made with a Dewar and Liveing direct vision spectroscope, and in order to obtain the necessary data for the conversion into wave-lengths of the micrometer readings of this instrument, careful measurements were made of eighty bright lines characteristic of twenty different elements.

Qualitative Analysis.

150 grammes of the finely-powdered nodules were boiled in a large new Berlin porcelain basin with specially-prepared perfectly pure hydrochloric acid. After prolonged treatment the whole was evaporated to dryness, in order to separate any silica which might have gone into solution. The dry mass was then moistened with strong hydrochloric acid, and subsequently digested with dilute hydrochloric acid, and the solution filtered from the insoluble residue (A), which was thoroughly washed, dried, bottled, and weighed.

Through the solution a current of pure sulphuretted hydrogen gas was passed for two days, after which the small precipitate that had gradually formed was collected on a small filter, washed with water containing a little sulphuretted hydrogen, dried, bottled, and weighed (B).

The filtrate from B was boiled to drive off the excess of sulphuretted hydrogen, and after cooling mixed with a little sulphuric acid and about one-third of its volume of alcohol.

After standing for some days the small precipitate which had formed was collected on a small filter, washed, dried, bottled, and weighed (C).

The alcohol in the filtrate from C was then boiled off, and excess of pure oxalic acid added. An extremely small precipitate separated out on prolonged standing. It was collected on a small filter, ignited. The ignited precipitate weighed little more than one milligramme (D).

The filtrate from D was nearly neutralised with ammonia, whereupon a considerable precipitation took place, accompanied obviously by absorption of oxygen from the air. The precipitate (E) was collected on a filter, and washed with hot water.

A further precipitate (F) was obtained by prolonged exposure of the solution to the air. The filtered solution was then acidified with hydrochloric acid, and the oxalic acid present destroyed by addition of pure recrystallised potassium permanganate.

To the solution thus obtained ammonia and ammonium sulphide were added to precipitate the metals of the iron group. The bulky precipitate was collected on two large filters, and washed with water containing ammonium sulphide. The filtrate was evaporated to dryness in large platinum basins, and the residue gently ignited, in order to drive off ammoniacal salts. The residue was bottled (G).

The iron group precipitate was treated in a closed flask with 5 per cent. hydrochloric acid, prepared by diluting 20 per cent. acid with sulphuretted hydrogen water. After standing two days the undissolved residue was filtered off and washed with hot water containing a little sulphuretted hydrogen, dried, bottled, and weighed (H).

The filtrate from H was evaporated to dryness in a platinum basin, and the residue treated with strong sulphuric acid. The resulting sulphates were ignited in small portions at a dull red heat in a platinum basin, in order to decompose the sulphates of iron and aluminium, &c. From time to time small portions of the ignited sulphates were extracted with water, and the filtered solution tested with ammonium sulphide. As soon as the ammonium sulphide gave a pure flesh-coloured precipitate of sulphide of manganese the ignition was stopped.

After the whole mass had been treated in this manner, it was boiled with water and filtered. The filtrate on evaporation gave a large residue of practically pure manganese sulphate (I).

The residue insoluble in water was ignited and bottled (K).

By this means the bulk of the manganese was separated from the other metals of the iron group without the use of any special reagent.

The 150 grammes of manganese nodules originally taken were thus split up into ten fractions of simpler though still, for the most part, complex composition.

Each of these fractions was subjected to a rigorous qualitative, and in several cases quantitative, analysis. Whenever practicable, the various products of analysis were examined spectroscopically and the principal lines measured.

The following is a brief summary of the results arrived at:—

A. Chiefly silica and silicates.

The results of a full quantitative analysis of a similar insoluble residue obtained from another portion of the nodules are given in Table III.

B. Sulphides of copper, lead, and molybdenum.
No arsenic, antimony, or tin.
No bismuth, cadmium, or mercury.

C. Calcium sulphate, containing merely spectroscopic traces of barium and strontium.

D. The hydrochloric acid solution of this small precipitate gave no characteristic emission or absorption spectrum.
Yttrium and cerium group metals absent.

E. and F. These precipitates contained iron, aluminium, and manganese. Yttrium and cerium group metals absent. Uranium, chromium, beryllium, and titanium absent.

G. This residue consisted chiefly of potassium chloride, derived from the potassium permanganate used. Sodium, magnesium, and a mere trace of lithium were also found. Traces of copper and iron group metals were also present.
Rubidium and cæsium were searched for spectroscopically but not found.

H. Consisted chiefly of sulphides of iron, nickel, and cobalt, along with a little thallium.

I. Practically pure manganese sulphate.

K. Elements found—Iron, aluminium, manganese, a trace of zinc. Uranium, beryllium, &c., searched for but not found.

Quantitative Analysis.

The qualitative analysis above described having been completed, the general outlines of a scheme for the quantitative analysis of these nodules were sketched out, based upon the qualitative results arrived at. In order to facilitate adherence to this scheme, a diagrammatic plan of the various operations was drawn up; and in order to maintain a clear and systematic account of the progress of the very complex and protracted investigation, this diagrammatic plan was filled in in detail as the written notes of the work done accumulated. During the course of the analysis this system of double record proved very useful, as it was always possible by referring to the diagram to get a rapid oversight of the work done or remaining to be done. When completed, the diagram appeared to give so full and clear a representation of the whole course of the analysis that it was decided to print it without alteration rather than to attempt a written account, which could hardly have failed to be difficult to follow. The diagram is therefore reproduced on the accompanying sheet. A brief account of the quantitative determinations not included in this diagram must, however, be given.

Analysis of the Insoluble Residue left on treating 200 *grammes of the Nodules with Hydrochloric Acid.*—The composition of this residue, which was dried *in vacuo* over sulphuric acid to constant weight, proved, after exhaustive qualitative analysis, to be comparatively simple. No special difficulties were therefore met with in the course of the quantitative analysis.

The loss on ignition was found to correspond exactly with direct estimations of the water contained in the residue after drying *in vacuo* over sulphuric acid to constant weight.

Table III. gives the percentage composition of the water-free residue.

A preliminary determination of silica gave 13·22 per cent. A second most careful determination with a larger quantity gave 13·38 per cent. This latter number was adopted as being certainly the more accurate.

On treating the crude silica with ammonium fluoride and sulphuric acid, a residue, consisting chiefly of titanic acid, was left. This residue was of course allowed for in calculating the percentage of silica.

The titanium was estimated with great care, being precipitated repeatedly by boiling the dilute sulphuric acid solution.

Analysis of the Aqueous Extract.—46·732 grammes of the powdered nodules were exhausted repeatedly with boiling water.

The complete extraction with water proved to be exceedingly tedious, and the solution was only obtained clear after repeated filtration. Aliquot portions were used for the determination of—(*a*) Total bases as sulphate; (*b*) potassium and sodium; (*c*) lithium; (*d*) chlorine; (*e*) sulphuric acid. Traces of calcium and magnesium were also found and estimated.

For the quantitative composition of the extract see Table I., column III.

The residue, insoluble in water, still contained sulphates, but no chlorides. The sulphuric acid was determined in a separate portion of the nodules.

Estimation of Water.—7·5337 grammes of the powdered nodules lost 1·7330 grammes on drying at 110° C. to constant weight. This is equivalent to 23·00 per cent.

A direct determination of the water evolved on heating to redness in a platinum boat gave, on the other hand, 29·83 per cent. of water. As the water collected in the bulb of the absorption tube was slightly acid, two further direct estimations were made, using freshly-ignited oxide of lead to keep back acid vapours. These determinations gave 29·64 and 29·67 per cent. of water respectively. The mean of these determinations, 29·65, was adopted.

Estimation of Peroxide-Oxygen.—These determinations were made by Bunsen's well-known method.

The standard thio-sulphate solution used was titrated against pure iodine, prepared according to Stas.

Three determinations gave 4·67, 4·71, and 4·75 per cent. of peroxide-oxygen respectively. The mean of these determinations, 4·71 per cent., was adopted.

Assuming the whole of this peroxide-oxygen to be present as MnO_2, the percentage of this compound would be 25·61, which corresponds to 20·90 per cent. MnO, as against 21·46 actually found. This assumption, however, is at once improbable and incapable of proof. It is at least equally probable that the cobalt, nickel, and thallium are all present as peroxides.

Fluorine.—An attempt was made to determine the fluorine in about 6 grammes of the nodules. The calcium fluoride ultimately obtained weighed less than a milligramme (0·0006 per cent.), so that fluorine, although undoubtedly present, is so in quantity too small to be accurately determined by any of the recognised methods, at least without undertaking a special research.

Estimation of Ammonia.—Only one estimation was made. About 6 grammes of the nodules were distilled with strong caustic soda solution, the distillate collected in hydrochloric acid, and the ammonia determined gravimetrically by precipitation with platinum chloride. From the weight of metallic platinum obtained the percentage of $(NH_4)_2O$ was calculated, and found to be 0·016 per cent. of the manganese nodules taken.

Estimation of Carbonic Acid.—After addition of excess of ferrous sulphate and of silver sulphate (in order to prevent liberation of chlorine), weighed portions of the powdered nodules were boiled with dilute sulphuric acid in a flask connected with a Liebig's condenser, chloride of calcium tubes, and finally potash bulbs. During the operation a slow current of pure air was passed through the apparatus.

Two estimations gave identical results, viz., 0·29 per cent. CO_2.

Estimation of Sulphuric Acid.—2·0347 grammes of the nodules were fused with sodium carbonate, the fuse thoroughly extracted with water, and the sulphuric acid determined in the usual manner.

0·83 per cent. SO_3 was obtained.

The sulphuric acid determined in an aliquot portion of the aqueous extract obtained by boiling 46·732 grammes of the nodules amounted only to 0·36 per cent., so that, unlike the chlorine, the sulphuric acid is chiefly present in the nodules in insoluble combinations.

The final results of the analysis are given in Tables I., II., and III.

Column I., Table I., gives the percentage composition of the powdered nodules without making any deduction for hygroscopic moisture.

Columns II. and III., Table I., give the percentages belonging to the residue insoluble in hydrochloric acid and to the aqueous extract.

Table II. gives the percentage composition after deducting the water, the residue insoluble in hydrochloric acid, and the aqueous extract.

Table III. gives the percentage composition of the residue insoluble in hydrochloric acid.

In conclusion, I desire to acknowledge most gratefully the kind and valuable assistance which I have received from friends and students in the course of my analysis. The spectroscopic examination and the earlier qualitative analyses were carried out in conjunction with Mr. F. M. Gibson, B.Sc. The final quantitative analysis, down to the subdivision into aliquot portions of the filtrate from the sulphuretted hydrogen precipitate, was carried out in conjunction with Mr. J. S. Ford, to whom I am specially indebted for his skilful and painstaking assistance. My thanks are also due to Mr. A. King, Dr. T. R. Marshall, and Dr. J. Shields, for their kind assistance, more particularly in carrying out a number of control determinations.

The investigation, by the kind permission of Professor Crum Brown, was carried out from first to last in the Chemical Laboratory of the University of Edinburgh.

TABLE I.

	I. Total.	II. In Insoluble Residue.	III. In Aqueous Extract.
H_2O,	29·65	...	...
Li_2O,	trace	...	trace
Na_2O,	1·81	0·65	1·16
K_2O,	0·25	0·17	0·08
$(NH_4)_2O$,	0·02	...	0·02
MgO,	2·34	...	0·04
CaO,	2·31	0·26	0·04
SrO,	0·02	0·02	...
BaO,	0·12	0·12	...
MnO,	21·46	trace	...
CoO,	0·28	...	...
NiO,	0·98	...	...
ZnO,	0·10	...	...
Tl_2O,	0·03	...	...
Fe_2O_3,	14·33	0·86	...
Al_2O_3,	5·49	2·32	...
CuO,	0·37	...	...
PbO,	0·05	...	...
MoO_3,	0·10	...	...
SO_3,	0·83	...	0·36
Te,	trace	...	...
Cl_2-O,	0·74	...	0·74
F,	trace	...	...
P_2O_5,	0·13	0·02	...
Vd_2O_5,	0·07	...	...
CO_2,	0·29	...	...
SiO_2,	13·38	13·38	...
TiO_2,	0·13	0·13	...
O (peroxide-oxygen),	4·71	...	...
	99·99	17·93	2·44

TABLE II.

Percentage Composition after deducting the Water, the Insoluble Residue, and the Aqueous Extract.

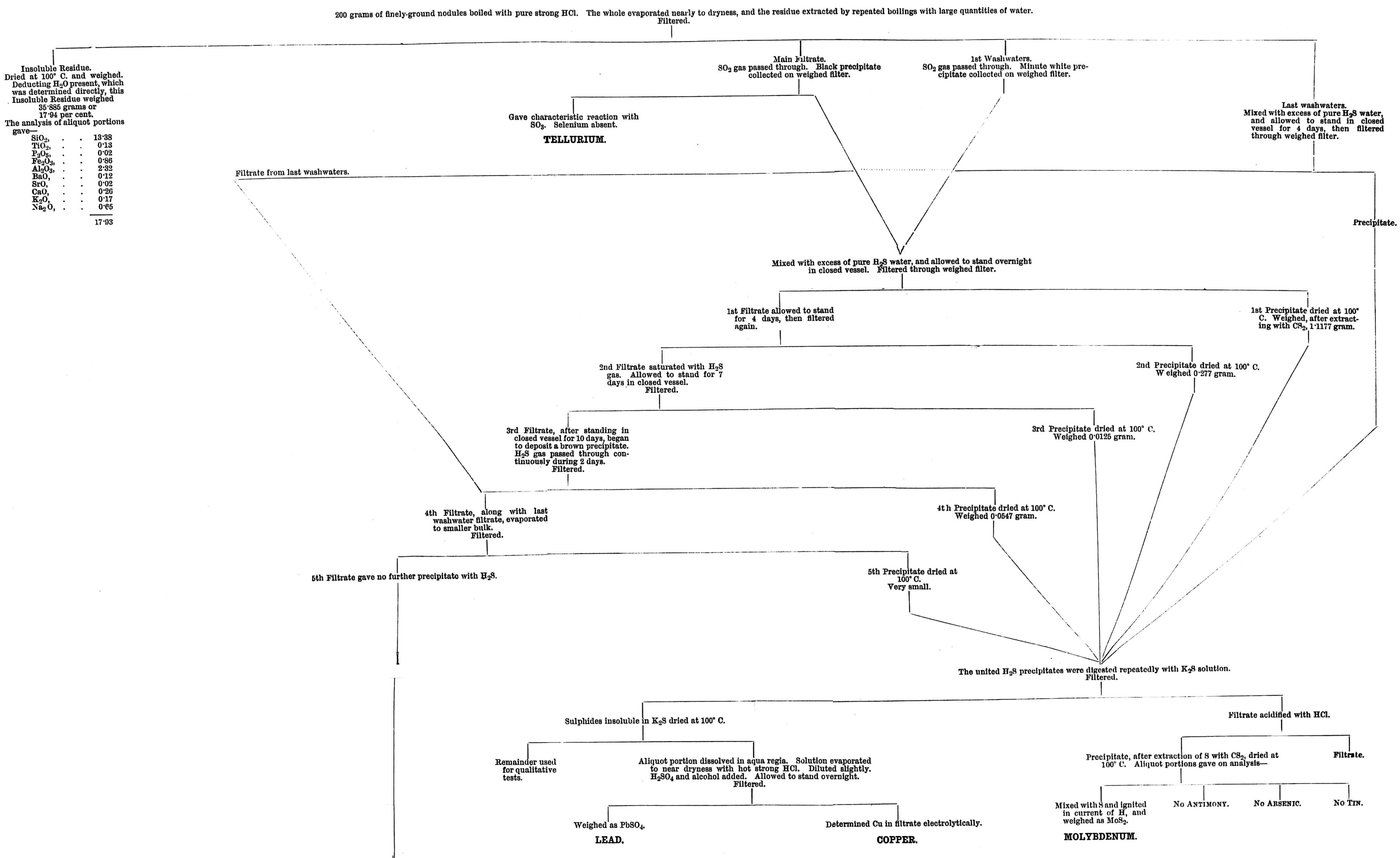
MgO,	4·60
CaO,	4·02
MnO,	42·94
NiO,	1·96
CoO,	0·56
ZnO,	0·20
Tl_2O,	0·06
Fe_2O_3,	26·97
Al_2O_3,	6·34
CuO,	0·74
PbO,	0·10
MoO_3,	0·20
SO_3,	0·94
CO_2,	0·58
P_2O_5,	0·22
Vd_2O_5,	0·14
Peroxide-oxygen,	9·42
	99·99

TABLE III.

Percentage composition of Insoluble Residue.

Na_2O,	3·62
K_2O,	0·95
CaO,	1·45
SrO,	0·11
BaO,	0·67
Fe_2O_3,	4·79
Al_2O_3,	12·93
P_2O_5,	0·11
SiO_2,	74·58
TiO_2,	0·72
	99·93

APPENDIX II.—DIAGRAM OF ANALYSIS.



Weight of solution after further evaporation was 3178·51 grams.
Divided into five portions.

367·47 grams.

917·83 grams.
Digested for 10 days with excess of pure Zinc.
Filtered.

Very small black precipitate.
Examined spectroscopically.
Thallium not found.

Filtrate.
Aliquot portions used for determination of Fe by titration.

297·0 grams.
Kept in reserve.

408·45 grams.

After removal of Cl by $AgNO_3$, the Phosphoric Acid precipitated by Ammonium Molybdate, and ultimately weighed as $Mg_2P_2O_7$. The filtrate from the Ammonium Phospho-Molybdate was allowed to stand in a closed vessel for several months, and then filtered from a further small precipitate.

PHOSPHORIC ACID.

1187·40 grams.

Boiled for several hours after addition of a large excess of Ammonium Polysulphide. Filtered.

Precipitate.
Digested with 12 per cent. HCl saturated with H_2S. Filtered.

Filtrate.
Precipitated again with $(NH_4)_2S$, filtered, and digested precipitate with H_2S water containing acetic acid and a little HCl. After standing 12 hours in closed vessel.
Filtered.

Filtrate.
Evaporated to small bulk. Re-precipitated with $(NH_4)_2S$. Found to contain traces of Ni and Co.

Precipitate.
Sulphides dissolved in strong HNO_3. The solution reduced by evaporating with excess of H_2SO_4 and subsequent boiling with SO_2 solution. KI added. After several days' standing, the precipitate, TlI, was collected on a weighed filter, dried at 100° C., and weighed.

THALLIUM.

Precipitate.
Sulphides dissolved in aqua regia, the solution reduced by evaporating with excess of H_2SO_4 and subsequent boiling with SO_2 solution. The concentrated solution gave no precipitate with KI, and therefore contained no Thallium.

Filtrate.
Acidified with HCl. The precipitated sulphur was pure and perfectly white, and was completely soluble in CS_2.

No VANADIUM.

$CaSO_4$ precipitated by addition of H_2SO_4 and Alcohol. Filtered after standing many days. Evaporated filtrate to small bulk, and added 4 vols. of Alcohol. Filtered from further portion of $CaSO_4$ (about ⅛ of total precipitate) after standing 48 hours.

Precipitate.
Ignited and weighed as $CaSO_4$. Dissolved in HCl, and added $(NH_4)OH$ and $(NH_4)_2S$.
Filtered.

Filtrate.
Precipitated lime with $Am\bar{O}$ and weighed as CaO.

LIME.

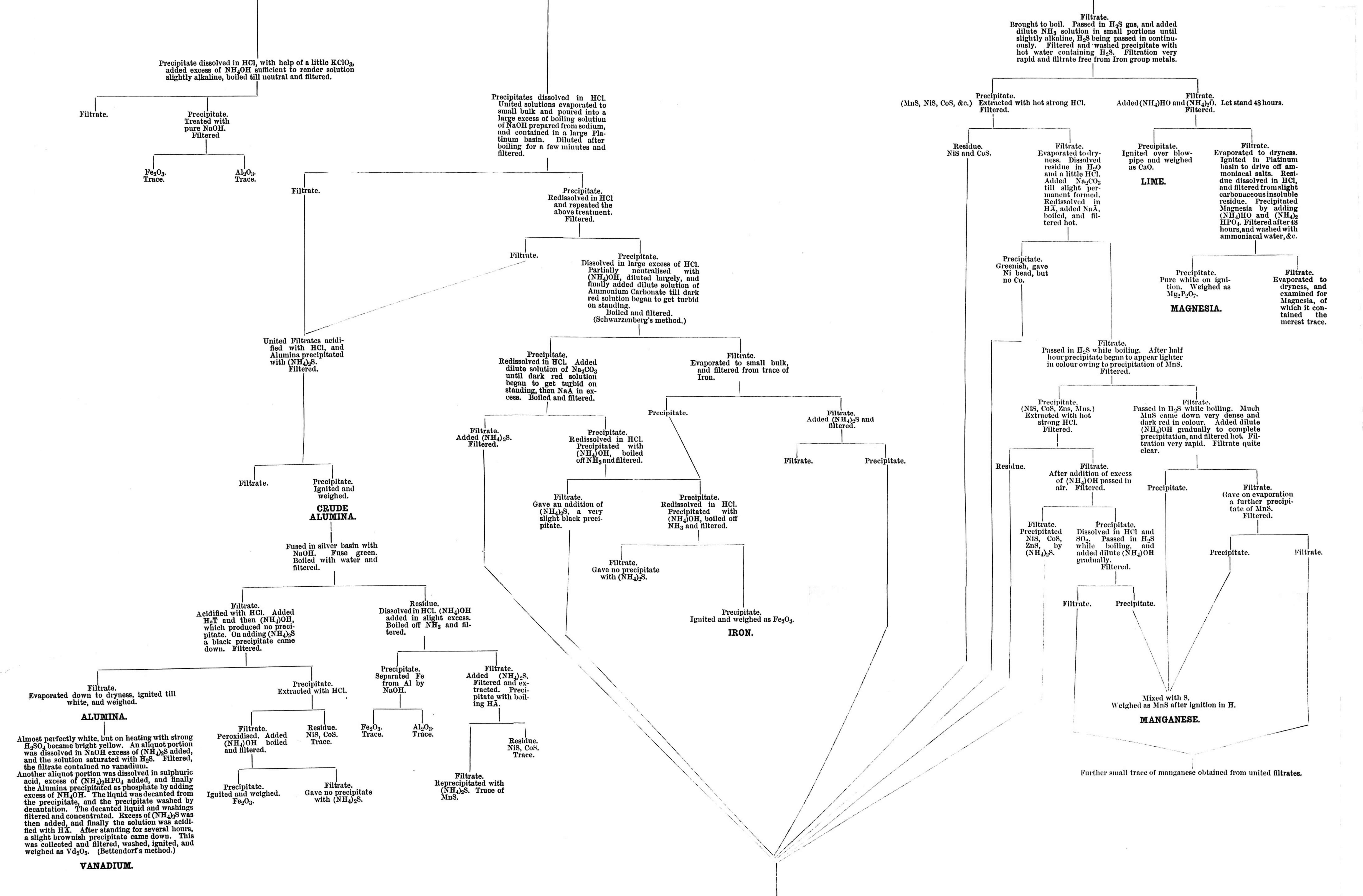
Precipitate.

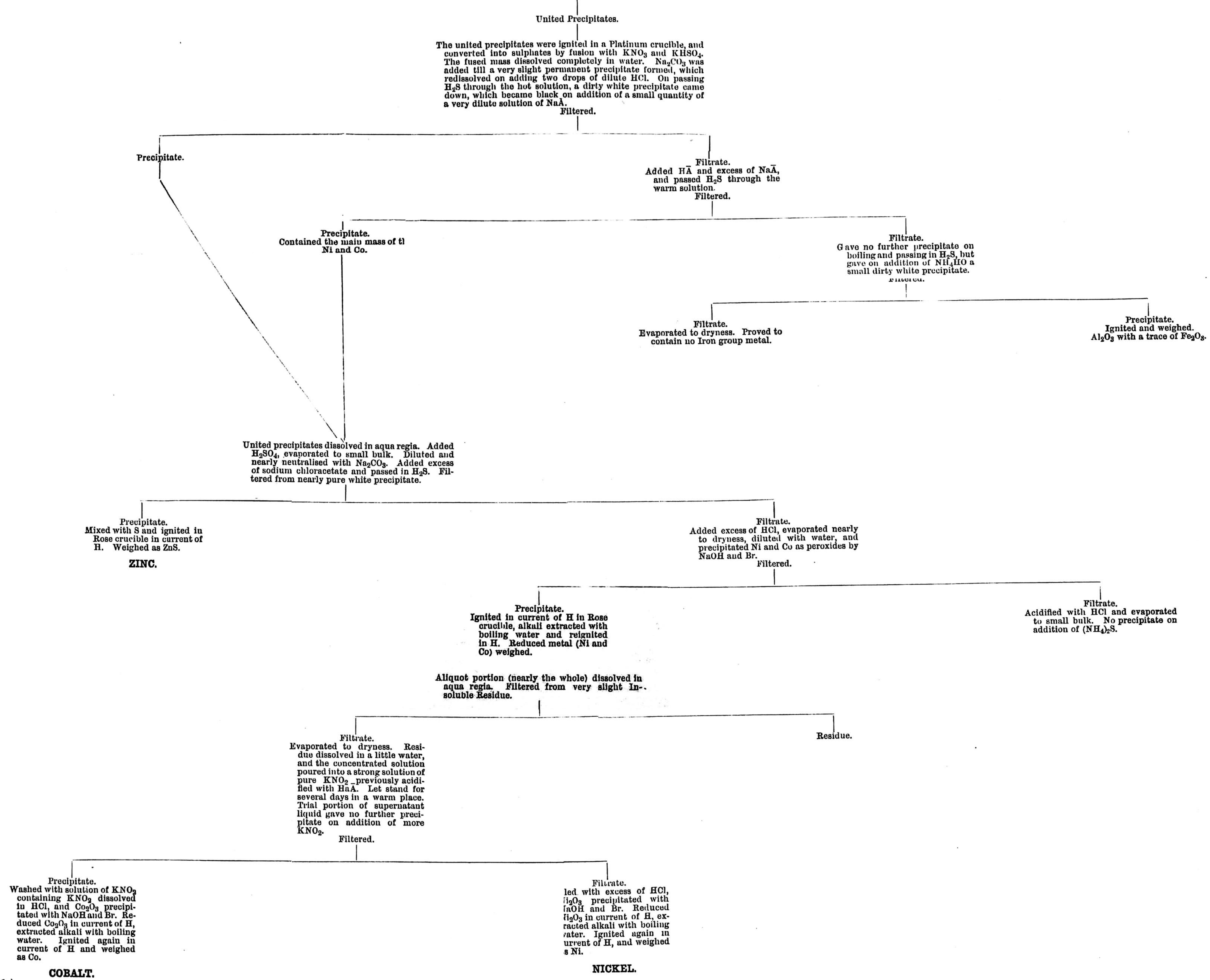
Filtrate.
Evaporated to smaller bulk, and added a further quantity of Alcohol. This produced precipitation of salts other than $CaSO_4$. Evaporated to dryness. Dissolved residue in HCl. Added Ammonium Carbonate to very slightly turbid solution, then $(NH_4)\bar{A}$, and boiled. Filtered hot.

Precipitate.

Filtrate.
Evaporated to small bulk, and filtered from slight precipitate.

Precipitate.


Filtrate.
Brought to boil. Passed in H_2S gas, and added dilute NH_3 solution in small portions until slightly alkaline, H_2S being passed in continuously. Filtered and washed precipitate with hot water containing H_2S. Filtration very rapid and filtrate free from Iron group metals.
Precipitate dissolved in HCl, with help of a little $KClO_3$, added excess of NH_4OH sufficient to render solution slightly alkaline, boiled till neutral and filtered.
Filtrate.
Precipitate. Treated with pure NaOH. Filtered
Fe_2O_3. Trace.
Al_2O_3. Trace.
Precipitates dissolved in HCl. United solutions evaporated to small bulk and poured into a large excess of boiling solution of NaOH prepared from sodium, and contained in a large Platinum basin. Diluted after boiling for a few minutes and filtered.
Filtrate.
Precipitate. Redissolved in HCl and repeated the above treatment. Filtered.
Filtrate.
Precipitate. Dissolved in large excess of HCl. Partially neutralised with $(NH_4)OH$, diluted largely, and finally added dilute solution of Ammonium Carbonate till dark red solution began to get turbid on standing. Boiled and filtered. (Schwarzenberg's method.)
United Filtrates acidified with HCl, and Alumina precipitated with $(NH_4)_2S$. Filtered.
Filtrate.
Precipitate. Ignited and weighed.
CRUDE ALUMINA.
Fused in silver basin with NaOH. Fuse green. Boiled with water and filtered.
Filtrate. Acidified with HCl. Added H_2T and then $(NH_4)OH$, which produced no precipitate. On adding $(NH_4)_2S$ a black precipitate came down. Filtered.
Filtrate. Evaporated down to dryness, ignited till white, and weighed.
ALUMINA.
Almost perfectly white, but on heating with strong H_2SO_4 became bright yellow. An aliquot portion was dissolved in NaOH excess of $(NH_4)_2S$ added, and the solution saturated with H_2S. Filtered, the filtrate contained no vanadium.
Another aliquot portion was dissolved in sulphuric acid, excess of $(NH_4)_2HPO_4$ added, and finally the Alumina precipitated as phosphate by adding excess of NH_4OH. The liquid was decanted from the precipitate, and the precipitate washed by decantation. The decanted liquid and washings filtered and concentrated. Excess of $(NH_4)_2S$ was then added, and finally the solution was acidified with HĀ. After standing for several hours, a slight brownish precipitate came down. This was collected and filtered, washed, ignited, and weighed as Vd_2O_5. (Bettendorf's method.)
VANADIUM.
Precipitate. Extracted with HCl.
Filtrate. Peroxidised. Added $(NH_4)OH$ boiled and filtered.
Residue. NiS, CoS. Trace.
Precipitate. Ignited and weighed. Fe_2O_3.
Filtrate. Gave no precipitate with $(NH_4)_2S$.
Residue. Dissolved in HCl. $(NH_4)OH$ added in slight excess. Boiled off NH_3 and filtered.
Precipitate. Separated Fe from Al by NaOH.
Fe_2O_3. Trace.
Al_2O_3. Trace.
Filtrate. Added $(NH_4)_2S$. Filtered and extracted. Precipitate with boiling HĀ.
Filtrate. Reprecipitated with $(NH_4)_2S$. Trace of MnS.
Residue. NiS, CoS. Trace.
Precipitate. Redissolved in HCl. Added dilute solution of Na_2CO_3 until dark red solution began to get turbid on standing, then NaĀ in excess. Boiled and filtered.
Filtrate. Added $(NH_4)_2S$. Filtered.
Precipitate. Redissolved in HCl. Precipitated with $(NH_4)OH$, boiled off NH_3 and filtered.
Filtrate. Gave an addition of $(NH_4)_2S$, a very slight black precipitate.
Precipitate. Redissolved in HCl. Precipitated with $(NH_4)OH$, boiled off NH_3 and filtered.
Filtrate. Gave no precipitate with $(NH_4)_2S$.
Precipitate. Ignited and weighed as Fe_2O_3.
IRON.
Filtrate. Evaporated to small bulk, and filtered from trace of Iron.
Precipitate.
Filtrate. Added $(NH_4)_2S$ and filtered.
Filtrate.
Precipitate.
Precipitate. (MnS, NiS, CoS, &c.) Extracted with hot strong HCl. Filtered.
Residue. NiS and CoS.
Filtrate. Evaporated to dryness. Dissolved residue in H_2O and a little HCl. Added Na_2CO_3 till slight permanent formed. Redissolved in HĀ, added NaĀ, boiled, and filtered hot.
Precipitate. Greenish, gave Ni bead, but no Co.
Filtrate. Passed in H_2S while boiling. After half hour precipitate began to appear lighter in colour owing to precipitation of MnS. Filtered.
Precipitate. (NiS, CoS, ZnS, MnS.) Extracted with hot strong HCl. Filtered.
Residue.
Filtrate. After addition of excess of $(NH_4)OH$ passed in air. Filtered.
Filtrate. Precipitated NiS, CoS, ZnS, by $(NH_4)_2S$.
Precipitate. Dissolved in HCl and SO_2. Passed in H_2S while boiling, and added dilute $(NH_4)OH$ gradually. Filtered.
Filtrate.
Precipitate.
Filtrate. Passed in H_2S while boiling. Much MnS came down very dense and dark red in colour. Added dilute $(NH_4)OH$ gradually to complete precipitation, and filtered hot. Filtration very rapid. Filtrate quite clear.
Precipitate.
Filtrate. Gave on evaporation a further precipitate of MnS. Filtered.
Precipitate.
Filtrate.
Mixed with S. Weighed as MnS after ignition in H.
MANGANESE.
Further small trace of manganese obtained from united filtrates.
Filtrate. Added $(NH_4)HO$ and $(NH_4)_2O$. Let stand 48 hours. Filtered.
Precipitate. Ignited over blowpipe and weighed as CaO.
LIME.
Filtrate. Evaporated to dryness. Ignited in Platinum basin to drive off ammoniacal salts. Residue dissolved in HCl, and filtered from slight carbonaceous insoluble residue. Precipitated Magnesia by adding $(NH_4)HO$ and $(NH_4)_2HPO_4$. Filtered after 48 hours, and washed with ammoniacal water, &c.
Precipitate. Pure white on ignition. Weighed as $Mg_2P_2O_7$.
MAGNESIA.
Filtrate. Evaporated to dryness, and examined for Magnesia, of which it contained the merest trace.


United Precipitates.
The united precipitates were ignited in a Platinum crucible, and converted into sulphates by fusion with KNO_3 and $KHSO_4$. The fused mass dissolved completely in water. Na_2CO_3 was added till a very slight permanent precipitate formed, which redissolved on adding two drops of dilute HCl. On passing H_2S through the hot solution, a dirty white precipitate came down, which became black on addition of a small quantity of a very dilute solution of $Na\bar{A}$. Filtered.
Precipitate.
Filtrate. Added $H\bar{A}$ and excess of $Na\bar{A}$, and passed H_2S through the warm solution. Filtered.
Precipitate. Contained the main mass of tl Ni and Co.
Filtrate. Gave no further precipitate on boiling and passing in H_2S, but gave on addition of NH_4HO a small dirty white precipitate. Filtered.
Filtrate. Evaporated to dryness. Proved to contain no Iron group metal.
Precipitate. Ignited and weighed. Al_2O_3 with a trace of Fe_2O_3.
United precipitates dissolved in aqua regia. Added H_2SO_4, evaporated to small bulk. Diluted and nearly neutralised with Na_2CO_3. Added excess of sodium chloracetate and passed in H_2S. Filtered from nearly pure white precipitate.
Precipitate. Mixed with S and ignited in Rose crucible in current of H. Weighed as ZnS.
ZINC.
Filtrate. Added excess of HCl, evaporated nearly to dryness, diluted with water, and precipitated Ni and Co as peroxides by NaOH and Br. Filtered.
Precipitate. Ignited in current of H in Rose crucible, alkali extracted with boiling water and reignited in H. Reduced metal (Ni and Co) weighed.
Filtrate. Acidified with HCl and evaporated to small bulk. No precipitate on addition of $(NH_4)_2S$.
Aliquot portion (nearly the whole) dissolved in aqua regia. Filtered from very slight Insoluble Residue.
Filtrate. Evaporated to dryness. Residue dissolved in a little water, and the concentrated solution poured into a strong solution of pure KNO_2 previously acidified with $H\bar{A}$. Let stand for several days in a warm place. Trial portion of supernatant liquid gave no further precipitate on addition of more KNO_2. Filtered.
Residue.
Precipitate. Washed with solution of KNO_3 containing KNO_2 dissolved in HCl, and Co_2O_3 precipitated with NaOH and Br. Reduced Co_2O_3 in current of H, extracted alkali with boiling water. Ignited again in current of H and weighed as Co.
COBALT.
Filtrate. led with excess of HCl, i_2O_3 precipitated with laOH and Br. Reduced i_2O_3 in current of H, extracted alkali with boiling vater. Ignited again in urrent of H, and weighed s Ni.
NICKEL.

This Page is Blank

APPENDIX III.

CHEMICAL ANALYSES.

The following analyses have been made during the Examination of the Challenger Deep-Sea Deposits by different analysts, and have been nearly all referred to in the body of the work. *The name of the analyst is affixed to each analysis immediately after the locality.*

1. Red Clay (after the finer parts had been washed away).—Station 5.

Lat. 24° 20′ N., long. 24° 28′ W., 2740 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	8·20
Portion soluble in Hydrochloric Acid = 77·30	Alumina,	4·70
	Ferric oxide,	3·50
	Calcium phosphate,	trace
	Calcium sulphate,	0·70
	Calcium carbonate,	56·39
	Magnesium carbonate,	0·98
	Silica,	11·03
Portion insoluble in Hydrochloric Acid = 14·50	Alumina,	1·80
	Ferric oxide,	0·80
	Lime,	0·50
	Magnesia,	0·40
	Silica,	11·00
		100·00

2. Red Clay (after the finer parts had been washed away).—Station 5.

Lat. 24° 20′ N., long. 24° 28′ W., 2740 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	2·60
Portion soluble in Hydrochloric Acid = 82·84	Alumina,	2·15
	Ferric oxide,	4·76
	Calcium phosphate,	2·09
	Manganese oxide,	...
	Calcium sulphate,	0·29
	Calcium carbonate,	60·29
	Magnesium carbonate,	0·72
	Silica,	12·54
Portion insoluble in Hydrochloric Acid = 14·56	Alumina,	3·13
	Ferric oxide,	0·84
	Lime,	0·68
	Magnesia,	0·11
	Silica,	9·80
		100·00

3. Red Clay.—Station 7.

Lat. 23° 23′ N., long. 31° 31′ W., 2750 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·45
Portion soluble in Hydrochloric Acid = 52·98 =	Alumina,	6·40
	Ferric oxide,	15·42
	Calcium phosphate,	trace
	Calcium sulphate,	1·60
	Calcium carbonate,	4·11
	Magnesium carbonate,	1·20
	Silica,	24·25
Portion insoluble in Hydrochloric Acid = 39·57 =	Alumina,	6·00
	Ferric oxide,	2·54
	Lime,	1·06
	Magnesia,	0·64
	Silica,	29·33
		100·00

4. Red Clay.—Station 8.

Lat. 23° 12′ N., long. 32° 56′ W., 2700 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	8·95
Portion soluble in Hydrochloric Acid = 63·01 =	Alumina,	8·95
	Ferric oxide,	9·70
	Calcium phosphate,	large trace
	Calcium sulphate,	2·24
	Calcium carbonate,	16·42
	Magnesium carbonate,	2·70
	Silica,	23·00
Portion insoluble in Hydrochloric Acid = 28·04 =	Alumina,	4·20
	Ferric oxide,	2·10
	Lime,	0·89
	Magnesia,	0·60
	Silica,	20·25
		100·00

5. Red Clay.—Station 9.

Lat. 23° 23′ N., long. 35° 16′ W., 3150 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	10·40
Portion soluble in Hydrochloric Acid = 43·74 =	Alumina,	8·30
	Ferric oxide,	9·75
	Calcium phosphate,	good trace
	Calcium sulphate,	0·87
	Calcium carbonate,	3·11
	Magnesium carbonate,	1·90
	Silica,	19·81
Portion insoluble in Hydrochloric Acid = 45·86 =	Alumina,	9·10
	Ferric oxide,	2·04
	Lime,	0·47
	Magnesia,	0·95
	Silica,	33·30
		100·00

6. RED CLAY.—Station 10.

Lat. 23° 10′ N., long. 38° 42′ W., 2720 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·61
Portion soluble in Hydrochloric Acid = 58·98	Alumina,	9·73
	Ferric oxide,	9·80
	Calcium phosphate,	...
	Calcium sulphate,	0·61
	Calcium carbonate,	13·30
	Magnesium carbonate,	1·81
	Silica,	24·73
Portion insoluble in Hydrochloric Acid = 33·41	Alumina,	5·50
	Ferric oxide,	2·96
	Lime,	0·23
	Magnesia,	0·19
	Silica,	24·53
		100·00

7. RED CLAY.—Station 18.

Lat. 19° 41′ N., long. 55° 13′ W., 2650 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·75
Portion soluble in Hydrochloric Acid = 60·00	Alumina,	8·25
	Ferric oxide,	11·37
	Calcium phosphate,	0·42
	Calcium sulphate,	0·52
	Calcium carbonate,	15·78
	Magnesium carbonate,	1·41
	Silica,	22·25
Portion insoluble in Hydrochloric Acid = 32·25	Alumina,	7·00
	Ferric oxide,	2·50
	Lime,	0·57
	Magnesia,	0·38
	Silica,	21·80
		100·00

8. RED CLAY.—Station 19.

Lat. 19° 15′ N., long. 57° 47′ W., 3000 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·44
Portion soluble in Hydrochloric Acid = 56·47	Alumina,	12·91
	Ferric oxide,	10·33
	Calcium phosphate,	trace
	Calcium sulphate,	0·96
	Calcium carbonate,	1·49
	Magnesium carbonate,	3·10
	Silica,	27·68
Portion insoluble in Hydrochloric Acid = 36·09	Alumina,	7·81
	Ferric oxide,	1·57
	Lime,	1·03
	Magnesia,	0·52
	Silica,	25·16
		100·00

9. Red Clay.—Station 20.

Lat. 18° 56′ N., long. 59° 35′ W., 2975 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·45
Portion soluble in Hydrochloric Acid = 56·83	Alumina,	12·28
	Ferric oxide,	11·44
	Calcium phosphate,	small trace
	Calcium sulphate,	1·47
	Calcium carbonate,	3·50
	Magnesium carbonate,	2·14
	Silica,	26·00
Portion insoluble in Hydrochloric Acid = 35·72	Alumina,	7·28
	Ferric oxide,	2·36
	Lime,	1·18
	Magnesia,	0·50
	Silica,	24·40
		100·00

10. Red Clay.—Station 21.

Lat. 18° 54′ N., long. 61° 28′ W., 3025 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·92
Portion soluble in Hydrochloric Acid = 50·42	Alumina,	7·04
	Ferric oxide,	12·25
	Calcium phosphate,	small trace
	Calcium sulphate,	0·51
	Calcium carbonate,	2·44
	Magnesium carbonate,	3·48
	Silica,	24·70
Portion insoluble in Hydrochloric Acid = 43·66	Alumina,	5·51
	Ferric oxide,	6·73
	Lime,	0·81
	Magnesia,	0·41
	Silica,	30·20
		100·00

11. Red Clay.—Station 27.

Lat. 22° 49′ N., long. 65° 19′ W., 2960 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·25
Portion soluble in Hydrochloric Acid = 44·16	Alumina,	6·50
	Ferric oxide,	7·83
	Calcium phosphate,	1·67
	Manganese oxide,	good trace
	Calcium sulphate,	trace
	Calcium carbonate,	3·25
	Magnesium carbonate,	1·13
	Silica	23·78
Portion insoluble in Hydrochloric Acid = 51·59	Alumina,	10·19
	Ferric oxide,	4·29
	Lime,	1·61
	Magnesia,	0·33
	Silica,	35·17
		100·00

12. RED CLAY (after the finer parts had been washed away).—Station 160.

Lat. 42° 42′ S., long. 134° 10′ E., 2600 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·00
Portion soluble in Hydrochloric Acid = 73·47	Alumina,	10·25
	Ferric oxide,	2·82
	Calcium phosphate,	2·09
	Manganese oxide,	1·99
	Calcium sulphate,	0·29
	Calcium carbonate,	36·80
	Magnesium carbonate,	0·76
	Silica,	18·47
Portion insoluble in Hydrochloric Acid = 21·53	Alumina,	4·03
	Ferric oxide,	2·02
	Lime,	0·79
	Magnesia,	0·18
	Silica,	14·51
		100·00

13. RED CLAY.—Station 226.

Lat. 14° 44′ N., long. 142° 13′ E., 2300 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·20
Portion soluble in Hydrochloric Acid = 57·30	Alumina,	4·80
	Ferric oxide,	15·20
	Calcium phosphate,	good trace
	Manganese oxide,	1·14
	Calcium sulphate,	0·46
	Calcium carbonate,	6·11
	Magnesium carbonate,	0·75
	Silica,	28·84
Portion insoluble in Hydrochloric Acid = 38·50	Alumina,	3·31
	Ferric oxide,	5·79
	Lime,	0·45
	Magnesia,	0·40
	Silica,	28·55
		100·00

14. RED CLAY.—Station 241.

Lat. 35° 41′ N., long. 157° 42′ E., 2300 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·30
Portion soluble in Hydrochloric Acid = 62·20	Alumina,	6·00
	Ferric oxide,	2·91
	Calcium phosphate,	2·09
	Manganese oxide,	1·14
	Calcium sulphate,	0·49
	Calcium carbonate,	22·63
	Magnesium carbonate,	0·94
	Silica,	26·00
Portion insoluble in Hydrochloric Acid = 33·50	Alumina,	5·30
	Ferric oxide,	2·20
	Lime,	2·20
	Magnesia,	0·40
	Silica,	23·40
		100·00

15. Red Clay.—Station 252.

Lat. 37° 52′ N., long. 160° 17′ W., 2740 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	3·60
Portion soluble in Hydrochloric Acid = 46·40	Alumina,	5·28
	Ferric oxide,	13·14
	Calcium phosphate,	small trace
	Manganese oxide,	trace
	Calcium sulphate,	0·51
	Calcium carbonate,	2·22
	Magnesium carbonate,	0·41
	Silica,	24·89
Portion insoluble in Hydrochloric Acid = 50·00	Alumina,	7·85
	Ferric oxide,	2·60
	Lime,	1·50
	Magnesia,	0·35
	Silica,	37·70
		100·00

16. Red Clay.—Station 253.

Lat. 38° 9′ N., long. 156° 25′ W., 3125 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·50
Portion soluble in Hydrochloric Acid = 45·69	Alumina,	8·31
	Ferric oxide,	7·95
	Calcium phosphate,	0·19
	Manganese oxide,	0·55
	Calcium sulphate,	0·37
	Calcium carbonate,	0·92
	Magnesium carbonate,	2·70
	Silica,	24·70
Portion insoluble in Hydrochloric Acid = 49·81	Alumina,	7·75
	Ferric oxide,	3·88
	Lime,	0·28
	Magnesia,	0·50
	Silica,	37·40
		100·00

17. Red Clay.—Station 256.

Lat. 30° 22′ N., long. 154° 56′ W., 2950 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·50
Portion soluble in Hydrochloric Acid = 45·32	Alumina,	6·00
	Ferric oxide,	9·77
	Calcium phosphate,	0·48
	Manganese oxide,	0·68
	Calcium sulphate,	0·42
	Calcium carbonate,	1·69
	Magnesium carbonate,	1·33
	Silica,	24·95
Portion insoluble in Hydrochloric Acid = 50·18	Alumina,	11·37
	Ferric oxide,	2·00
	Lime,	1·14
	Magnesia,	0·85
	Silica,	34·82
		100·00

18. RED CLAY.—Station 275.

Lat. 11° 20′ S., long. 150° 30′ W., 2610 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	6·50
Portion soluble in Hydrochloric Acid = 66·10	Alumina,	7·45
	Ferric oxide,	15·71
	Calcium phosphate,	0·76
	Manganese oxide,	3·85
	Calcium sulphate,	0·58
	Calcium carbonate,	3·74
	Magnesium carbonate,	1·96
	Silica,	32·05
Portion insoluble in Hydrochloric Acid = 27·40	Alumina,	6·35
	Ferric oxide,	2·35
	Lime,	0·44
	Magnesia,	0·30
	Silica,	17·96
		100·00

19. RED CLAY (after the finer parts had been washed away).—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	2·20
Portion soluble in Hydrochloric Acid = 80·70	Copper,	trace
	Alumina,	9·00
	Ferric oxide,	9·03
	Calcium phosphate,	3·44
	Manganese oxide,	2·28
	Calcium sulphate,	0·58
	Calcium carbonate,	38·13
	Magnesium carbonate,	0·94
	Silica,	17·30
Portion insoluble in Hydrochloric Acid = 17·10	Alumina,	4·27
	Ferric oxide,	1·07
	Lime,	0·22
	Magnesia,	0·11
	Silica,	11·43
		100·00

20. CRYSTALS OF PHILLIPSITE.—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Dittmar).

There were two specimens, one marked "No. 1," the other "No. 2."

According to a verbal communication from Mr. Murray, No. 1 contains Foraminifera, which were removed from part of the original specimen to produce No. 2.

No. 2, when viewed under the microscope, was found to consist mainly of groups of yellowish crystals. In No. 1 these crystals were associated with a multitude of calcareous fragments.

These two specimens were analysed in the same manner, but not, I am sorry to have to add, with the same degree of success. While fully convinced of the correctness of the numbers to be given for No. 1, those for No. 2, I fear, do not possess the degree of precision which I should wish them to have.

In either case the substance was disintegrated by means of hot hydrochloric acid, and the insoluble part, after removal of the soluble silica by means of boiling carbonate of soda solution, ignited and weighed.

The hydrochloric acid solution was exhaustively analysed, separate portions of substance serving for the determination of alkalies and water respectively.

No. 1, Found in 100 parts.

		In combining weight.	
Undecomposable silicates,	7·65		
Water,	12·31	H_2O	× 1·3680
Carbonic acid,	12·52	CO_2	× 0·5690
Phosphoric acid,	3·19	P_2O_5	× 0·0449
Silica,	25·60	SiO_2	× 0·8533
Alumina,	8·43	Al_2O_3	× 0·1640
Ferric oxide,	5·40	Fe_2O_3	× 0·0675
Manganous oxide,	1·29	MnO	× 0·0363
Lime,	9·93	CaO	× 0·3546
Magnesia,	5·95	MgO	× 0·2975
Potash,	2·60	K_2O	× 0·0553
Soda,	3·61	Na_2O	× 0·1163
	98·48		

Number of eqq. of phosphoric and carbonic acids = 0·7037; of lime and magnesia = 0·6521; excess of acid = 0·0516 eqq.

Excess of acid eqq.,	0·0516
Eqq. of ferric oxide,	0·2025
Excess of ferric oxide,	0·1509

to be carried over to the silica as $Fe_2O_3 \times 0·0503$. Doing so, we have in multiples of

SiO_2	R_2O_3	RO and R_2O	H_2O
0·8533	0·2143	0·2079	1·368; or
1	0·2511	0·2437	1·60; or
4	1·004	1·025	6·4

This, if we leave the water on one side, is the formula of a metasilicate; but, as the substance is decomposable by hydrochloric acid, it must be looked upon as a hydric ortho-silicate (a zeolite) of the formula

$$\left.\begin{array}{r}(Al_2O_3,\ Fe_2O_3)''' \\ RO \\ 4H_2O\end{array}\right\} 4SiO_2 + 2Aq.,$$

mixed with the normal carbonates and phosphates of lime and magnesia, and some phosphate of ferric oxide.

This, at least, appears to me the most plausible theory, although possibly the close agreement of the above co-efficients with the small integers of the formula may be purely accidental.

21. Crystals of Phillipsite.—Station 276. Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Dittmar).

No. 2, Found in 100 parts.

		In combining weight.	
Undecomposable silicates,	8·04 (by difference).		
Water,[1]	19·79	H_2O	× 1·8660
Carbonic acid,	5·17	CO_2	× 0·1993
Phosphoric acid,	0·65	P_2O_5	× 0·0078
Silica,	35·38	SiO_2	× 1·0000
Alumina,	15·04	Al_2O_3	× 0·2481
Ferric oxide,	7·35	Fe_2O_3	× 0·0779
Manganous oxide,	0·47	MnO	× 0·0112
Lime,	1·73	CaO	× 0·0524
Magnesia,	2·35	MgO	× 0·0997
Potash,[2]	1·63	K_2O	× 0·0294
Soda,[2]	2·40	Na_2O	× 0·0657
	100·00		

[1] 9·10 of this water proved volatile at 100° C.

[2] After the summary determination of the alkalies as chlorides, the weight of the $PtCl_6K_2$ was lost. The numbers given are calculated on the assumption of the ratio of potash and soda being the same as in No. 1.

Joint number of $\left(\frac{P_2O_5 \text{ and } CO_2}{3}\right)$'s =	0·2227
" " of (CaO and MgO)'s =	0·1521
Excess of acid Eqq.	0·0706
The ferric oxide = $\frac{1}{3}Fe_2O_3$ ×	0·2337
Excess $\frac{1}{3}Fe_2O_3$ ×	0·1631

Transferring this (*i.e.*, 0·0544 × Fe_2O_3) to the silicate part, we have

	SiO_2	R_2O_3	RO R_2O	H_2O (red heat)	H_2O 100°
×	1	0·3025	0·1063	1·008	0·8576
(In eqq.		1·0138)			
× or 10		3·025	1·063	10·08	8·6

Here again we have a surprisingly close approximation to small integers, leading to the formula

$$\left.\begin{matrix}3R_2O_3\\1RO\\10H_2O\end{matrix}\right\}^{xx} 10SiO_2+8Aq.$$

But unfortunately this formula does not agree with the one found for the silicate in No. 1. From the analyses it seems that No. 2 was prepared from No. 1 by treatment with dilute acid; if so, then clearly, if one of the two formulæ represents a chemical species (or mixture of isomorphous species), the other certainly does not.

22. Red Clay.—Station 281. Lat. 22° 21′ S., long. 150° 17′ W., 2385 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·70
Portion soluble in Hydrochloric Acid = 74·47	Alumina,	8·80
	Ferric oxide,	24·60
	Calcium phosphate,	small trace
	Manganese oxide,	2·73
	Calcium sulphate,	trace
	Calcium carbonate,	2·50
	Magnesium carbonate,	3·24
	Silica,	32·60
Portion insoluble in Hydrochloric Acid = 17·83	Alumina,	1·60
	Ferric oxide,	3·80
	Lime,	0·84
	Magnesia,	0·32
	Silica,	11·27
		100·00

23. Red Clay.—Station 285. Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	9·00
Portion soluble in Hydrochloric Acid = 77·03	Copper,	trace
	Alumina,	7·50
	Ferric oxide,	23·55
	Calcium phosphate,	0·70
	Manganese oxide,	14·53
	Calcium sulphate,	0·58
	Calcium carbonate,	4·07
	Magnesium carbonate,	1·13
	Silica,	24·97
Portion insoluble in Hydrochloric Acid = 13·97	Alumina,	2·85
	Ferric oxide,	1·05
	Lime,	0·55
	Magnesia,	0·09
	Silica,	9·43
		100·00

24. Red Clay.—Station 9. Lat. 23° 23′ N., long. 35° 11′ W., 3150 fathoms (Hornung).

I. 1·1459 grms. of substance dried at 110° C., fused with carbonates of soda and potash, gave 0·6519 grm. of silica, 0·2323 grm. of alumina, 0·1148 grm. of ferric oxide, 0·0150 grm. of lime, 0·0293 grm. of magnesia, and 0·0770 grm. loss on ignition.

II. 1·1162 grms. of substance dried at 110° C., treated with sulphuric and hydrofluoric acids, gave 0·0219 grm. of potash, and 0·0092 grm. of soda.

Silica,	56·89
Alumina,	20·28
Ferric oxide,	10·02
Lime,	1·31
Magnesia,	2·56
Potash,	1·91
Soda,	0·81
Loss on ignition,	6·72
Barium, manganese, and phosphoric acid,	traces
	100·50

25. Red Clay.—Station 29. Lat. 27° 49′ N., long. 64° 59′ W., 2700 fathoms (Renard).

I. 1·370 grms. of substance dried at 110° C., fused with the carbonates of soda and potash, gave 0·0513 grm. of water, 0·5774 grm. of silica, 0·2776 grm. of alumina, 0·0967 grm. of peroxide of iron, 0·1811 grm. of lime, 0·0815 grm. of pyrophosphate of magnesia = 0·0294 grm. of magnesia.

II. 0·9872 grm. of substance, dried at 110° C., gave 0·0969 grm. of carbonic acid.

III. 1·329 grms. of substance dried at 110° C., treated with hydrofluoric and sulphuric acids, gave 0·0416 grm. of the chlorides of potash and soda, 0·0769 grm. of chloroplatinate of potash = 0·0149 grm. of potash, and, by difference, 0·0095 grm. of soda.

Silica,	42·15
Alumina,	20·27
Peroxide of iron,	7·06
Lime,	13·22
Magnesia,	2·15
Potash,	1·12
Soda,	0·72
Carbonic acid,	9·82
Water,	3·75
	100·26

26. Red Clay (after the finer parts had been washed away).—Station 281.
Lat. 22° 21′ S., long. 150° 17′ W., 2385 fathoms (Hornung).

0·3436 grm. of substance, dried at 100° C., lost	0·0297 grm.	= 8·52 per cent.
0·8375 ,, ,, ,,	0·0657 ,,	= 7·81 ,,
0·8392 ,, ,, ,,	0·0698 ,,	= 8·28 ,,
1·1275 ,, ,, ,,	0·0933 ,,	= 8·27 ,,
	Mean loss on ignition	= 8·22 ,,

I. 0·3024 grm. of substance, dried at 100° C., fused with the carbonates of potash and soda in a porcelain tube, gave 0·0194 grm. of water.

II. 0·7694 grm. of substance, dried at 100° C., gave 0·3333 grm. of silica, 0·1074 grm. of alumina, 0·1346 grm. of peroxide of iron, 0·0459 grm. of lime, 0·1258 grm. of pyrophosphate of magnesia = 0·0453 grm. of magnesia.

III. 0·4973 grm. of substance, dried at 100° C., treated at 140° C. in a closed glass tube with sulphuric acid, required 3·5 c.c. of permanganate of potash (1 c.c. of permanganate of potash = 0·04813 grm. of protoxide of iron), corresponding to 0·02166 grm. of protoxide of iron.

IV. 0·9945 grm. of substance, dried at 100° C., treated with sulphuric and hydrofluoric acids, gave 0·0587 grm. of the chlorides of soda and potash, and 0·0865 grm. of chloroplatinate of potash = 0·0165 grm. of potash and 0·0173 grm. of soda.

Silica,	43·32
Alumina,	13·96
Peroxide of iron,	17·50
Protoxide of iron,	4·36
Lime,	5·96
Magnesia,	5·89
Potash,	1·66
Soda,	1·74
Water,	6·41
	100·80

27. Red Clay (after removal of carbonate of lime by dilute acid).—Station 286.
Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Klement).

I. 1·5318 grms. of substance, dried at 110° C., gave 0·0230 grm. of carbonic acid.

II. 1·0940 grms. of substance, dried at 110° C., fused with the carbonates of soda and potash, gave 0·0973 grm. of water, 0·4279 grm. of silica, 0·1685 grm. of alumina, 0·1961 grm. of peroxide of iron, 0·0552 grm. of dioxide of manganese, 0·0916 grm. of lime, 0·0720 grm. of pyrophosphate of magnesia.

III. 0·9345 grm. of substance, dried at 110° C., gave 0·0981 grm. of loss on ignition, and, after being treated with hydrofluoric and sulphuric acids, 0·0434 grm. of the chlorides of soda and potash, and 0·0611 grm. of chloroplatinate of potash.

Silica,	39·10
Alumina,	15·40
Peroxide of iron,	17·93
Manganese dioxide,	5·75
Lime,	8·37
Magnesia,	2·37
Potash,	1·27
Soda,	1·40
Water,	8·89
Carbonic acid,	1·50
	101·98

Note.—Before the blow-pipe this substance melted into a deep-coloured scoriaceous bead.

28. Radiolarian Ooze.—Station 265. Lat. 12° 42′ N., long. 152° 1′ W., 2900 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·30
Portion soluble in Hydrochloric Acid = 63·21	Alumina,	6·75
	Ferric oxide,	11·20
	Calcium phosphate,	0·65
	Manganese oxide,	0·57
	Calcium sulphate,	0·29
	Calcium carbonate,	2·54
	Magnesium carbonate,	2·46
	Silica,	38·75
Portion insoluble in Hydrochloric Acid = 32·49	Alumina,	6·19
	Ferric oxide,	3·09
	Lime,	1·85
	Magnesia,	0·34
	Silica,	21·02
		100·00

29. Radiolarian Ooze.—Station 274. Lat. 7° 25′ S., long. 152° 15′ W., 2750 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·41
Portion soluble in Hydrochloric Acid = 79·48	Alumina,	8·32
	Ferric oxide,	14·24
	Calcium phosphate,	1·39
	Manganese oxide,	3·23
	Calcium sulphate,	0·41
	Calcium carbonate,	3·89
	Magnesium carbonate,	1·50
	Silica,	46·50
Portion insoluble in Hydrochloric Acid = 13·11	Alumina,	2·20
	Ferric oxide,	0·75
	Lime,	0·39
	Magnesia,	0·25
	Silica,	9·52
		100·00

30. Radiolarian Ooze.—Station 266. Lat. 11° 7′ N., long. 152° 3′ W., 2750 fathoms (Renard).

I. 0·6580 grm. of substance gave 0·1087 grm. of loss on ignition, 0·3478 grm. of silica, 0·0011 grm. of cupric oxide, 0·0391 grm. of peroxide of iron, 0·0384 grm. of alumina, 0·0345 grm. of phosphate of alumina = 0·0145 grm. of alumina and 0·0200 grm. of phosphoric acid, 0·0099 grm. of pyrophosphate of magnesia, 0·0063 grm. of phosphoric acid, 0·0141 grm. of manganous sulphide = 0·0115 grm. of manganous oxide, 0·0435 grm. of lime, and 0·0884 grm. of pyrophosphate of magnesia = 0·0318 grm. of magnesia, and traces of cobalt, soda, and potash.

II. 0·4725 grm. of substance heated with 2 grms. of carbonate of soda in the water-bath for thirty hours, water being constantly added, gave 0·0607 grm. of silica = 12·84 per cent.

Silica,	52·85
Copper,	0·16
Peroxide of iron,	5·94
Alumina,	8·22
Phosphoric acid,	3·99
Manganous oxide,	1·74
Lime,	6·61
Magnesia,	4·84
Cobalt, soda, potash,	traces
Loss on ignition,	16·52
	100·87

31. Diatom Ooze.—Station 157. Lat. 53° 55′ S., long. 108° 35′ E., 1950 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·30
Portion soluble in Hydrochloric Acid = 89·98	Alumina,	0·55
	Ferric oxide,	0·39
	Calcium phosphate,	0·41
	Manganese oxide,	...
	Calcium sulphate,	0·29
	Calcium carbonate,	19·29
	Magnesium carbonate,	1·13
	Silica,	67·92
Portion insoluble in Hydrochloric Acid = 4·72	Consisting of alumina and ferric oxide, with silica,	4·72
		100·00

32. Diatom Ooze (after removal of carbonate of lime by dilute acid).—Station 157.

Lat. 53° 55′ S., long. 108° 35′ E., 1950 fathoms (Renard).

I. 0·5618 grm. of substance, dried at 120° C., gave 0·0330 grm. of loss on ignition, then treated with hydrofluoric and sulphuric acids gave 0·5092 grm. of silica, 0·00112 grm. of barium, 0·0056 grm. of the chlorides of potash and soda, 0·0044 grm. of chloroplatinate of potash, corresponding to 0·00134 grm. of chloride of potash = 0·00085 grm. of potash, and 0·00426 grm. of chloride of soda = 0·00225 grm. of soda.

II. 0·6487 grm. of substance, dried at 120° C., gave 0·0379 grm. of loss on ignition, then treated with hydrofluoric and sulphuric acids gave 0·5870 grm. of silica, 0·0013 grm. of barium, 0·0057 grm. of peroxide of iron, 0·0089 grm. of alumina, 0·0022 grm. of lime, and 0·0055 grm. of pyrophosphate of magnesia = 0·00198 grm. of magnesia, and traces of phosphoric acid.

	I.	II.	Mean.
Silica,	90·63	90·49	90·56
Peroxide of iron,	...	0·88	0·88
Alumina,	...	1·31	1·31
Lime,	...	0·33	0·33
Barium,	0·20	0·20	0·20
Magnesia,	...	0·30	0·30
Potash,	0·15	...	0·15
Soda,	0·40	...	0·40
Phosphoric acid,	trace	trace	trace
Loss on ignition,	5·87	5·84	5·85
			99·98

32a. Diatoms from Surface-net.—Station 157.

Lat. 53° 55′ S., long. 108° 35′ E. (Anderson).

Water,	4·87
Organic matter,	16·75
Alumina,	1·38
Silica soluble in acid,	1·00
Silica insoluble in acid,	76·00
	100·00

33. Globigerina Ooze.—Station 1.

Lat. 27° 24′ N., long. 16° 55′ W., 1890 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·91
Portion soluble in Hydrochloric Acid = 73·07	Alumina,	5·26
	Ferric oxide,	3·95
	Calcium phosphate,	large trace
	Calcium sulphate,	0·44
	Calcium carbonate,	50·00
	Magnesium carbonate,	1·32
	Silica,	12·10
Portion insoluble in Hydrochloric Acid = 19·02	Alumina, Ferric oxide,	3·47
	Lime,	1·26
	Magnesia,	0·52
	Silica,	13·77
		100·00

34. Globigerina Ooze.—Station 2.
Lat. 25° 52′ N., long. 19° 22′ W., 1945 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·02
Portion soluble in Hydrochloric Acid = 82·90	Alumina,	3·23
	Ferric oxide,	4·18
	Calcium phosphate,	trace
	Calcium sulphate,	0·69
	Calcium carbonate,	64·55
	Magnesium carbonate,	1·17
	Silica,	9·08
Portion insoluble in Hydrochloric Acid = 12·08	Alumina,	1·79
	Ferric oxide,	0·60
	Lime,	0·33
	Magnesia,	0·28
	Silica,	9·08
		100·00

35. Globigerina Ooze.—Station 11.
Lat. 22° 45′ N., long. 40° 37′ W., 2575 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	9·13
Portion soluble in Hydrochloric Acid = 76·59	Alumina,	5·61
	Ferric oxide,	4·65
	Calcium phosphate,	...
	Calcium sulphate,	1·02
	Calcium carbonate,	51·16
	Magnesium carbonate,	1·93
	Silica,	12·22
Portion insoluble in Hydrochloric Acid = 14·28	Insoluble residue, principally alumina and ferric oxide, with silica,	14·28
		100·00

Note.—Material at command only 9·80 grains; this yielded:—

Loss on ignition,	0·895 gr.
Soluble in acid,	7·506 ,,
Insoluble ,,	1·399 ,,
	9·800 ,,

When treated with dilute hydrochloric acid it evolved a perceptible tarry odour.

36. Globigerina Ooze.—Station 12.
Lat. 21° 57′ N., 43° 29′ W., 2025 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	8·80
Portion soluble in Hydrochloric Acid = 80·22	Alumina,	19·24
	Ferric oxide,	13·74
	Calcium phosphate,	fair trace
	Calcium sulphate,	1·37
	Calcium carbonate,	43·93
	Magnesium carbonate,	1·94
Portion insoluble in Hydrochloric Acid = 10·98	General residue, consisting of soluble silica with the insoluble silicates,	10·98
		100·00

Note.—Material at command only 9·10 grains; this yielded:—

Loss on ignition,	0·80 gr.
Soluble in acid,	7·30 ,,
Insoluble ,,	1·00 ,,
	9·10 ,,

When treated with dilute hydrochloric acid it evolved a perceptible tarry odour.

37. Globigerina Ooze.—Station 13.

Lat. 21° 38′ N., long. 44° 39′ W., 1900 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	6·68
Portion soluble in Hydrochloric Acid = 82·14	Alumina, Ferric oxide,	5·86
	Calcium phosphate,	small trace
	Calcium sulphate,	0·51
	Calcium carbonate,	74·50
	Magnesium carbonate,	1·27
Portion insoluble in Hydrochloric Acid = 11·23	General residue, consisting of soluble silica with the insoluble silicates,	11·23
		100·00

Note.—Material at command only 19·60 grains; this yielded:—

Loss on ignition,	1·30	gr.
Soluble in acid,	16·10	,,
Insoluble ,,	2·20	,,
	19·60	,,

38. Globigerina Ooze.—Station 14.

Lat. 21° 1′ N., long. 46° 29′ W., 1950 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·58
Portion soluble in Hydrochloric Acid = 90·82	Alumina, Ferric oxide,	3·33
	Calcium phosphate,	1·12
	Calcium sulphate,	1·20
	Calcium carbonate,	79·17
	Magnesium carbonate,	1·40
	Silica,	4·60
Portion insoluble in Hydrochloric Acid = 4·60	Insoluble residue, principally alumina and ferric oxide, with silica,	4·60
		100·00

Note.—Material at command only 24 grains; this yielded:—

Loss on ignition,	1·10	gr.
Soluble in acid,	21·80	,,
Insoluble ,,	1·10	,,
	24·00	,,

39. Globigerina Ooze.—Station 15.

Lat. 20° 49′ N., long. 48° 45′ W., 2325 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·17
Portion soluble in Hydrochloric Acid = 87·50	Alumina, Ferric oxide,	6·25
	Calcium phosphate,	large trace
	Calcium sulphate,	1·91
	Calcium carbonate,	67·60
	Magnesium carbonate,	2·58
	Silica,	9·16
Portion insoluble in Hydrochloric Acid = 8·33	Insoluble residue, principally alumina and ferric oxide, with silica,	8·33
		100·00

Note.—Material at command only 12 grains; this yielded:—

Loss on ignition,	0·50	gr.
Soluble in acid,	10·50	,,
Insoluble ,,	1·00	,,
	12·00	,,

40. Globigerina Ooze.—Station 16.

Lat. 20° 39′ N., long. 50° 33′ W., 2435 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	9·60
Portion soluble in Hydrochloric Acid = 78·40	Alumina,	4·00
	Ferric oxide,	7·10
	Calcium phosphate,	small trace
	Calcium sulphate,	2·32
	Calcium carbonate,	52·22
	Magnesium carbonate,	0·76
	Silica,	12·00
Portion insoluble in Hydrochloric Acid = 12·00	Alumina, Ferric oxide,	2·96
	Lime,	0·64
	Magnesia,	0·40
	Silica,	8·00
		100·00

Note.—When treated with dilute hydrochloric acid this substance evolved a perceptible tarry odour.

41. Globigerina Ooze.—Station 17.

Lat. 20° 7′ N., long. 52° 32′ W., 2385 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	6·84
Portion soluble in Hydrochloric Acid = 83·44	Alumina,	2·69
	Ferric oxide,	9·05
	Calcium phosphate,	1·74
	Calcium sulphate,	0·81
	Calcium carbonate,	58·40
	Magnesium carbonate,	0·68
	Silica,	10·07
Portion insoluble in Hydrochloric Acid = 9·72	Insoluble residue, principally alumina and ferric oxide, with silica,	9·72
		100·00

Note.—Material at command only 27·80 grains; this yielded:—

Loss on ignition,	1·90	gr.
Soluble in acid,	23·20	,,
Insoluble ,,	2·70	,,
	27·80	,,

42. Globigerina Ooze.—Station 64.

Lat. 35° 35′ N., long. 50° 27′ W., 2700 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	7·90
Portion soluble in Hydrochloric Acid = 65·39	Alumina,	4·75
	Ferric oxide,	5·95
	Calcium phosphate,	2·80
	Manganese oxide,	trace
	Calcium sulphate,	0·29
	Calcium carbonate,	37·51
	Magnesium carbonate,	1·13
	Silica,	12·96
Portion insoluble in Hydrochloric Acid = 26·71	Alumina,	6·35
	Ferric oxide,	1·08
	Lime,	0·41
	Magnesia,	0·12
	Silica,	18·75
		100·00

43. Globigerina Ooze.—Station 146.

Lat. 46° 46′ S., long. 45° 31′ E., 1375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	2·90
Portion soluble in Hydrochloric Acid = 94·40 =	Alumina, Ferric oxide,	0·91
	Calcium sulphate,	0·84
	Calcium carbonate,	86·36
	Magnesium carbonate,	0·19
	Silica,	6·10
Portion insoluble in Hydrochloric Acid = 2·70 =	Consisting of alumina and ferric oxide, with silica,	2·70
		100·00

44. Globigerina Ooze.—Station 176.

Lat. 18° 30′ S., long. 153° 52′ E., 1450 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·00
Portion soluble in Hydrochloric Acid = 82·80 =	Alumina,	2·00
	Ferric oxide,	6·16
	Calcium phosphate,	0·84
	Calcium sulphate,	0·58
	Calcium carbonate,	62·41
	Magnesium carbonate,	1·51
	Silica,	9·30
Portion insoluble in Hydrochloric Acid = 12·20 =	Alumina,	2·30
	Ferric oxide,	1·04
	Lime,	0·40
	Magnesia,	0·26
	Silica,	8·20
		100·00

45. Globigerina Ooze (after the finer parts had been washed away).—Station 224.

Lat. 7° 45′ N., long. 144° 20′ E., 1850 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	1·50
Portion soluble in Hydrochloric Acid = 97·57 =	Alumina,	1·25
	Ferric oxide,	0·47
	Calcium phosphate,	0·28
	Manganese oxide,	...
	Calcium sulphate,	0·29
	Calcium carbonate,	93·14
	Magnesium carbonate,	0·57
	Silica,	1·57
Portion insoluble in Hydrochloric Acid = 0·93 =	Consisting of alumina and ferric oxide, with silica,	0·93
		100·00

46. Globigerina Ooze.—Station 246.

Lat. 36° 10′ N., long. 178° 0′ E., 2050 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·40
Portion soluble in Hydrochloric Acid = 75·84	Alumina,	2·92
	Ferric oxide,	4·91
	Calcium phosphate,	1·05
	Manganese oxide,	1·10
	Calcium sulphate,	0·56
	Calcium carbonate,	47·57
	Magnesium carbonate,	0·83
	Silica,	16·90
Portion insoluble in Hydrochloric Acid = 19·76	Alumina,	2·90
	Ferric oxide,	0·90
	Lime,	0·34
	Magnesia,	0·22
	Silica,	15·40
		100·00

47. Globigerina Ooze.—Station 293.

Lat. 39° 4′ S., long. 105° 5′ W., 2025 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	6·80
Portion soluble in Hydrochloric Acid = 89·68	Alumina,	1·30
	Ferric oxide,	20·94
	Calcium phosphate,	0·41
	Manganese oxide,	4·80
	Calcium sulphate,	0·46
	Calcium carbonate,	54·67
	Magnesium carbonate,	0·90
	Silica,	6·20
Portion insoluble in Hydrochloric Acid = 3·52	Alumina,	0·60
	Ferric oxide,	0·30
	Lime,	0·12
	Magnesia,	0·10
	Silica,	2·40
		100·00

48. Globigerina Ooze (after the finer parts had been washed away).—Station 296.

Lat. 38° 6′ S., long. 88° 2′ W., 1825 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	2·25
Portion soluble in Hydrochloric Acid = 95·32	Alumina,	4·50
	Ferric oxide,	0·73
	Calcium phosphate,	2·77
	Manganese oxide,	good trace
	Calcium sulphate,	0·58
	Calcium carbonate,	82·55
	Magnesium carbonate,	1·13
	Silica,	3·06
Portion insoluble in Hydrochloric Acid = 2·43	Alumina,	0·61
	Ferric oxide,	0·12
	Lime,	0·14
	Magnesia,	0·05
	Silica,	1·51
		100·00

49. Globigerina Ooze.—Station 297.

Lat. 37° 29′ S., long. 83° 7′ W., 1775 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·10
Portion soluble in Hydrochloric Acid = 92·23 =	Alumina,	1·95
	Ferric oxide,	3·69
	Calcium phosphate,	0·19
	Manganese oxide,	good trace
	Calcium sulphate,	0·44
	Calcium carbonate,	81·13
	Magnesium carbonate,	0·85
	Silica,	3·98
Portion insoluble in Hydrochloric Acid = 3·67 =	Alumina, Ferric oxide,	0·35
	Lime,	0·39
	Magnesia,	0·16
	Silica,	2·77
		100·00

50. Globigerina Ooze.—Station 300.

Lat. 33° 42′ S., long. 78° 18′ W., 1375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	1·70
Portion soluble in Hydrochloric Acid = 82·05 =	Alumina,	4·75
	Ferric oxide,	4·50
	Calcium phosphate,	trace
	Manganese oxide,	0·85
	Calcium sulphate,	0·29
	Calcium carbonate,	62·17
	Magnesium carbonate,	0·94
	Silica,	8·55
Portion insoluble in Hydrochloric Acid = 16·25 =	Alumina,	3·79
	Ferric oxide,	2·06
	Lime,	0·96
	Magnesia,	0·14
	Silica,	9·30
		100·00

51. Globigerina Ooze.—Station 302.

Lat. 42° 43′ S., long. 82° 11′ W., 1450 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	1·00
Portion soluble in Hydrochloric Acid = 97·18 =	Alumina,	1·00
	Ferric oxide,	1·72
	Calcium phosphate,	0·28
	Manganese oxide,	...
	Calcium sulphate,	0·73
	Calcium carbonate,	91·32
	Magnesium carbonate,	0·30
	Silica,	1·83
Portion insoluble in Hydrochloric Acid = 1·82 =	Consisting of alumina and ferric oxide, with silica,	1·82
		100·00

52. Globigerina Ooze.—Station 332.

Lat. 37° 29′ S., long. 27° 31′ W., 2200 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	2·82
Portion soluble in Hydrochloric Acid = 84·95	Alumina,	3·75
	Ferric oxide,	1·51
	Calcium phosphate,	1·74
	Manganese oxide,	trace
	Calcium sulphate,	0·58
	Calcium carbonate,	65·67
	Magnesium carbonate,	1·33
	Silica,	10·37
Portion insoluble in Hydrochloric Acid = 12·23	Alumina,	2·18
	Ferric oxide,	0·55
	Lime,	0·33
	Magnesia,	0·11
	Silica,	9·06
		100·00

53. Globigerina Ooze.—Station 338.

Lat. 21° 15′ S., long. 14° 2′ W., 1990 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	1·40
Portion soluble in Hydrochloric Acid = 97·11	Alumina,	0·65
	Ferric oxide,	0·60
	Calcium phosphate,	0·90
	Manganese oxide,	...
	Calcium sulphate,	0·19
	Calcium carbonate,	92·54
	Magnesium carbonate,	0·87
	Silica,	1·36
Portion insoluble in Hydrochloric Acid = 1·49	Consisting of alumina and ferric oxide, with silica,	1·49
		100·00

54. Red Mud.—Station 120.

Lat. 8° 37′ S., long. 34° 28′ W., 675 fathoms (Hornung).

0·7287 grm. of substance dried at 100° C., lost	0·0131 grm.	= 2·43 per cent.
0·8569 ,, ,, ,,	0·01659 ,,	= 1·93 ,,
0·9462 ,, ,, ,,	0·0220 ,,	= 2·32 ,,
0·9806 ,, ,, ,,	0·0230 ,,	= 2·34 ,,
	Mean loss on ignition,	= 2·27 ,,

I. 0·5884 grm. of substance dried at 100° C., fused with the carbonates of soda and potash, gave 0·0354 grm. of water, 0·1863 grm. of silica, 0·1511 grm. of lime, 0·0266 grm. of peroxide of iron, 0·0542 grm. of alumina, 0·0309 grm. of pyrophosphate of magnesia = 0·0122 grm. of magnesia.

II. 0·8381 grm. of substance dried at 100° C., treated with hydrofluoric and sulphuric acids, gave 0·0435 grm. of the chlorides of soda and potash, 0·058 grm. of chloroplatinate of potash = 0·0112 grm. of potash and, by difference, 0·0137 grm. of soda.

III. 0·9204 grm. of substance dried at 100° C. gave 0·02268 grm. of chlorine.

IV. 0·9397 grm. of substance dried at 100° C. gave 0·1610 grm. of carbonic acid.

V. 0·9484 grm. of substance dried at 100° C. gave 0·0076 grm. of sulphate of barium = 0·026 grm. of sulphuric anhydride.

Water,	6·02
Silica,	31·66
Alumina,	9·21
Peroxide of iron,	4·52
Lime,	25·68
Magnesia,	2·07
Soda,	1·63
Potash,	1·33
Sulphuric anhydride,	0·27
Carbonic acid,	17·13
Chlorine,	2·46
	101·98
On subtracting the oxygen corresponding to the chlorine,	0·87
There remain	101·11

55. Red Mud (determination of soluble salts retained in the sediment).—Station 120.

Lat. 8° 37′ S., long. 34° 28′ W., 675 fathoms (Hornung).

The substance was washed with warm and cold distilled water till the water no longer gave the reaction of chlorine. It was afterwards pulverised and treated with hydrofluoric and sulphuric acids.

1·4088 grms. of substance dried at 100° C. gave 0·0496 grm. of the chlorides of soda and potash, and 0·1013 grm. of chloroplatinate of potash = 0·0195 grm. of potash and 0·0099 grm. of soda :—

Potash (K_2O),	1·38 per cent.
Soda (Na_2O),	0·70 ,,

56. Globigerina Ooze.—Station 176.

Lat. 18° 30′ S., long. 173° 52′ E., 1450 fathoms (Renard).

I. 1·0463 grms. of substance dried at 110° C., fused with the carbonates of soda and potash, gave 0·1852 grm. of silica, 0·0508 grm. of alumina, 0·0711 grm. of peroxide of iron, 0·0176 grm. of peroxide of manganese, 0·3670 grm. of lime, 0·0474 grm. of pyrophosphate of magnesia = 0·0171 grm. of magnesia.

II. 1·9834 grms. of substance dried at 110° C., treated with hydrofluoric and sulphuric acids, gave 0·0328 grm. of the chlorides of soda and potash, 0·0347 grm. of chloroplatinate of potash = 0·0065 grm. of potash and, by difference, 0·0129 grm. of soda.

III. 0·9571 grm. of substance dried at 110° C. served for the determination of carbonic acid = 0·2785 grm.

IV. 1·2462 grms. of substance dried at 110° C. served for the determination of water.

Silica,	17·71
Alumina,	4·86
Peroxide of iron,	6·80
Peroxide of manganese,	1·69
Lime,	35·08
Magnesia,	1·64
Potash,	0·32
Soda,	0·65
Carbonic acid,	29·10
Water,	2·95
Copper, nickel, cobalt, and phosphoric acid,	traces
	100·80

57. GLOBIGERINA OOZE (residue after removal of carbonate of lime by dilute acid).—Station 224.

Lat. 7° 45′ N., long. 144° 20′ E., 1850 fathoms (Renard).

The ooze was first treated in the manner described on pages 220 and 221.

I. 0·5660 grm. of substance dried at 110° C. served for the direct determination of water, and gave 0·0401 grm. of water.

II. 0·9345 grm. of substance dried at 110° C. gave 0·5995 grm. of silica, 0·1403 grm. of alumina, 0·0755 grm. of peroxide of iron, 0·0155 grm. of lime, 0·0444 grm. of pyrophosphate of magnesia = 0·0160 grm. of magnesia.

III. 0·8390 grm. of substance dried at 110° C. gave 0·0294 grm. of the chlorides of soda and potash, 0·0483 grm. of chloroplatinate of potash = 0·00976 grm. of potash and, by difference, 0·0076 grm. of soda.

Silica,	64·16
Alumina,	15·13
Peroxide of iron,	8·19
Lime,	1·66
Magnesia,	1·79
Potash,	1·01
Soda,	0·90
Water,	7·10
Barium, manganese, and phosphoric acid,	traces
	99·94

58. GLOBIGERINA OOZE (determination of organic matter).—Station 224.

Lat. 7° 45′ N., long. 144° 20′ E., 1850 fathoms (Hornung).

0·9905 grm. of substance, dried at 100° C., lost 0·0537 grm.	= 5·42	per cent.
0·9588 ,, ,, ,, 0·0558 ,,	= 5·82	,,
Mean loss on ignition,	= 5·62	,,

I. 0·4413 grm. of substance dried at 100° C., burnt with oxide of copper, gave 0·0453 grm. of carbonic acid = 0·01235 grm. of carbon.

II. 0·9012 grm. of substance dried at 100° C., mixed with oxide of copper, and burnt in a current of carbonic acid (barometer, 743·95 mm., mean temperature, 22°·5 C.), gave 6·4 cc. of nitrogen = 0·0753 grm.

Carbon,	2·80 per cent.
Nitrogen,	0·785 ,,

The proportion of carbon and nitrogen in this organic substance is thus 53·48 : 15.

59. GLOBIGERINA OOZE (residue after removal of carbonate of lime by dilute acid).—Station 338.

Lat. 21° 15′ S., long. 14° 2′ W., 1990 fathoms (Klement).

1·0185 grms. of the ooze dried at 110° C. gave 0·4120 grm. of carbonic acid, corresponding to 0·9364 grm. of carbonate of lime = 91·94 per cent.

A rather large quantity of the ooze was treated as described on pages 220 and 221.

I. 0·8360 grm. of substance dried at 110° C., fused with the carbonates of soda and potash, gave 0·4219 grm. of silica, 0·1506 grm. of alumina, 0·1066 grm. of peroxide of iron, 0·0220 grm. of dioxide of manganese, 0·0143 grm. of lime, 0·0567 grm. of pyrophosphate of magnesia.

II. 1·1293 grms. of substance dried at 110° C. gave 0·1235 grm. of loss on ignition, and, after treatment with hydrofluoric and sulphuric acids, 0·0423 grm. of the chlorides of soda and potash, 0·0647 grm. of chloroplatinate of potash.

Silica,	50·47
Alumina,	18·01
Peroxide of iron,	12·75
Manganese dioxide,	3·00
Lime,	1·71
Magnesia,	2·44
Potash,	1·11
Soda,	1·05
Water,	10·93
	101·47

NOTE.—Before the blow-pipe this substance melted into a grey-green bead, like volcanic ash.

59A. GLOBIGERINA OOZE (determination of soluble silica, alumina, and iron).—Station 338.
Lat. 21° 15′ S., long. 14° 2′ W., 1990 fathoms (Klement).

On treating the ooze with boiling hydrochloric acid a certain quantity of silica, alumina, iron, and manganese was dissolved. After this operation there remained 2·21 grms. of insoluble residue, and the quantity dissolved and re-precipitated by ammonia represented 0·0487 grm. of silica, 0·0404 grm. of alumina, and 0·0917 grm. of peroxide of iron.

Silica,	26·94
Alumina,	22·34
Peroxide of iron,	50·72
	100·00

60. PTEROPOD OOZE.—Station 22.

Lat. 18° 40′ N., long. 62° 56′ W., 1420 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	3·80
Portion soluble in Hydrochloric Acid = 92·75	Alumina, Ferric oxide,	4·42
	Calcium phosphate,	2·41
	Calcium sulphate,	0·41
	Calcium carbonate,	80·69
	Magnesium carbonate,	0·68
	Silica,	4·14
Portion insoluble in Hydrochloric Acid = 3·45	Principally alumina and ferric oxide, with silica,	3·45
		100·00

NOTE.—When treated with dilute hydrochloric acid this substance evolved a perceptible tarry odour.

61. PTEROPOD OOZE.—Station 23.

Lat. 18° 24′ N., long. 62° 56′ W., 450 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·00
Portion soluble in Hydrochloric Acid = 93·95	Alumina,	1·80
	Ferric oxide,	3·00
	Calcium phosphate,	good trace
	Calcium sulphate,	1·00
	Calcium carbonate,	84·27
	Magnesium carbonate,	1·28
	Silica,	2·60
Portion insoluble in Hydrochloric Acid = 2·05	Principally alumina and ferric oxide, with silica,	2·05
		100·00

NOTE.—When treated with dilute hydrochloric acid this substance evolved a perceptible tarry odour.

62. Pteropod Ooze (after the finer parts had been washed away).—Station 24.

Lat. 18° 38′ 30″ N., long. 65° 5′ 30″ W., 390 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	2·00
Portion soluble in Hydrochloric Acid = 94·10	Alumina,	0·80
	Ferric oxide,	3·06
	Calcium phosphate,	2·44
	Manganese oxide,	...
	Calcium sulphate,	0·73
	Calcium carbonate,	82·66
	Magnesium carbonate,	0·76
	Silica,	3·65
Portion insoluble in Hydrochloric Acid = 3·90	Consisting of alumina and ferric oxide, with silica,	3·90
		100·00

63. Blue Mud.—Station 213.

Lat. 5° 47′ N., long. 124° 1′ E., 2050 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·92
Portion soluble in Hydrochloric Acid = 42·24	Alumina,	7·75
	Ferric oxide,	7·50
	Calcium phosphate,	trace
	Manganese oxide,	good trace
	Calcium sulphate,	0·58
	Calcium carbonate,	1·75
	Magnesium carbonate,	1·14
	Silica,	23·52
Portion insoluble in Hydrochloric Acid = 52·84	Alumina,	7·33
	Ferric oxide,	3·73
	Lime,	1·63
	Magnesia,	0·31
	Silica,	39·84
		100·00

64. Blue Mud.—Station 323.

Lat. 35° 39′ S., long. 50° 47′ W., 1900 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·60
Portion soluble in Hydrochloric Acid = 44·82	Alumina,	5·50
	Ferric oxide,	5·61
	Calcium phosphate,	1·39
	Manganese oxide,	...
	Calcium sulphate,	0·42
	Calcium carbonate,	2·94
	Magnesium carbonate,	0·76
	Silica,	28·20
Portion insoluble in Hydrochloric Acid = 49·58	Alumina,	8·05
	Ferric oxide,	2·77
	Lime,	2·51
	Magnesia,	0·25
	Silica,	36·00
		100·00

65. Blue Mud.—Station 323.

Lat. 35° 39′ S., long. 50° 47′ W., 1900 fathoms (Renard).

I. 0·8069 grm. of substance dried at 110° C., fused with the carbonates of soda and potash, gave 0·4804 grm. of silica, 0·1566 grm. of alumina, 0·0576 grm. of peroxide of iron, 0·0135 grm. of lime, 0·0427 grm. of pyrophosphate of magnesia = 0·0155 grm. of magnesia, and 0·0503 grm. of loss on ignition.

II. 1·4212 grms. of substance dried at 110° C., treated with hydrofluoric and sulphuric acids, gave 0·0995 grm. of the chlorides of soda and potash, 0·1603 grm. of chloroplatinate of potash = 0·0202 grm. of potash and, by difference, 0·0382 grm. of soda.

Silica,	59·54
Alumina,	19·42
Peroxide of iron,	7·15
Lime,	1·68
Magnesia,	1·93
Potash,	1·35
Soda,	2·68
Water,	6·24
Phosphoric and sulphuric acids,	traces
	99·99

66. Green Sand.—Station 141.

Lat. 34° 41′ S., long. 18° 36′ E., 98 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	9·10
Portion soluble in Hydrochloric Acid = 67·90	Alumina,	2·30
	Ferric oxide,	4·70
	Calcium phosphate,	trace
	Calcium sulphate,	1·07
	Calcium carbonate,	49·46
	Magnesium carbonate,	2·02
	Silica,	8·35
Portion insoluble in Hydrochloric Acid = 23·00	Alumina,	0·95
	Ferric oxide,	0·35
	Lime,	0·22
	Magnesia,	0·13
	Silica,	21·35
		100·00

67. Green Mud.—Station 164b.

Lat. 34° 13′ S., long. 151° 38′ E., 410 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	3·30
Portion soluble in Hydrochloric Acid = 72·29	Alumina,	2·50
	Ferric oxide,	12·30
	Calcium phosphate,	0·70
	Manganese oxide,	...
	Calcium sulphate,	0·58
	Calcium carbonate,	46·36
	Magnesium carbonate,	0·57
	Silica,	9·28
Portion insoluble in Hydrochloric Acid = 24·41	Alumina,	1·58
	Ferric oxide,	0·42
	Lime,	0·30
	Magnesia,	0·12
	Silica,	21·99
		100·00

68. Volcanic Mud.—Station VIIr.

Lat. 28° 41′ N., long. 16° 6′ W., 640 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·94
Portion soluble in Hydrochloric Acid = 62·98	Alumina,	5·91
	Ferric oxide,	7·02
	Calcium phosphate,	0·52
	Calcium sulphate,	1·05
	Calcium carbonate,	35·68
	Magnesium carbonate,	2·04
	Silica,	10·76
Portion insoluble in Hydrochloric Acid = 32·08	Alumina,	4·30
	Ferric oxide,	5·38
	Lime,	2·58
	Magnesia,	0·65
	Silica,	19·17
		100·00

Note.—When treated with dilute hydrochloric acid this substance evolved a perceptible tarry odour.

69. Volcanic Mud.—Station VIIt.

Lat. 28° 42′ N., long. 17° 8′ W., 1750 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	6·30
Portion soluble in Hydrochloric Acid = 68·57	Alumina,	5·71
	Ferric oxide,	7·14
	Calcium phosphate,	good trace
	Calcium sulphate,	1·15
	Calcium carbonate,	41·43
	Magnesium carbonate,	1·43
	Silica,	11·71
Portion insoluble in Hydrochloric Acid = 25·13	Alumina,	3·71
	Ferric oxide,	3·43
	Lime,	1·43
	Magnesia,	0·72
	Silica,	15·84
		100·00

Note.—When treated with dilute hydrochloric acid this substance evolved a perceptible tarry odour.

70. Volcanic Mud.—Station VIII.

Lat. 28° 3′ 15″ N., long. 17° 27′ W., 620 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	6·22
Portion soluble in Hydrochloric Acid = 66·23	Alumina,	5·00
	Ferric oxide,	11·69
	Calcium phosphate,	large trace
	Manganese oxide,	trace
	Calcium sulphate,	0·27
	Calcium carbonate,	32·22
	Magnesium carbonate,	0·83
	Silica,	16·22
Portion insoluble in Hydrochloric Acid = 27·55	Alumina,	4·22
	Ferric oxide,	3·77
	Lime,	1·44
	Magnesia,	0·22
	Silica,	17·90
		100·00

71. Coral Sand.—Station 172.

Lat. 20° 58′ S., long. 175° 9′ W., 18 fathoms (Renard).

I. 1·1310 grms. of substance dried at 110° C., treated with hydrochloric acid, gave 0·016 grm. of phosphoric acid, alumina, and iron, 0·5686 grm. of lime, 0·0944 grm. of pyrophosphate of magnesia = 0·0340 grm. of magnesia.

II. 0·852 grm. of substance dried at 105° C. served for the determination of carbonic acid, and gave 0·3602 grm.

III. 2·2746 grms. of substance dried at 110° C., treated with dilute hydrochloric acid, gave 0·06346 grm. of flocculent residue of organic matter.

Lime,	50·27
Magnesia,	3·00
Carbonic acid,	42·28
Alumina, iron, and phosphoric acid,	1·42
Organic substances,	2·78
Manganese and alkalies,	traces
	99·75

72. Phosphatic Concretions.—Station 142.

Lat. 35° 4′ S., long. 18° 37′ E., 150 fathoms (Klement).

I. 0·8215 grm. of substance dried at 110° C. gave 0·0990 grm. of carbonic acid, and 0·0328 grm. of sulphate of barium.

II. 0·5715 grm. of substance dried at 110° C. gave 0·1784 grm. of pyrophosphate of magnesia (P_2O_5), 0·0078 grm. of silica, 0·2253 grm. of lime, 0·0107 grm. of pyrophosphate of magnesia (MgO), 0·0068 grm. of alumina, 0·0145 grm. of peroxide of iron, and 0·0991 grm. of residue insoluble in dilute nitric acid.

III. 0·2428 grm. of insoluble residue, calcined and fused with the carbonates of soda and potash, gave 0·1880 grm. of silica, 0·0301 grm. of alumina, 0·0192 grm. of peroxide of iron, 0·0026 grm. of lime, and 0·0069 grm. of pyrophosphate of magnesia.

		Ratio of Equivalents.	
Phosphoric acid,	19·96	0·422	0·713
Carbonic acid,	12·05	0·274	
Sulphuric anhydride,	1·37	0·017	
Silica,	1·36		
Lime,	39·41	0·704	0·721
Magnesia,	0·67	0·017	
Peroxide of iron,	2·54		
Alumina,	1·19		
Loss on ignition,[1]	...		
Insoluble residue,	17·34		
	95·89		

Composition of the insoluble residue:—

Silica,	77·43
Alumina,	12·40
Peroxide of iron,	7·91
Lime,	1·07
Magnesia,	1·02
	99·83

[1] An accident during the operation prevented the determination of the loss on ignition.

73. Phosphatic Concretions.—Station 143.

Lat. 36° 48′ S., long. 19° 24′ E., 1900 fathoms (Klement).

I. 1·1045 grms. of substance dried at 110° C. gave 0·1175 grm. of carbonic acid, and 0·0447 grm. of sulphate of barium.

II. 0·4952 grm. of substance dried at 110° C. gave 0·1822 grm. of pyrophosphate of magnesia (P_2O_5), 0·0127 grm. of silica, 0·2028 grm. of lime, 0·0114 grm. of pyrophosphate of magnesia (MgO), 0·0138 grm. of peroxide of iron, 0·0071 grm. of alumina, and 0·0591 grm. of residue insoluble in dilute nitric acid.

III. 3·3276 grms. of substance dried at 110° C. gave 0·1213 grm. of loss on ignition.

IV. 0·1892 grm. of insoluble residue, calcined and fused with the carbonates of soda and potash, gave 0·1449 grm. of silica, 0·0262 grm. of alumina, 0·0150 grm. of peroxide of iron, 0·0024 grm. of lime, 0·0064 grm. of pyrophosphate of magnesia.

		Ratio of Equivalents.	
Phosphoric acid,	23·54	0·498	0·757
Carbonic acid,	10·64	0·242	
Sulphuric anhydride,	1·39	0·017	
Silica,	2·56		
Lime,	40·95	0·731	0·752
Magnesia,	0·83	0·021	
Peroxide of iron,	1·43		
Alumina,	2·79		
Loss on ignition,	3·65		
Insoluble residue,	11·93		
	99·71		

Composition of the insoluble residue:—

Silica,	76·58
Alumina,	13·85
Peroxide of iron,	7·93
Lime,	1·27
Magnesia,	1·18
	100·81

74. Phosphatic Concretions.—Station 143.

Lat. 36° 48′ S., long. 19° 24′ E., 1900 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·10
Portion soluble in Hydrochloric Acid = 86·74	Copper,	mere trace
	Alumina,	3·00
	Ferric oxide,	5·80
	Calcium phosphate,	49·57
	Manganese oxide,	2·70
	Nickel,	...
	Cobalt,	...
	Calcium sulphate,	2·62
	Calcium carbonate,	16·07
	Magnesium carbonate,	0·98
	Silica,	6·00
Portion insoluble in Hydrochloric Acid = 9·16	Alumina, Ferric oxide,	0·60
	Lime,	0·16
	Magnesia,	fair trace
	Silica,	8·40
		100·00

Note.—Two pieces of heavy and hard material, smooth on the outside and of a grey colour; inside colour lighter grey.

75. Manganese Nodules (nuclei of bone).—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·70
Portion soluble in Hydrochloric Acid = 91·09	Copper,	trace
	Alumina,	2·30
	Ferric oxide,	13·88
	Calcium phosphate,	53·12
	Manganese oxide,	3·62
	Nickel,	trace
	Cobalt,	trace
	Calcium sulphate,	2·62
	Calcium carbonate,	11·56
	Magnesium carbonate,	0·75
	Silica,	3·24
Portion insoluble in Hydrochloric Acid = 4·21	Alumina,	0·50
	Ferric oxide,	1·70
	Lime,	0·51
	Magnesia,	0·15
	Silica,	1·35
		100·00

Note.—Two nodules, harder than the rest, coated with a light brown shell, which easily peeled off, and after being removed was reserved.

76. Pumice.—Station 226.

Lat. 14° 44′ N., long. 142° 13′ E., 2300 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	8·90
Portion soluble in Hydrochloric Acid = 74·59	Copper,	small trace
	Alumina,	7·00
	Ferric oxide,	26·28
	Calcium phosphate,	good trace
	Manganese oxide,	10·25
	Nickel,	small trace
	Cobalt,	...
	Calcium sulphate,	0·29
	Calcium carbonate,	1·29
	Magnesium carbonate,	0·68
	Silica,	28·80
Portion insoluble in Hydrochloric Acid = 16·51	Alumina,	2·74
	Ferric oxide,	1·36
	Lime,	1·01
	Magnesia,	0·40
	Silica,	11·00
		100·00

Note.—Material like pumice, light in weight, with reddish particles on surface.

77. Pumice.—Station 246.

Lat. 36° 10′ N., long. 178° 0′ E., 2050 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·90
Portion soluble in Hydrochloric Acid = 32·60	Copper,	small trace
	Alumina,	2·50
	Ferric oxide,	7·30
	Calcium phosphate,	0·20
	Manganese oxide,	4·56
	Nickel,	small trace
	Cobalt,	...
	Calcium sulphate,	0·60
	Calcium carbonate,	1·94
	Magnesium carbonate,	2·00
	Silica,	13·50
Portion insoluble in Hydrochloric Acid = 61·50	Alumina,	6·00
	Ferric oxide,	5·20
	Lime,	1·70
	Magnesia,	0·54
	Silica,	48·06
		100·00

Note.—Pieces resembling pumice in a disintegrating state; as received, that is to say dry, the material floated in water for a time but afterwards sank.

78. Pumice.—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·50
Portion soluble in Hydrochloric Acid = 56·27	Copper,	trace
	Alumina,	6·00
	Ferric oxide,	11·00
	Calcium sulphate,	mere trace
	Manganese oxide,	5·70
	Nickel,	trace
	Cobalt,	trace
	Calcium sulphate,	0·25
	Calcium carbonate,	1·90
	Magnesium carbonate,	3·02
	Silica,	28·40
Portion insoluble in Hydrochloric Acid = 39·23	Alumina,	3·40
	Ferric oxide,	5·25
	Lime,	1·35
	Magnesia,	0·50
	Silica,	28·73
		100·00

Note.—Four small pieces of matter (three soft and one hard) resembling pumice.

79. Pumice.—Station 184.

Lat. 12° 8′ S., long. 145° 10′ E., 1400 fathoms (Renard).

I. 1·5321 grms. of substance dried at 110° C., fused with the carbonates of soda and potash, gave 0·0260 grm. of water, 0·7747 grm. of silica, 0·0122 grm. of titanic acid, 0·1578 grm. of alumina, 0·0757 grm. of peroxide of iron, 0·0021 grm. of protoxide of manganese, 0·1422 grm. of lime, 0·3490 grm. of pyrophosphate of magnesia = 0·1420 grm. of magnesia.

II. 0·520 grm. of substance dried at 110° C., treated with hydrofluoric and sulphuric acids, required for the determination of protoxide of iron 6·5 c.c. of permanganate of potash = 0·0395 grm. of protoxide of iron (1 c.c. of permanganate of potash = 0·005846 grm. of protoxide of iron).

III. 1·0252 grms. of substance dried at 110° C. gave 0·0127 grm. of potash and, by difference, 0·0288 grm. of soda.

Silica,	50·56
Titanic acid,	0·80
Alumina,	10·80
Peroxide of iron,	4·95
Protoxide of iron,	7·59
Protoxide of manganese,	0·14
Lime,	9·35
Magnesia,	0·27
Potash,	1·24
Soda,	2·81
Water,	1·70
	98·71

80. Pumice.—Station 241.

Lat. 35° 41′ N., long. 157° 42′ E., 2300 fathoms (Renard).

I. 1·2725 grms. of substance dried at 110° C., fused with the carbonates of soda and potash, gave 0·7755 grm. of silica, 0·2032 grm. of alumina, 0·1155 grm. of peroxide of iron, 0·0371 grm. of lime, 0·0629 grm. of loss on ignition, 0·0493 grm. of pyrophosphate of magnesia = 0·0178 grm. of magnesia.

II. 1·0515 grms. of substance dried at 110° C., treated with hydrofluoric and sulphuric acids, gave 0·0707 grm. of the chlorides of soda and potash, 0·0914 grm. of chloroplatinate of potash = 0·0169 grm. of potash and, by difference, 0·0246 grm. of soda.

Silica,	60·95
Alumina,	15·97
Peroxide of iron,	9·08
Lime,	2·92
Magnesia,	1·40
Potash,	1·61
Soda,	2·34
Loss on ignition,	4·95
Manganese,	large trace
	99·22

81. Basic Volcanic Glass.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Renard).

I. 0·8463 grm. of substance, fused with the carbonates of soda and potash, gave 0·4510 grm. of silica, 0·1258 grm. of alumina, 0·0991 grm. of ferric oxide, 0·0788 grm. of lime, 0·1834 grm. of pyrophosphate of magnesia = 0·06619 grm. of magnesia.

II. 0·5448 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 6·6 c.c. permanganate of potash solution (1 c.c. permanganate of potash solution = 0·0058463 grm. of ferrous oxide) = 0·03859 grm. of ferrous oxide.

III. 1·5701 grms. of substance gave 0·0265 grm. of water (loss on ignition).

IV. 1·5235 grms. of substance, treated with hydrofluoric and sulphuric acids, gave 0·08159 grm. of the chlorides of potash and soda, 0·0243 grm. of chloroplatinate of potash, corresponding to 0·0074 grm of chloride of potash = 0·0047 grm. of potash, and 0·0741 grm. of chloride of soda = 0·0392 grm. of soda.

Silica,	53·29
Ferric oxide,	3·84
Ferrous oxide,	7·08
Alumina,	14·86
Lime,	9·31
Magnesia,	7·81
Potash,	0·31
Soda,	2·57
Water,	1·69
	100·76

82. Basic Volcanic Glass.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Sipöcz).

I. 1·0841 grms. of substance, fused with the carbonates of soda and potash, gave 0·5417 grm. of silica, 0·1543 grm. of ferric oxide, 0·1267 grm. of alumina, 0·1215 grm. of lime, 0·3864 grm. of pyrophosphate of magnesia = 0·1392 grm. of magnesia, and 0·0056 grm. of pyrophosphate of magnesia = 0·0036 grm. of phosphoric acid, and trace of manganese.

II. 0·5185 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 9·4 c.c. permanganate of potash solution (1 c.c. permanganate of potash solution = 0·0058463 grm. of ferrous oxide), corresponding to 0·05495 grm. of ferrous oxide.

III. 1·0448 grms. of substance, treated with hydrofluoric and sulphuric acids, gave 0 0357 grm. of the chlorides of soda and potash, 0·0137 grm. of chloroplatinate of potash. The finely pulverised scoria, passed through fuming hydrochloric acid, was but incompletely decomposed.

Silica,	49·97
Alumina,	11·68
Ferric oxide,	2·45
Ferrous oxide	10·60
Manganous oxide,	trace
Lime,	11·20
Magnesia,	12·84
Potash,	0·25
Soda,	1·60
Phosphoric acid,	0·33
	100·92

83. Palagonite.—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Dittmar).

A brown, apparently amorphous, substance, some of it powdery, some in lumps, which when broken exhibited a dirty-white fracture. The microscope showed white and yellow crystalline parts, and here and there black globules, also a few metallic-looking particles. Having been led to understand (by Mr Murray) that there were good grounds for looking upon this substance as disintegrated "pumice," and knowing that pumice is in a very high degree proof against the action of even strong acids, it struck me that the proper mode of investigating this substance was to extract from it all that could be rendered soluble by successive treatment with a (*a*) hot hydrochloric acid, (*b*) boiling carbonate of soda solution, (*c*) semi-concentrated boiling vitriol, (*d*) boiling carbonate of soda solution; to analyse the ultimate residue, and compare the results with reliable published analyses of pumice or obsidians. This line of research was accordingly adopted; but not wishing to rely altogether on second-hand information in this respect, an undoubted specimen of pumice from the Challenger collection was examined in precisely the same manner.

The results of the (rough) *proximate* analyses were as follows:—
Found in 100 parts of

	Real Pumice.	Quasi-Pumice.
Moisture (100°),	1·0	13·5
Part decomposible by hot hydrochloric acid,[1]	6·9	34·0
Part decomposible by hot vitriol,	5·1	44·5
Ultimate residue,	87·0	8·0
	100·0	100·0

The ultimate residues were ignited before being weighed and they were analysed in that condition, which, as it now strikes me, may perhaps have been a mistake; but if so it cannot now be rectified. The results of the analyses were as follows:—

Found in 100 parts of *purified*

	Pumice.	Quasi-Pumice.
Silica,	76·41	56·77
Alumina (including trace of Fe_2O_3),	15·53	25·21
Lime,	2·11	9·09
Magnesia,	0·40	1·37
Potash,	2·26	3·36
Soda,	2·98	4·19
Moisture,[2]	0·20	1·11
	99·89	101·10

Converting these numbers into multiples of SiO_2, Al_2O_3, &c., we have for the

	Real Pumice.	Quasi.
SiO_2,	1	1
Al_2O_3,	0·1186	0·2592
(or $\frac{1}{3}$ Al_2O_3),	(0·3558)	(0·7776)
CaO,	0·0296	0·1716
MgO,	0·0079	0·0362
K_2O,	0·0189	0·0378
Na_2O,	0·0377	0·0714

or, taking RO as a general symbol for $R''O$, $\frac{1}{3}Al_2O_3$, R'_2O, we have in multiples of

	SiO_2	RO
Real Pumice,	1	0·4499
Quasi,	1	1·0946

or, separating the bases into R_2O_3's and RO's (where RO = CaO, K_2O, &c.)

	SiO_2	R_2O_3	RO
Real Pumice,	10	1·19	1 (−0·06)
Quasi,	4	1·037	1·27

Rammesberg, in his Dictionary of Chemical Mineralogy (quoting from an extensive research by Abich) gives a number of analyses by that chemist, from which it appears that pumices and obsidians (which, with him, are only two forms of the same genus) arrange themselves into two sets—A and B.

The	(SiO_2)s	(R_2O_3)s	(RO)s
in A are,	4·5 to 5·5	1	1
in B are,	6·5 to 8·5	1	
Orthoclase and albite,	6	1	1
General symbols,	n	m	p

[1] By difference; includes combined H_2O.

[2] Absorbed during preservation in tubes.

We see that in both our specimens $m=p$ as in Abich's pumices; but while our "quasi" is just a little too basic for the A-set, our purified pumice is far too acid for set B even. The excess of base in our quasi-pumice might be explained by the presence in it of Anorthite,[1] which according to Tschermak always accompanies albite as a normal admixture. Going by Abich's determinations our quasi-pumice would appear to stand closer to what he calls pumice than our undoubtedly genuine pumice does.

[1] $\left.\begin{matrix} CaO \\ Al_2O \end{matrix}\right\} 2SiO_2$; *i.e.*, 4(RO or $R_2^{\frac{2}{3}}$O) for $2SiO_2$.

84. Glauconite.—Station 164B.

Lat. 34° 13′ S., long. 151° 38′ E., 410 fathoms (Sipöcz).

I. 0·4544 grm. of substance, fused with the carbonates of soda and potash, gave 0·0311 grm. of water, 0·2573 grm. of silica, 0·0770 grm. of peroxide of iron, 0·0570 grm. of alumina, trace of manganese, 0·0077 grm. of lime, and 0·0315 grm. of pyrophosphate of magnesia = 0·01135 grm. of magnesia.

II. 0·3519 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0199 grm. of the chlorides of potash and soda, 0·0456 grm. of chloroplatinate of potash, corresponding to 0·0139 grm. of chloride of potash = 0·00889 grm. of potash, and 0·0060 grm. of chloride of soda = 0·00318 grm. of soda.

III. 0·1483 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 0·3 c.c. permanganate of potash (1 c.c. permanganate of potash = 0·0058355 grm. of protoxide of iron), corresponding to 0·0175 grm. of protoxide of iron.

Silica,	56·62
Peroxide of iron,	15·63
Alumina,	12·54
Protoxide of iron,	1·18
Lime,	1·69
Magnesia,	2·49
Potash,	2·52
Soda,	0·90
Water,	6·84
Manganese,	trace
	100·41

Note.—This substance contained about 65 per cent. of white, pale grey, and some yellow casts, 20 per cent. pale green casts, and 11 per cent. of dark green casts, together with 14 per cent. of mineral particles and siliceous organisms (J. M.).

85. Glauconite.—Station 164B.

Lat. 34° 13′ S., long. 151° 38′ E., 410 fathoms (Sipöcz).

I. 0·6340 grm. of substance, fused with the carbonates of soda and potash, gave 0·0352 grm. of water, 0·3299 grm. of silica, 0·1664 grm. of peroxide of iron, 0·0566 grm. of alumina, trace of manganese, 0·0080 grm. of lime, and 0·055 grm. of pyrophosphate of magnesia = 0·019856 grm. of magnesia.

II. 0·5320 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0380 grm. of the chlorides of potash and soda, 0·1164 grm. of chloroplatinate of potash, corresponding to 0·0355 grm. of chloride of potash = 0·02243 grm. of potash, and 0·0025 grm. of chloride of soda = 0·00133 grm. of soda.

III. 0·2633 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 0·75 c.c. permanganate of potash (1 c.c. permanganate of potash = 0·0058355 grm. of protoxide of iron), corresponding to 0·004376 grm. of protoxide of iron.

Silica,	50·85
Peroxide of iron,	24·40
Alumina,	8·92
Protoxide of iron,	1·66
Lime,	1·26
Magnesia,	3·13
Potash,	4·21
Soda,	0·25
Water,	5·55
Manganese,	trace
	100·23

NOTE.—This substance contained 15 per cent. of white, pale grey, and yellow casts, 35 per cent. pale green casts, 45 per cent. of dark green particles, together with 5 per cent. of mineral particles and siliceous organisms (J. M.).

86. GLAUCONITE.—Station 164B.

Lat. 34° 13′ S., long. 151° 38′ E., 410 fathoms (Sipöcz).

I. 0·7312 grm. of substance, fused with the carbonates of soda and potash, gave 0·0416 grm. of water, 0·3788 grm. of silica, 0·1896 grm. of peroxide of iron, 0·0634 grm. of alumina, trace of manganese, 0·0093 grm. of lime, and 0·0618 grm. of pyrophosphate of magnesia = 0·02227 grm. of magnesia.

II. 0·6828 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0450 grm. of the chlorides of potash and soda, 0·1367 grm. of chloroplatinate of potash, corresponding to 0·0417 grm. of chloride of potash = 0·02634 grm. of potash, and 0·0033 grm. of chloride of soda = 0·00175 grm. of soda.

III. 0·3205 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 0·85 c.c. permanganate of potash (1 c.c. permanganate of potash = 0·0058355 grm. of protoxide of iron), corresponding to 0·00496 grm. of protoxide of iron.

Silica,	51·80
Peroxide of iron,	24·21
Alumina,	8·67
Protoxide of iron,	1·54
Lime,	1·27
Magnesia,	3·04
Potash,	3·86
Soda,	0·25
Water,	5·68
Manganese,	trace
	100·32

NOTE.—This substance contained 10 per cent. of white, pale grey, and yellow casts, 25 per cent. of pale green casts, 60 per cent. of dark green casts, together with 5 per cent. of mineral particles and siliceous organisms (J. M.).

87. GLAUCONITE.—Station 164B.

Lat. 34° 13′ S., long. 151° 38′ E., 410 fathoms (Sipöcz).

I. 0·7543 grm. of substance, fused with the carbonates of soda and potash, gave 0·0435 grm. of water, 0·4147 grm. of silica, 0·1777 grm. of peroxide of iron, 0·0626 grm. of alumina, trace of manganese, 0·0098 grm. of lime, and 0·0575 grm. of pyrophosphate of magnesia = 0·02072 grm. of magnesia.

II. 0·7413 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0432 grm. of the chlorides of potash and soda, 0·1292 grm. of chloroplatinate of potash, corresponding to 0·0394 grm. of chloride of potash = 0·0249 grm. of potash, and 0·0038 grm. of chloride of soda = 0·0020 grm. of soda.

III. 0·2987 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 1 c.c. permanganate of potash (1 c.c. permanganate of potash = 0·0058355 grm. of protoxide of iron), corresponding to 0·0058355 grm. of protoxide of iron.

IV. 0·4112 grm. of substance gave 0·0242 grm. of loss on ignition, and fused with the carbonates of soda and potash gave 0·2277 grm. of silica, 0·0986 grm. of peroxide of iron, 0·0326 grm. of alumina, trace of manganese, 0·0057 grm. of lime, and 0·0325 grm. of pyrophosphate of magnesia = 0·01207 grm. of magnesia.

	I.	II.	III.	IV.	Mean
Silica,	54·97	...	...	55·37	55·17
Peroxide of iron,	21·39	...	...	21·84	21·59
Alumina,	8·30	...	...	7·93	8·12
Protoxide of iron,	...	...	1·95	...	1·95
Lime,	1·30	...	...	1·38	1·34
Magnesia,	2·74	...	...	2·93	2·83
Potash,	...	3·36	...	...	3·36
Soda,	...	0·27	...	...	0·27
Water,	5·76	...	...	...	5·76
Manganese,	...	...	...	...	trace
					100·39

Note.—This substance contained 30 per cent. of white, pale grey, and yellow casts, 40 per cent. pale green casts, 20 per cent. dark green casts, together with 10 per cent. of mineral particles and remains of siliceous organisms (J. M.).

88. Glauconite.—Station 185b.

Lat. 11° 38′ 15″ S., long. 143° 59′ 38″ E., 155 fathoms (Sipöcz).

I. 0·3695 grm. of substance, fused with the carbonates of soda and potash, gave 0·0401 grm. of water, 0·1025 grm. of silica, 0·1548 grm. of peroxide of iron, 0·0481 grm. of alumina, trace of manganese, 0·0044 grm. of lime, and 0·0474 grm. of pyrophosphate of magnesia = 0·0171 grm. of magnesia.

II. 0·2740 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0082 grm. of the chlorides of potash and soda, 0·0137 grm. of chloroplatinate of potash, corresponding to 0·0042 grm. of chloride of potash = 0·0025 grm. of potash, and 0 0040 grm. of chloride of soda = 0·0017 grm. of soda.

III. 0·0990 grm. of substance required for oxidation, after treatment with hydrofluoric and sulphuric acids, 0·3 c.c. permanganate of potash (1 c.c. permanganate of potash = 0·0058355 grm. of protoxide of iron), corresponding to 0·00175 grm. of protoxide of iron.

Silica,	27·74
Peroxide of iron,	39·93
Alumina,	13·02
Protoxide of iron,	1·76
Manganese,	trace
Lime,	1·19
Magnesia,	4·62
Potash,	0·95
Soda,	0·62
Water,	10·85
	100·68

89. Phillipsite.—Station 275.

Lat. 11° 20′ S., long. 150° 30′ W., 2610 fathoms (Sipöcz).

I. 0·5080 grm. of substance, after drying 16 hours at 125° C., lost 0·0465 grm. of water and gave 0·0385 grm. of loss on ignition, and then fused with the carbonates of soda and potash, gave 0·2418 grm. of silica, 0·0301 grm. of peroxide of iron, 0·0868 grm. of alumina, 0·0024 grm. manganoso-manganic oxide = 0·0022 grm. of manganous oxide, 0·0163 grm. of lime, and 0·0176 grm. of pyrophosphate of magnesia = 0·00634 grm. of magnesia.

II. 0·3224 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0494 grm. of the chlorides of potash and soda, 0·0806 grm. of chloroplatinate of potash, corresponding to 0·0246 grm. of chloride of potash = 0·0155 grm. of potash, and 0·0248 grm. of chloride of soda = 0·01315 grm. of soda.

Silica,	47·60	
Peroxide of iron,	5·92	
Alumina,	17·09	
Manganous oxide,	0·43	
Lime,	3·20	
Magnesia,	1·24	
Potash,	4·81	
Soda,	4·08	
Water at 125° C.,	9·15	16·74
Water Loss on ignition,	7·59	
	101·11	

90. Phillipsite.—Station 275.

Lat. 11° 20′ S., long. 150° 30′ W., 2610 fathoms (Sipöcz).

I. 0·5411 grm. of substance, after drying 30 hours at 125° C., lost 0·0506 grm. of water and gave 0·0398 grm. of loss on ignition, and then fused with the carbonates of soda and potash, gave 0·2699 grm. of silica, 0·0300 grm. of peroxide of iron, 0·0894 grm. of alumina, 0·0026 grm. of manganoso-manganic oxide = 0·0024 grm. of manganous oxide, 0·0075 grm. of lime, and 0·0180 grm. of pyrophosphate of magnesia = 0·0065 grm. of magnesia.

II. 0·4115 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0690 grm. of the chlorides of potash and soda, 0·1091 grm. of chloroplatinate of potash, corresponding to 0·0333 grm. of chloride of potash = 0·0210 grm. of potash, and 0·0357 grm. of chloride of soda = 0·0189 grm. of soda.

Silica,	49·88	
Peroxide of iron,	5·54	
Alumina,	16·52	
Manganous oxide,	0·44	
Lime,	1·38	
Magnesia,	1·20	
Potash,	5·10	
Soda,	4·59	
Water at 125° C.,	9·33	16·68
Water Loss on ignition,	7·35	
	101·33	

91. Phillipsite.—Station 275.

Lat. 11° 20′ S., long. 150° 30′ W., 2610 fathoms (Renard).

I. 0·7228 grm. of substance, after drying 10 hours at 125° C., lost 0·0575 grm. of water and gave 0·0685 grm. of loss on ignition, and then fused with the carbonates of soda and potash, gave 0·3520 grm. of silica, 0·0446 grm. of peroxide of iron, 0·1271 grm. of alumina, 0·0123 grm. of lime, 0·0208 grm. of pyrophosphate of magnesia = 0·0074 grm. of magnesia.

II. 0·75479 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·1112 grm. of the chlorides of potash and soda, 0·1879 grm. of chloroplatinate of potash, corresponding to 0·0579 grm. of chloride of potash = 0·0365 grm. of potash, and 0·0533 grm. of chloride of soda = 0·0283 grm. of soda.

Silica,	48·70	
Peroxide of iron,	6·17	
Alumina,	17·58	
Lime,	1·70	
Magnesia,	1·02	
Potash,	4·83	
Soda,	3·75	
Water at 125° C.,	7·95	17·42
Water Loss on ignition,	9·47	
	101·17	

92. Phillipsite.—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Dittmar).

This specimen (which amounted to only a very few grams), when viewed under the microscope, appeared to consist mainly of tufts of yellow well-shaped crystals mixed with brown amorphous matter and black roundish particles. I tried a variety of methods for isolating the crystals, such as treatment with cold dilute hydrochloric acid, dilute sulphuric acid, oxalic acid, &c., but did not succeed; the crystals themselves were too readily disintegrated by acids. On the other hand, even treatment with hot hydrochloric acid left more than mere hydrated silica; I therefore decided upon separating the subtance into two parts by means of hot hydrochloric acid and analysing separately the disintegrated portion (including soluble silica of residue), and the de-silicated residue. Such an analysis accordingly was started, but unfortunately it was lost through a serious oversight in the manipulation of the silicas, and not caring to risk the small remnant of substance that was left in comparatively difficult processes, I simply analysed it as it was, *i.e.*, without previously separating it into two parts. The first analysis served to check some of the numerical results, and as the agreements were satisfactory, the following analysis may be said to rest partly on double determinations.

Sketch of Method of Analysis.—A known weight (0·6068 grm.) of air-dry powdered substance was placed in a platinum boat and dehydrated in a current of dry air, first at 100°, then at a red heat (within a combustion tube), the volatilised water, in the second case, being collected in a tared chloride-of-calcium tube. The residue was weighed, transferred to a platinum crucible, again weighed, and then ignited *strongly*, when it suffered an additional loss of weight. The residue was fused with carbonates of potash and soda and analysed as usual. In a separate portion the alkalies were determined according to Lawrence Smith.

Found in 100 parts of substance:—

	Per Cent.	In multiples of combining weights.
Silica,	57·85	1·000
Alumina,	20·09	0·203
Ferric oxide,	8·59	0·0555
Manganous oxide,	2·51	0·0362
Lime,	5·43	0·1006
Magnesia,	3·10	0·0804
Potash,	3·95	0·0436
Soda,	1·31	0·0218
	102·83	
Error,	2·83	
	100·00	
Water vol. at 100°,	9·74	: $H_2O = 0·5612$ (*a*)
Water vol. at redness,	10·56	: $H_2O = 0·6085$ (*b*)
Further loss at strong red heat,	4·83	: $H_2O = 0·2785$ (*c*)
	Sa 125·13	

Assuming the "Fe_2O_3" reported to have been FeO (in the substance), we have for the co-efficients of

					c	*b*	*a*
	SiO_2	Al_2O_3	RO	R_2O	H_2O	H_2O	H_2O
	1	0·203	0·328	0·065	0·2785	0·6085	0·5612
or	SiO_2	Al_2O_3	RO	R_2O	H_2O		
	5	1·015	1·64	0·325	7·24		
or	5	1	2 (RO + R_2O)		7 (about)		

The substance, then, *would appear* to be a kind of (mixed) zeolite, of the formula

$$\left.\begin{matrix} Al_2O''' \\ 2RO \\ 5H_2O \end{matrix}\right\} 5SiO_2 + \times Aq;$$

the H_2O's supplementing what would otherwise be a meta- into an ortho-silicate, which explains its decomposibility by hydrochloric acid. I am, however, very far from asserting that the substance really *is* such a zeolite. Before doing so I should wish to repeat my analysis with a larger supply of *purified* material.

93. Basic Volcanic Glass.—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Sipöcz).

A. *Unaltered Nucleus* (spec. grav., 2·90).

I. 0·9040 grm. of substance, fused with the carbonates of soda and potash, gave 0·4227 grm. of silica, 0·1254 grm. of peroxide of iron, 0·1601 grm. of alumina, 0·0043 grm. of manganoso-manganic oxide, 0·1045 grm. of lime, and 0·2604 grm. of pyrophosphate of magnesia.

II. 0·3390 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 6·35 c.c. permanganate of potash (1 c.c. permanganate of potash = 0·0058296 grm. of protoxide of iron), corresponding to 0·037018 grm. of protoxide of iron.

III. 0·8385 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0314 grm. of the chlorides of potash and soda, 0·0075 grm. of chloroplatinate of potash, corresponding to 0·0023 grm. of chloride of potash = 0·00144 grm. of potash, and 0·0291 grm. of chloride of soda = 0·01543 grm. of soda.

Silica,	46·76
Peroxide of iron,	1·73
Protoxide of iron,	10·92
Alumina,	17·71
Manganous oxide,	0·44
Lime,	11·56
Magnesia,	10·37
Potash,	0·17
Soda,	1·83
	101·49

94. Palagonite.—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Sipöcz).

B. *Decomposed Coating.*

I. 0·5681 grm. of substance, dried at 105° C., gave 0·0543 grm. of loss on ignition, then fused with the carbonates of soda and potash gave 0·2541 grm. of silica, 0·0828 grm. of peroxide of iron, 0·0924 grm. of alumina, 0·0159 grm. of manganoso-manganic oxide, 0·0107 grm. of lime, and 0·0554 grm. of pyrophosphate of magnesia = 0·01239 grm. of magnesia.

II. 0·3801 grm. of substance, dried at 105° C., treated with hydrofluoric and sulphuric acids, gave 0·0565 grm. of the chlorides of potash and soda, 0·0794 grm. of chloroplatinate of potash, corresponding to 0·0242 grm. of chloride of potash = 0·0153 grm. of potash, and 0·0323 grm. of chloride of soda = 0·017126 grm. of soda.

Silica,	44·73
Peroxide of iron,	14·57
Alumina,	16·26
Manganic oxide,	2·89
Lime,	1·88
Magnesia,	2·23
Potash,	4·02
Soda,	4·50
Water,	9·56
	100·64

95. Basic Volcanic Glass (spec. grav., 2·89).—Station 302.

Lat. 42° 43′ S., long. 82° 11′ W., 1450 fathoms (Renard).

I. 1·0852 grms. of substance, fused with the carbonates of soda and potash, gave 0·5084 grm. of silica, 0·1480 grm. of peroxide of iron, 0·1930 grm. of alumina, 0·0046 grm. of manganous sulphide, 0·1288 grm. of lime, and 0·2783 grm. of pyrophosphate of magnesia = 0·10028 grm. of magnesia.

II. 0·4320 grm. of substance, treated with hydrofluoric and sulphuric acids, required for oxidation 8·0 c.c. of permanganate of potash (1 c.c. permanganate of potash = 0·0058296 grm. of protoxide of iron), corresponding to 0·04663 grm. of protoxide of iron.

III. 0·6690 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0287 grm. of the chlorides of soda and potash, 0·0080 grm. of chloroplatinate of potash, corresponding to 0·00244 grm. chloride of potash = 0·001542 grm. of potash, and 0·02626 grm. of chloride of soda = 0·01392 grm. of soda.

IV. 1·0251 grms. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0393 grm. of the chlorides of potash and soda, 0·0122 grm. of chloroplatinate of potash, corresponding to 0·0037 grm. of chloride of potash = 0·00235 grm. of potash, and 0·00356 grm. of chloride of soda = 0·01887 grm. of soda.

V. 0·9799 grm. of substance, treated with hydrofluoric and sulphuric acids, gave 0·0460 grm. of the chlorides of potash and soda, 0·0200 grm. of chloroplatinate of potash, corresponding to 0·0061 grm. of chloride of potash = 0·00385 grm. of potash, and 0·0399 grm. of chloride of soda = 0·02116 grm. of soda.

	I.	II.	III.	IV.	V.	Mean.
Silica,	46·84	...	...	...	...	46·84
Peroxide of iron,	1·64	...	...	...	...	1·64
Protoxide of iron,	...	10·79	...	...	...	10·79
Alumina,	17·78	...	...	...	...	17·78
Manganous oxide	0·34	...	...	...	...	0·34
Lime,	11·87	...	...	...	...	11·87
Magnesia,	9·24	...	...	...	...	9·24
Potash,	...	...	0·23	0·23	0·39	0·28
Soda,	...	...	2·08	1·84	2·16	2·02
						100·80

96. Manganese Nodule.—Station 3.

Lat. 25° 45′ N., long. 20° 12′ W., 1525 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	24·84
Portion soluble in Hydrochloric Acid = 70·46	Copper,	trace
	Alumina,	2·50
	Ferric oxide,	31·60
	Calcium phosphate,	0·90
	Manganese oxide,	25·64
	Calcium sulphate,	1·16
	Calcium carbonate,	3·15
	Magnesium carbonate,	1·51
	Silica,	4·00
Portion insoluble in Hydrochloric Acid = 4·70	Alumina,	1·00
	Ferric oxide,	1·30
	Lime,	0·30
	Magnesia,	0·10
	Silica,	2·00
		100·00

97. Manganese Nodule.—Station 3.

Lat. 25° 45′ N., long. 20° 12′ W., 1525 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	18·30
Portion soluble in Hydrochloric Acid = 78·38	Copper,	small trace
	Alumina,	1·70
	Ferric oxide,	40·71
	Calcium phosphate,	0·34
	Manganese oxide,	22·80
	Nickel,	mere trace
	Cobalt,	...
	Calcium sulphate,	1·17
	Calcium carbonate,	5·15
	Magnesium carbonate,	1·51
	Silica,	5·00
Portion insoluble in Hydrochloric Acid = 3·32	Alumina,	0·55
	Ferric oxide,	0·68
	Lime,	0·25
	Magnesia,	0·18
	Silica,	1·66
		100·00

Note.—Small mass of a brown and blackish colour, no definite shape, but appeared as if broken from some larger mass.

97a. Coral (*Pleurocorallium johnsoni*) attached to the preceding nodule.—Station 3.

Lat. 25° 45′ N., long. 20° 12′ W., 1525 fathoms (Anderson).

Water,	0·30
Calcium carbonate,	93·39
Magnesium carbonate,	6·00
Calcium phosphate, Ferric oxide,	0·10
Silica,	trace
Insoluble residue,	0·05
	99·84

98. Manganese Nodule.—Station 16.

Lat. 20° 39′ N., long. 50° 33′ W., 2435 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	13·63
Portion soluble in Hydrochloric Acid = 82·73	Copper,	small trace
	Alumina,	2·95
	Ferric oxide,	36·08
	Calcium phosphate,	good trace
	Manganese oxide,	29·32
	Nickel,	trace
	Cobalt,	...
	Calcium sulphate,	1·05
	Calcium carbonate,	1·96
	Magnesium carbonate,	4·32
	Silica,	7·05
Portion insoluble in Hydrochloric Acid = 3·64	Alumina, Ferric oxide, Lime, Magnesia, Silica,	3·64
		100·00

Note.—Pieces of a very small nodule, smooth, grey on the outside, yellowish inside, weight only 44 grains.

99. Manganese Nodule.—Station 160. Lat. 42° 42′ S., long. 134° 10′ E., 2600 fathoms (Brazier)

	Loss on ignition after drying at 230° Fahr.,	20·40
Portion soluble in Hydrochloric Acid = 70·30	Copper,	good trace
	Alumina,	2·00
	Ferric oxide,	19·08
	Calcium phosphate,	0·20
	Manganese oxide,	32·48
	Nickel,	good trace
	Cobalt,	...
	Calcium sulphate,	0·58
	Calcium carbonate,	3·07
	Magnesium carbonate,	1·72
	Silica,	11·17
Portion insoluble in Hydrochloric Acid = 9·30	Alumina,	0·45
	Ferric oxide,	0·50
	Lime,	0·35
	Magnesia,	0·20
	Silica,	7·80
		100·00

Note.—Irregular-shaped nodules.

100. Manganese Nodule (external portion).—Station 160. Lat. 42° 42′ S., long. 134° 10′ E., 2600 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·00
Portion soluble in Hydrochloric Acid = 75·60	Copper,	abundant trace
	Alumina,	4·60
	Ferric oxide,	16·70
	Calcium phosphate,	mere trace
	Manganese oxide,	39·32
	Calcium sulphate,	0·58
	Magnesium carbonate,	1·60
	Calcium carbonate,	3·00
	Silica,	9·80
Portion insoluble in Hydrochloric Acid = 13·40	Alumina, Ferric oxide,	1·00
	Lime,	0·28
	Magnesia,	0·12
	Silica,	12·00
		100·00

101. Manganese Nodule (internal portion).—Station 160. Lat. 42° 42′ S., long. 134° 10′ E. 2600 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	10·25
Portion soluble in Hydrochloric Acid = 73·72	Copper,	abundant trace
	Alumina,	1·80
	Ferric oxide,	15·10
	Calcium phosphate,	mere trace
	Manganese oxide,	33·62
	Calcium sulphate,	0·58
	Calcium carbonate,	3·00
	Magnesium carbonate,	3·02
	Silica,	16·60
Portion insoluble in Hydrochloric Acid = 16·03	Alumina,	2·10
	Ferric oxide,	1·50
	Lime,	0·40
	Magnesia,	0·30
	Silica,	11·73
		100·00

102. MANGANESE NODULES.—Station 248. Lat. 37° 41′ N., long. 177° 4′ W., 2900 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	16·50
Portion soluble in Hydrochloric Acid = 61·10	Copper,	large trace
	Alumina,	2·50
	Ferric oxide,	20·50
	Calcium phosphate,	good trace
	Manganese oxide,	22·50
	Nickel,	good trace
	Cobalt,	...
	Calcium sulphate,	0·85
	Calcium carbonate,	2·65
	Magnesium carbonate,	1·10
	Silica,	11·00
Portion insoluble in Hydrochloric Acid = 22·40	Alumina,	2·17
	Ferric oxide,	1·16
	Lime,	0·65
	Magnesia,	0·32
	Silica,	18·10
		100·00

NOTE.—For the purpose of analysis a small nodule and an equal quantity of a large one were mixed as a whole.

103. MANGANESE NODULES.—Station 252. Lat. 37° 52° N., long. 160° 17′ W., 2740 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	10·60
Portion soluble in Hydrochloric Acid = 68·48	Copper,	small trace
	Alumina,	3·50
	Ferric oxide,	19·33
	Calcium phosphate,	trace
	Manganese oxide,	28·50
	Nickel,	good trace
	Cobalt,	...
	Calcium sulphate,	0·88
	Calcium carbonate,	3·37
	Magnesium carbonate,	1·90
	Silica,	11·00
Portion insoluble in Hydrochloric Acid = 20·92	Alumina,	2·35
	Ferric oxide,	1·15
	Lime,	0·45
	Magnesia,	0·23
	Silica,	16·74
		100·00

NOTE.—Three smooth round nodules.

104. MANGANESE NODULE (internal portion).—Station 252. Lat. 37° 52′ N., long. 160° 17′ W., 2740 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	20·80
Portion soluble in Hydrochloric Acid = 64·53	Copper,	trace
	Alumina,	5·00
	Ferric oxide,	17·83
	Calcium phosphate,	mere trace
	Manganese oxide,	25·37
	Calcium sulphate,	0·58
	Calcium carbonate,	3·58
	Magnesium carbonate,	2·27
	Silica,	9·90
Portion insoluble in Hydrochloric Acid = 14·67	Alumina,	1·70
	Ferric oxide,	0·90
	Lime,	0·50
	Magnesia,	0·20
	Silica,	11·37
		100·00

105. Manganese Nodule (external portion).—Station 252.

Lat. 37° 52′ N., long. 160° 17′ W., 2740 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	15·20
Portion soluble in Hydrochloric Acid = 62·53	Copper,	trace
	Alumina,	4·50
	Ferric oxide,	16·92
	Calcium phosphate,	mere trace
	Manganese oxide,	25·48
	Calcium sulphate,	0·58
	Calcium carbonate,	3·58
	Magnesium carbonate,	2·27
	Silica,	9·20
Portion insoluble in Hydrochloric Acid = 22·27	Alumina,	2·10
	Ferric oxide,	0·90
	Lime,	0·65
	Magnesia,	0·20
	Silica,	18·42
		100·00

106. Manganese Nodules.—Station 252.

Lat. 37° 52′ N., long. 160° 17′ W., 2740 fathoms (Dittmar).

The nodules had a brown or brownish black colour, and, in size and shape, were pretty much like potatoes. They were easily broken by the hammer, and were then seen to consist of a clay-like nucleus enclosed in concentric layers of dark coloured matter, the degree of blackness increasing with the distance from the centre. In some cases, however, the whole of a section was found to be almost uniformly black. My work was limited to exhaustively determining the elementary composition of the nodules, and to trying to ascertain, as far as possible by chemical methods, the state of combination of the several elements present. In the latter connection I proposed to direct my attention more particularly to the manganese, and to ascertain whether that metal is present altogether as binoxide, or partly, if not wholly, in the form of lower oxides.

Qualitative Analysis.

To obtain a true average sample of the nodules, it would have been necessary to pound finely and thoroughly mix the entire stock, but I did not consider myself justified in taking this course; I therefore satisfied myself with selecting a few nodules and pounding these. The powder was well mixed and preserved as "substance to be analysed." A preliminary trial showed that the substance gave up to boiling water nothing but small quantities of chlorides and sulphates[1] (which I thought might safely be put down as sea-water solids), and besides showed that the filtration of the aqueous infusion was a very tedious process. Hence, in proceeding to the actual analysis (which was executed with 100 grms. of substance), the turbid liquid obtained in extracting the small portion of substance soluble in water was simply poured away. The residue was next digested in the cold in acetic acid of 25 per cent. until the carbonates of lime and magnesia and substances of a similar nature could be assumed to be dissolved, and the residue collected on filters and washed with water. This operation was not attended with any visible evolution of gas, which, however, does not prove the absolute absence of carbonates in the substance. The acetic acid extract was evaporated to dryness and the residue (5·23 grms.) analysed. Qualitative tests showed the presence of considerable quantities of lime, magnesia, and soda, a little alumina, and traces of iron, copper, and chlorine. There was absolutely no manganese, which

[1] The aqueous extract contained no lime salts, showing the absence of sulphate of lime.

proves that the original substance could not have contained any manganous carbonate or hydrate. The principal bases were determined quantitatively with the following results:—

Alumina,	0·170	per 100 parts of original substance.
Lime,	0·446	
Magnesia,	0·365	
Soda,[1]	0·597	

The residue left undissolved by the acetic acid was exhausted with hot hydrochloric acid of 20 per cent., the solution filtered, evaporated to dryness, to eliminate the dissolved silica, the silica filtered off and weighed. It amounted to 0·73 grms., *i.e.*, 0·73 per cent. of the original substance. The de-silicated solution was made up to 400 c.c., and aliquot portions used for the following experiments. One portion served for a thorough qualitative analysis, the results of which are included in the statement of quantitative determinations given below; but it is perhaps as well to state explicitly that lithium, beryllium, and the metals of the arsenic group, although very specially sought for, could not be detected. A second portion (25 grms. of original substance) was devoted to the quantitative determination of the cobalt, nickel, copper, and lead. A third portion was used for the determination of the alkalies.

The residue left undissolved by the hydrochloric acid amounted to 26·3 grms. (dried at 100° C., but not completely). Of these 26·3 grms. of matter separate portions were used for determining the following components:—(*a*) the water volatile on ignition; (*b*) the silica which had been rendered soluble by the treatment with hydrochloric acid—it was extracted by means of boiling carbonate of soda solution and separated out and weighed as usual; (*c*) the part disintegrable by the method customarily used for the analysis of clays, viz., by treatment in the heat with concentrated sulphuric acid, and evaporation of the acid from the substance—the silica and alumina thus rendered soluble being determined by the usual methods.

Found in the 26·3 grms. of matter insoluble in hydrochloric acid—

Water,	1·99
Silica, set free by hydrochloric acid,	6·74
Alumina[2] rendered soluble by sulphuric acid,	1·62
Silica, rendered soluble by sulphuric acid,	0·83
Ultimate residue,	14·91
	26·09
Loss,	0·21
	26·30

As the hydrochloric acid solution had been nearly all used in the numerous qualitative trials made, and the quantitative determinations reported, a special portion of "original substance" (identical with the 100 grms. used for making that solution) was employed for determining the alumina, ferric oxide, manganese, lime, and magnesia extractable by hot hydrochloric acid. Other portions served for the direct determination of the total water and of the total carbonic acid.

The results are included in the following:—

Summary of Quantitative Determinations.

	P.	E.	P./E.
Total water,[3]	24·90		
Total carbonic acid,	0·38		
Total phosphoric acid, extractable by hydrochloric acid,	0·07		
(a) In Acetic Acid Extract.			
Lime,	0·45		
Magnesia,	0·36		
Soda,	0·60		

[1] Including a little potash. [2] Includes a little oxide of iron.

[3] Determined directly, by expulsion in a combustion tube and collecting in chloride of calcium.

(b) In Hydrochloric Acid Extract from Acetic Acid Residue.

Silica,		7·47
Oxide of lead,	0·01	
Oxide of copper,	0·272	0·93
Oxide of cobalt,	0·25	
Oxide of nickel,	0·40	
Manganous oxide,		19·39 : 35·5 = 0·546
Loose oxygen,		3·95 : 8 = 0·494
Lime,		1·33
Magnesia,		1·42
Alkalies (R_2O),		0·34
Alumina,		3·03
Ferric oxide,		16·20

(c) In Sulphuric Acid Extract from Hydrochloric Acid Residue.

Alumina and ferric oxide,	1·62
Silica,	0·83

(d) Ultimate Residue.

Silicates and Silica,	14·91
	98·18

Special Experiments on the State of Oxidation of the Manganese.

The loose oxygen reported above had been determined in two ways, viz., firstly by Bunsen's method: distilling with hydrochloric acid, and titrating the iodine equivalent of the chlorine liberated by means of thiosulphate—chemically pure iodine serving as a standard; and secondly, by Fresenius and Will's method: digestion of the substance with dilute sulphuric and oxalic acids, collecting the carbonic acid liberated in a tared potash bulb and soda-lime tube, and determining the increase of weight shown by the absorption apparatus. In the latter case the carbonic acid of the carbonates was determined in a separate portion of substance, setting it free by means of a mixed solution of ferrous chloride and hydrochloric acid and weighing it as above. In order to see whether the second method is affected by the presence in the substance of ferrous oxide (as Bunsen's undoubtedly is), a quantity of a pure "peroxide" of manganese was made by heating pure nitrate first to about 200° C., then to redness, and the percentage of loose oxygen in this preparation determined according to Fresenius and Will; first in the usual manner and then after addition to the substance of a known weight of artificial ferroso-ferric oxide (Fe_3O_4) prepared in the wet way from ferrous sulphate.

The results were as follows:—

Percentage of Loose Oxygen found.

By the oxalic acid method,	7·99	8·13
By the same in presence of Fe_3O_4,[1]	7·98	

Hence the presence of ferrous oxide does not sensibly affect the oxalic acid method, which at the same time showed me that the substance of the manganese nodules analysed could not have contained much ferrous oxide. In fact the 3·95 per cent. of loose oxygen reported in the summary were deduced from the following determinations:—

Oxygen found by oxalic acid,	4·02 = 0·502 × "O"
Oxygen found by iodine method,	3·88 = 0·485 × "O"
Difference,	0·017 × "O"
Manganous oxide found,	19·39 = 0·546 × MnO

The difference (0·017 × "O"), if not simply due to observational errors, would correspond to 0·017 × Fe_2O_3 = 0·017 × 72 = 1·22 per cent. of ferrous oxide = 1·36 per cent. of ferric oxide, leaving 16·2 − 1·36 = 14·84 of

[1] MnO . O = 0·6454 grm.; Fe_3O_4 = 0·18 grm., CO_2 obtained = 0·2832 grm. = 7·98 per cent. of oxygen.

real ferric oxide. But at any rate there cannot be much ferrous oxide present, or it would have told more strongly on the iodine result.

Another result which would appear to follow from the reported numbers, is that the loose oxygen is not sufficient to supplement the manganous oxide into binoxide. Taking 4·02 as the correct percentage of loose oxygen, we have for the percentage of—

Manganous oxide, ...	$0·044 \times MnO$ [1]
Real manganese oxide, ...	$0·502 \times MnO_2$

Now the oxides MnO, FeO (as above calculated), CaO, MgO as reported under (*b*), amount in all to $0·197 \times R''O$.

These may be present in combination with manganese binoxide as components of psilomelanic compounds, leaving a balance of $0·305 \times MnO_2$ of real uncombined (or hydrated) binoxide of manganese.

I know of no test for discriminating between free manganese binoxide and manganese oxide combined with oxides of the type R″O; what can be done in a case like the one in hand is to determine the exact ratio of the "MnO" present in all to the loose oxygen present. But a complicated complete analysis like the one reported, however carefully done, cannot possibly supply sufficiently exact data for this purpose.

I therefore selected from my stock a nodule which seemed to be exceptionally rich in manganese, and determined, by a specially devised process, the total manganese, as manganous oxide, and (by the ordinary methods) the loose oxygen.

To determine the total manganese, a weighed quantity of homogeneous substance was disintegrated by hydrochloric acid, the iron and alumina precipitated by means of acetate of soda and filtered off, and from the filtrate the manganese precipitated by means of bromine in presence of zinc salt. The precipitate (which contains all the manganese as binoxide) was dissolved by dilute sulphuric acid in an atmosphere of carbonic acid with a known weight of standardized ferrous sulphate and the excess of "ferrosum" titrated by permanganate. That this method, which every chemist will recognise as a slight modification of Kessler's, gives exact results had been proved by a series of experiments on known weights of manganese given as a solution of pure chloride which had been standardized by means of nitrate of silver.

In the analysis of the nodule two determinations gave—

I.	II.	Mean.
16·54	16·30	16·42

per cent. of manganous oxide (present as $MnO \cdot O_x$). The loose oxygen was found to be as follows:—

			Mean.
Iodine method, ...	3·775	3·764	3·77
Oxalic acid method,[2]	3·85	3·95	3·90

Dividing by the combining weights we have—

$$16·42 : 35·5 = 0·4626$$
$$3·77 : 8·0 = 0·4712$$
$$3·90 : 8·0 = 0·4874$$

Here the oxygen found is a little more than what would be sufficient to make the manganous oxide into binoxide. Possibly some of the loose oxygen may have been present as peroxide of cobalt (Co_2O_3); but I have had no time yet to inquire further into the matter experimentally. All I can say is that the determinations were made with great care at a time when we had become very familiar with all the manipulations involved, and I think I am safe in asserting that that particular nodule in all probability contains its manganese in the form of binoxide only.

[1] Here, as everywhere, $H = 0·5 \therefore MnO = 35·5$.

[2] 0·877 grm. of the substance when decomposed by acid (with ferrous chloride) gave less than 1 mgrm. of carbonic acid.

The following two analyses were made by Gümbel and Church from specimens obtained from members of the Expedition. Church does not mention the station from which his specimens came, but in all probability they came from Station 252 (J. M.).

106A. MANGANESE NODULES.—Station 252. Lat. 37° 52′ N., long. 160° 17′ W., 2740 fathoms (C. W. Gümbel, *Sitzungsb. d. bayer. Akad. d. Wiss.*, 1878, ii. pp 189–209; also *Neues Jahrb. f. Min. &c.*, 1878, p. 869).

Oxide of iron,	27·460
Peroxide of manganese,	23·600
Water,	17·819
Silica,	16·030
Alumina,	10·210
Soda,	2·358
Chlorine,	0·941
Lime,	0·920
Titanic acid,	0·660
Sulphuric acid,	0·484
Potash,	0·396
Magnesia,	0·181
Carbonic acid,	0·047
Phosphoric acid,	0·023
Oxide of copper,	0·023
Oxides of nickel and cobalt,	0·012
Barium,	0·009
Doubtful traces of lead, antimony, boron, lithium, and iodine,	...
Traces of organic substances,	...
	101·173

106B. MANGANESE NODULES.—Station 252. Lat. 37° 52′ N., long. 160° 17′ W., 2740 fathoms (A. H. Church, *Mineralogical Magazine*, vol. i. pp. 50–53, 1876).

Water lost *in vacuo*,	24·55
Water retained at 100° C., but evolved at a red heat,	10·00
Manganese dioxide,	30·22
Ferric dioxide,	20·02
Alumina,	3·30
Silica,	10·37
Chlorine,	0·71
Mg, Ca, Cu, Na, Cl, P_2O_5, &c.,	0·83
	100·00

107. MANGANESE NODULE.—Station 253. Lat. 38° 9′ N., long. 156° 25′ W., 3125 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	12·10
Portion soluble in Hydrochloric Acid = 73·20	Copper,	good trace
	Alumina,	4·70
	Ferric oxide,	21·20
	Calcium phosphate,	0·45
	Manganese oxide,	26·21
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate,	0·75
	Calcium carbonate,	3·06
	Magnesium carbonate,	0·86
	Silica,	15·97
Portion insoluble in Hydrochloric Acid = 14·70	Alumina,	1·80
	Ferric oxide,	0·90
	Lime,	0·52
	Magnesia,	0·32
	Silica,	11·16
		100·00

108. Manganese Nodules.—Station 256.

Lat. 30° 22′ N., long. 154° 56′ W., 2950 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·30
Portion soluble in Hydrochloric Acid = 77·57	Copper,	large trace
	Alumina,	2·30
	Ferric oxide,	18·80
	Calcium phosphate,	good trace
	Manganese oxide,	39·57
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate,	0·58
	Calcium carbonate,	2·58
	Magnesium carbonate,	4·54
	Silica,	9·20
Portion insoluble in Hydrochloric Acid = 11·13	Alumina,	1·40
	Ferric oxide,	0·80
	Lime,	0·33
	Magnesia,	good trace
	Silica,	8·60
		100·00

Note.—Several small nodules, irregular in shape, average weight 200 grains, light grey colour outside, blackish grey inside, except centre, which was also of a light grey colour and very friable.

109. Manganese Nodule.—Station 264.

Lat. 14° 19′ N., long. 152° 37′ W., 3000 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	8·90
Portion soluble in Hydrochloric Acid = 83·92	Copper,	large trace
	Alumina,	2·65
	Ferric oxide,	21·38
	Calcium phosphate,	trace
	Manganese oxide,	29·09
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate,	0·62
	Calcium carbonate,	2·58
	Magnesium carbonate,	3·40
	Silica,	24·20
Portion insoluble in Hydrochloric Acid = 7·18	Alumina,	0·60
	Ferric oxide,	1·70
	Lime,	0·45
	Magnesia,	0·33
	Silica,	4·10
		100·00

Note.—Peculiar grey material, rough, a few brown particles attached to its surface.

110. Manganese Nodules.—Station 274.

Lat. 7° 25′ S., long. 152° 15′ W., 2750 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	12·60
Portion soluble in Hydrochloric Acid = 82·60	Copper,	0·79
	Alumina,	1·00
	Ferric oxide,	8·41
	Calcium phosphate,	1·35
	Manganese oxide,	51·46
	Nickel,	good trace
	Cobalt,	...
	Calcium sulphate,	0·59
	Calcium carbonate,	3·58
	Magnesium carbonate,	4·92
	Silica,	10·50
Portion insoluble in Hydrochloric Acid = 4·80	Alumina,	0·60
	Ferric oxide,	0·60
	Lime,	0·45
	Magnesia,	0·15
	Silica,	3·00
		100·00

Note.—Portions of two nodules sawn through, so as to obtain a fair average.

111. Manganese Nodudes (external portions).—Station 274.

Lat. 7° 25′ S., long. 152° 15′ W., 2750 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	12·50
Portion soluble in Hydrochloric Acid = 82·90	Copper,	0·79
	Alumina,	0·30
	Ferric oxide,	11·97
	Calcium phosphate,	0·83
	Manganese oxide,	52·39
	Nickel,	good trace
	Cobalt,	...
	Calcium sulphate,	0·75
	Calcium carbonate,	3·95
	Magnesium carbonate,	2·12
	Silica,	9·80
Portion insoluble in Hydrochloric Acid = 4·60	Alumina,	0·56
	Ferric oxide,	0·94
	Lime,	0·34
	Magnesia,	0·11
	Silica,	2·65
		100·00

112. MANGANESE NODULES (internal portions).—Station 274.

Lat. 7° 25′ S., long. 152° 15′ W., 2750 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·40
Portion soluble in Hydrochloric Acid = 84·50	Copper,	0·79
	Alumina,	0·30
	Ferric oxide,	9·75
	Calcium phosphate,	0·35
	Manganese oxide,	55·89
	Nickel,	good trace
	Cobalt,	...
	Calcium sulphate,	0·58
	Calcium carbonate,	3·88
	Magnesium carbonate,	4·16
	Silica,	8·80
Portion insoluble in Hydrochloric Acid = 4·10	Alumina,	0·31
	Ferric oxide,	0·78
	Lime,	0·33
	Magnesia,	0·14
	Silica,	2·54
		100·00

113. MANGANESE NODULES (average sample).—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	16·30
Portion soluble in Hydrochloric Acid = 77·56	Copper,	good trace
	Alumina,	5·00
	Ferric oxide,	40·50
	Calcium phosphate,	fair trace
	Manganese oxide,	11·40
	Nickel,	trace
	Cobalt,	trace
	Calcium sulphate,	0·87
	Calcium carbonate,	5·06
	Magnesium carbonate,	1·13
	Silica,	13·60
Portion insoluble in Hydrochloric Acid = 6·14	Alumina,	1·30
	Ferric oxide,	1·50
	Lime,	0·70
	Magnesia,	0·70
	Silica,	1·94
		100·00

114. MANGANESE NODULES (external portions).—Station 276.

Lat 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	14·40
Portion soluble in Hydrochloric Acid = 78·00	Copper,	good trace
	Alumina,	2·00
	Ferric oxide,	45·00
	Calcium phosphate,	small trace
	Manganese oxide,	14·82
	Nickel,	trace
	Cobalt,	trace
	Calcium sulphate,	0·99
	Calcium carbonate,	4·30
	Magnesium carbonate,	1·13
	Silica,	9·76
Portion insoluble in Hydrochloric Acid = 7·60	Alumina,	1·10
	Ferric oxide,	1·40
	Lime,	0·70
	Magnesia,	0·50
	Silica,	3·90
		100·00

115. MANGANESE NODULES (internal portions).—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	14·10
Portion soluble in Hydrochloric Acid = 72·75	Copper,	trace
	Alumina,	8·90
	Ferric oxide,	21·00
	Calcium phosphate,	good trace
	Manganese oxide,	1·91
	Nickel,	...
	Cobalt,	...
	Calcium sulphate,	0·41
	Calcium carbonate,	2·70
	Magnesium carbonate,	1·53
	Silica,	36·30
Portion insoluble in Hydrochloric Acid = 13·15	Alumina,	1·80
	Ferric oxide,	2·00
	Lime,	0·85
	Magnesia,	0·50
	Silica,	8·00
		100·00

116. Manganese Nodule.—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Brazier).
Weight, 6·70 grains.

	Grains.
Loss on ignition,	2·10
Alumina,	1·26
Ferric oxide, Manganese oxide, }	1·79
Calcium carbonate,	0·40
Magnesium carbonate,	good trace
Soluble silica,	0·75
Insoluble residue,	0·40
	6·70

	Per cent.
Loss on ignition,	31·34
Portion soluble in hydrochloric acid,	62·68
Portion insoluble in hydrochloric acid,	5·98
	100·00

117. Manganese Nodules.—Station 281.

Lat. 22° 21′ S., long. 150° 17′ W., 2385 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	16·00
Portion soluble in Hydrochloric Acid = 73·21	Copper,	good trace
	Alumina,	2·00
	Ferric oxide,	29·00
	Calcium phosphate,	trace
	Manganese oxide,	22·22
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate,	0·29
	Calcium carbonate,	2·79
	Magnesium carbonate,	1·51
	Silica,	15·40
Portion insoluble in Hydrochloric Acid = 10·79	Alumina,	1·25
	Ferric oxide,	1·33
	Lime,	0·84
	Magnesia,	0·15
	Silica,	7·22
		100·00

Note.—Nodules, average weight 170 grains, apparently consisting of two varieties; some on breaking were of a dark brown colour, others of a slatey-brown colour. The former constitute this analysis, the latter Analysis 119.

118. Manganese Nodules.—Station 281.

Lat. 22° 21′ S., long. 150° 17′ W., 2385 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	10·98
Portion soluble in Hydrochloric Acid = 75·77	Copper,	good trace
	Alumina,	3·38
	Ferric oxide,	32·50
	Calcium phosphate,	...
	Manganese oxide,	19·92
	Calcium sulphate,	0·63
	Calcium carbonate,	2·81
	Magnesia,	1·41
	Silica,	15·12
Portion insoluble in Hydrochloric Acid = 13·25	Alumina,	1·30
	Ferric oxide,	1·52
	Lime,	0·84
	Magnesia,	0·35
	Silica,	9·24
		100·00

Note.—Several small nodules; material insufficient to test for nickel and cobalt. Residue after acid, grey clay.

119. Manganese Nodules.—Station 281.

Lat. 22° 21′ S., long. 15° 17′ W., 2385 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·66
Portion soluble in Hydrochloric Acid = 71·62	Copper,	trace
	Alumina,	2·70
	Ferric oxide,	27·80
	Calcium phosphate,	good trace
	Manganese oxide,	6·51
	Nickel,	trace
	Cobalt,	trace
	Calcium sulphate,	0·29
	Calcium carbonate,	2·79
	Magnesium carbonate,	1·13
	Silica,	30·40
Portion insoluble in Hydrochloric Acid = 22·72	Alumina,	2·13
	Ferric oxide,	5·04
	Lime,	2·69
	Magnesia,	0·36
	Silica,	12·50
		100·00

Note.—See Analysis 117.

120. Manganese Nodules.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	12·90
Portion soluble in Hydrochloric Acid = 76·20	Copper,	good trace
	Alumina,	2·50
	Ferric oxide,	24·63
	Calcium phosphate,	good trace
	Manganese oxide,	36·54
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate,	0·34
	Calcium carbonate,	1·86
	Magnesium carbonate,	1·13
	Silica,	9·20
Portion insoluble in Hydrochloric Acid = 10·90	Alumina,	1·94
	Ferric oxide,	0·72
	Lime,	0·56
	Magnesia,	0·10
	Silica,	7·58
		100·00

Note.—Small nodules, average weight 90 grains, dark brown colour outside, yellowish grey inside. Several taken as a whole for analysis.

121. Manganese Nodules.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	9·25
Portion soluble in Hydrochloric Acid = 69·22	Copper,	trace
	Alumina,	7·42
	Ferric oxide,	11·64
	Calcium phosphate,	7·15
	Manganese oxide,	24·71
	Calcium sulphate,	0·73
	Calcium carbonate,	3·59
	Magnesium carbonate,	1·30
	Silica,	12·68
Portion insoluble in Hydrochloric Acid = 21·53	Alumina,	3·80
	Ferric oxide,	2·20
	Lime,	0·38
	Magnesia,	0·09
	Silica,	15·06
		100·00

122. Manganese Nodule.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	19·30
Portion soluble in Hydrochloric Acid = 60·52	Copper,	trace
	Alumina,	6·20
	Ferric oxide,	20·10
	Calcium phosphate,	good trace
	Manganese oxide,	16·14
	Calcium sulphate,	0·87
	Calcium carbonate,	4·36
	Magnesium carbonate,	0·75
	Silica,	12·10
Portion insoluble in Hydrochloric Acid = 20·18	Alumina,	2·40
	Ferric oxide,	3·00
	Lime,	1·91
	Magnesia,	0·32
	Silica,	12·55
		100·00

123. Manganese Nodule.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	13·00
Portion soluble in Hydrochloric Acid = 63·09	Copper,	trace
	Alumina,	9·50
	Ferric oxide,	16·40
	Calcium phosphate,	2·63
	Manganese oxide,	22·06
	Calcium sulphate,	1·05
	Calcium carbonate,	0·97
	Magnesium carbonate,	0·98
	Silica,	9·50
Portion insoluble in Hydrochloric Acid = 23·91	Alumina,	4·70
	Ferric oxide,	1·10
	Lime,	1·40
	Magnesia,	0·21
	Silica,	16·50
		100·00

124. Manganese Nodule.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	8·23
Portion soluble in Hydrochloric Acid = 75·81	Copper,	trace
	Alumina,	8·14
	Ferric oxide,	25·04
	Calcium phosphate,	trace
	Manganese oxide,	8·54
	Calcium sulphate,	0·38
	Calcium carbonate,	2·49
	Magnesium carbonate,	0·62
	Silica,	30·60
Portion insoluble in Hydrochloric Acid = 15·96	Alumina,	1·25
	Ferric oxide,	3·49
	Lime,	0·70
	Magnesia,	0·52
	Silica,	10·00
		100·00

125. Manganese Nodule (internal portion).—Station 285.
Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	13·60
Portion soluble in Hydrochloric Acid = 80·30	Copper,	trace
	Alumina,	9·50
	Ferric oxide,	18·98
	Calcium phosphate,	trace
	Manganese oxide,	13·98
	Calcium sulphate,	trace
	Calcium carbonate,	3·00
	Magnesium carbonate,	1·04
	Silica,	33·80
Portion insoluble in Hydrochloric Acid = 6·10	Alumina,	1·15
	Ferric oxide,	2·00
	Lime,	0·45
	Magnesia,	0·14
	Silica,	2·36
		100·00

125a. Manganese Nodules.—Station 285.
Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	23·40
Portion soluble in Hydrochloric Acid = 58·52	Copper,	good trace
	Alumina,	8·15
	Ferric oxide,	12·75
	Calcium phosphate,	0·90
	Manganese oxide,	22·20
	Calcium sulphate,	0·75
	Calcium carbonate,	4·15
	Magnesium carbonate,	0·14
	Silica,	9·62
Portion insoluble in Hydrochloric Acid = 18·08	Alumina,	3·33
	Ferric oxide,	1·44
	Lime,	0·99
	Magnesia,	good trace
	Silica,	12·18
		100·00

125b. Manganese Nodule (internal portion).—Station 285.
Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Anderson).

	Loss on ignition after drying at 100° C.,	9·32
Portion soluble in Hydrochloric Acid = 42·78	Alumina,	9·17
	Ferric oxide,	13·90
	Manganese dioxide,	10·46
	Magnesia,	0·57
	Potash,	1·84
	Soda,	2·15
	Phosphoric acid,	0·22
	Silica,	4·47
Portion insoluble in Hydrochloric Acid = 47·45	Alumina,	3·65
	Ferric oxide,	3·00
	Magnesia,	0·89
	Potash,	0·68
	Silica,	39·23
		99·55

Note.—The material was white or brownish white, and was easily cut with a knife; it contained 14·95 per cent. of moisture, very light in weight, and fused into a blackish glass.

126. Manganese Nodules.—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	8·70
Portion soluble in Hydrochloric Acid = 78·30	Copper,	good trace
	Alumina,	2·50
	Ferric oxide,	24·00
	Calcium phosphate,	0·70
	Manganese oxide,	27·40
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate,	0·87
	Calcium carbonate,	4·37
	Magnesium carbonate,	1·36
	Silica,	17·10
Portion insoluble in Hydrochloric Acid = 13·00	Alumina,	1·90
	Ferric oxide,	1·20
	Lime,	0·84
	Magnesia,	0·15
	Silica,	8·91
		100·00

Note.—Several small brittle nodules taken as a whole.

127. Manganese Nodules (internal portions).—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	15·50
Portion soluble in Hydrochloric Acid = 65·60	Copper,	good trace
	Alumina,	2·31
	Ferric oxide,	21·87
	Calcium phosphate,	0·69
	Manganese oxide,	22·79
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate	0·51
	Calcium carbonate,	2·65
	Magnesium carbonate,	0·68
	Silica,	14·10
Portion insoluble in Hydrochloric Acid = 18·90	Alumina,	1·60
	Ferric oxide,	2·20
	Lime,	0·50
	Magnesia,	0·30
	Silica,	14·30
		100·00

Note.—Two small hard nodules, coated with a brown shell (which was removed). They were black throughout, except a small white centre in one, and a small tooth or portion of a tooth in the other.

128. MANGANESE NODULES (external portions).—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·35
Portion soluble in Hydrochloric Acid = 74·97	Copper,	good trace
	Alumina,	1·68
	Ferric oxide,	16·48
	Calcium phosphate,	good trace
	Manganese oxide,	38·15
	Nickel,	good trace
	Cobalt,	trace
	Calcium sulphate,	0·94
	Calcium carbonate,	5·01
	Magnesium carbonate,	3·26
	Silica,	9·50
Portion insoluble in Hydrochloric Acid = 13·68	Alumina,	1·18
	Ferric oxide,	1·40
	Lime,	0·37
	Magnesia,	0·22
	Silica,	10·51
		100·00

NOTE.—The brown shelly coatings of the various other specimens.

129. MANGANESE NODULES.—Station 289.

Lat. 39° 41′ S., long. 131° 23′ W., 2550 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	13·80
Portion soluble in Hydrochloric Acid = 69·70	Copper,	0·31
	Alumina,	2·50
	Ferric oxide,	19·79
	Calcium phosphate,	0·40
	Manganese oxide,	32·02
	Nickel, Cobalt,	0·25
	Calcium sulphate,	0·58
	Calcium carbonate,	3·08
	Magnesium carbonate,	1·87
	Silica,	8·90
Portion insoluble in Hydrochloric Acid = 16·50	Alumina,	1·66
	Ferric oxide,	1·20
	Lime,	0·78
	Magnesia,	0·26
	Silica,	12·60
		100·00

NOTE.—Irregular shaped nodules, dark in colour, somewhat similar in appearance to those of Station 160.

130. Manganese Nodules.—Station 293.

Lat. 39° 4′ S., long. 105° 5′ W., 2025 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·20
Portion soluble in Hydrochloric Acid = 76·20 =	Copper,	large trace
	Alumina,	1·00
	Ferric oxide,	20·06
	Calcium phosphate,	0·69
	Manganese oxide,	37·61
	Nickel,	good trace
	Cobalt,	...
	Calcium sulphate,	0·70
	Calcium carbonate,	4·21
	Magnesium carbonate,	3·93
	Silica,	8·00
Portion insoluble in Hydrochloric Acid = 12·60 =	Alumina,	2·21
	Ferric oxide,	0·80
	Lime,	0·78
	Magnesia,	0·11
	Silica,	8·70
		100·00

Note.—Small irregular shaped nodules—average weight 65 grains—blackish appearance outside, grey inside, very light and friable.

131. Manganese Nodules.—Station 297.

Lat. 37° 29′ S., long. 83° 7′ W., 1775 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·30
Portion soluble in Hydrochloric Acid = 81·57 =	Copper,	small trace
	Alumina,	0·50
	Ferric oxide,	28·48
	Calcium phosphate,	good trace
	Manganese oxide,	30·77
	Nickel,	small trace
	Cobalt,	small trace
	Calcium sulphate,	0·87
	Calcium carbonate,	6·36
	Magnesium carbonate,	4·39
	Silica,	10·20
Portion insoluble in Hydrochloric Acid = 7·13 =	Alumina,	0·50
	Ferric oxide,	1·30
	Lime,	0·61
	Magnesia,	0·18
	Silica,	4·54
		100·00

Note.—Small irregular shaped nodules, grey colour outside, black inside.

131A. MANGANESE NODULES (internal portions).—Station 297.

Lat. 37° 29′ S., long. 83° 7′ W., 1775 fathoms (Anderson).

	Loss on ignition after drying at 100° C.,	8·66
Portion soluble in Hydrochloric Acid = 40·68	Alumina,	14·04
	Ferric oxide,	10·23
	Manganese dioxide,	4·16
	Magnesia,	0·75
	Potash,	3·61
	Soda,	3·22
	Phosphoric acid,	large trace
	Silica,	4·67
Portion insoluble in Hydrochloric Acid = 50·48	Alumina,	4·63
	Ferric oxide,	0·63
	Magnesia,	0·46
	Potash,	0·46
	Soda,	0·23
	Silica,	44·07
		99·82

NOTE.—The nuclei used in this analysis were white or brownish white in colour, very light in weight, and easily cut with a knife. They contained 13·4 per cent. of moisture, and on ignition fused into a blackish glass.

132. MANGANESE NODULES.—Station 299.

Lat. 33° 31′ S., long. 74° 43′ W., 2160 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·80
Portion soluble in Hydrochloric Acid = 77·50	Copper,	trace
	Alumina,	0·70
	Ferric oxide,	6·08
	Calcium phosphate,	trace
	Manganese oxide,	55·67
	Nickel,	small trace
	Cobalt,	...
	Calcium sulphate,	0·58
	Calcium carbonate,	5·57
	Magnesium carbonate,	1·90
	Silica,	7·00
Portion insoluble in Hydrochloric Acid = 10·70	Alumina,	2·30
	Ferric oxide,	0·70
	Lime,	0·49
	Magnesia,	0·11
	Silica,	7·10
		100·00

NOTE.—Two smaller nodules taken as a whole.

133. MANGANESE NODULES.—Station 299.

Lat. 33° 31′ S., long. 74° 43′ W., 2160 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	10·00
Portion soluble in Hydrochloric Acid = 77·50	Copper,	trace
	Alumina,	0·30
	Ferric oxide,	14·00
	Calcium phosphate,	trace
	Manganese oxide,	46·89
	Nickel,	small trace
	Cobalt,	...
	Calcium sulphate,	0·58
	Calcium carbonate,	2·57
	Magnesium carbonate,	4·16
	Silica,	9·00
Portion insoluble in Hydrochloric Acid = 12·50	Alumina,	2·60
	Ferric oxide,	0·70
	Lime,	0·51
	Magnesia,	0·29
	Silica,	8·40
		100·00

NOTE.—The softer parts of some of the nodules.

134. MANGANESE NODULES.—Station 299.

Lat. 33° 31′ S., long. 74° 43′ W., 2160 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	10·40
Portion soluble in Hydrochloric Acid = 80·64	Copper,	trace
	Alumina,	...
	Ferric oxide,	5·86
	Calcium phosphate,	trace
	Manganese oxide,	63·23
	Nickel,	small trace
	Cobalt,	...
	Calcium sulphate,	0·51
	Calcium carbonate,	2·79
	Magnesium carbonate,	2·65
	Silica,	5·60
Portion insoluble in Hydrochloric Acid = 8·96	Alumina,	2·40
	Ferric oxide,	0·60
	Lime,	0·34
	Magnesia,	0·13
	Silica,	5·49
		100·00

NOTE.—The hard parts of some of the nodules.

135. Manganese Nodule.—Station 302.

Lat. 42° 43′ S., long. 82° 11′ W., 1450 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·40
Portion soluble in Hydrochloric Acid = 82·80	Copper,	small trace
	Alumina,	0·55
	Ferric oxide,	39·75
	Calcium phosphate,	good trace
	Manganese oxide,	22·27
	Nickel,	mere trace
	Cobalt,	...
	Calcium sulphate,	1·27
	Calcium carbonate,	4·08
	Magnesium carbonate,	3·48
	Silica,	11·40
Portion insoluble in Hydrochloric Acid = 5·80	Alumina,	0·60
	Ferric oxide,	1·10
	Lime,	0·39
	Magnesia,	0·11
	Silica,	3·60
		100·00

Note.—Small mass, no definite shape, but appeared as if broken from some larger mass, similar to the specimen from Station 3.

136. Manganese Nodule.—Station 276.

Lat. 13° 28′ S., long. 149° 30′ W., 2350 fathoms (Renard).

I. 0·8271 grm. of substance dried at 100° C., gave 0·0787 grm. of water, 0·1600 grm. of silica, 0·0264 grm. of lime, 0·0526 grm. of alumina, 0·2208 grm. of peroxide of iron, 0·0148 grm. of magnesia, 0·2354 grm. of manganese sesquioxide (Mn_2O_3) = 0·2189 grm. of manganous oxide (MnO), 0·0119 grm. of nickel (Ni) = 0·0151 grm. of oxide of nickel.

II. 0·1425 grm. of substance dried at 100° C., treated with hydrochloric acid and the resulting gas conducted into a solution of iodide of potash liberated iodine; 12 c.c. of thiosulphate of potash (1 c.c. = 0·937 c.c. of the standard solution); 1 c.c. of the standard solution $= \frac{Cl}{10}$ or $\frac{O}{20}$, whence 1 c.c. = 3·55 grms. of chlorine or 0·8 grm. of oxygen—

$$1000 : 0·8 = 12 \times 0·9377 : x.$$
$$\therefore 1000 : 0·8 = 11·24 : x.$$

$\therefore x$ = 0·008992 grm. of oxygen capable of liberating chlorine from hydrochloric acid, *i.e.*, 6·31 per cent. of oxygen.

The atomic ratio of 0·384 O is required if Mn be present as MnO_2 and Ni as Ni_2O_3, but 0·394 O was the ratio observed—

	a	*b*	$\frac{a}{b}$
Manganous oxide,	26·46	MnO = 71	0·372
Nickel,	1·82	Ni = 74·8	0·024
Oxygen,	6·31	O = 16	0·394

$$0·372 + \frac{0·024}{2} = 0·384$$

The formula $MnO_2 + \frac{1}{2}H_2O$ requires 9·18 per cent. of water. Consequently 26·46 per cent. of manganous oxide, which corresponds to 32·42 per cent. of manganese binoxide, is equivalent to 3·28 per cent. of water.

26·7 per cent. of ferric oxide requires as limonite 4·50 per cent. of water.

Water,	9·51
Silica,	19·34
Lime,	3·19
Alumina,	6·36
Ferric oxide,	26·70
Magnesia,	1·79
Manganous oxide,	26·46
Nickel oxide,	1·82
Oxygen,	6·31
	101·48

137. Shark's Tooth.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	11·00
Portion soluble in Hydrochloric Acid = 84·00	Copper,	trace
	Alumina,	13·00
	Ferric oxide,	6·87
	Calcium phosphate,	21·63
	Manganese oxide,	28·49
	Calcium sulphate,	1·60
	Calcium carbonate,	4·17
	Magnesium carbonate,	2·64
	Silica,	5·60
Portion insoluble in Hydrochloric Acid = 5·00	Insoluble residue, principally alumina and ferric oxide, with silica,	5·00
		100·00

Note.—The teeth used in Analyses 137 and 138 gave evidence of fluorides. The interior of this tooth had evidently decayed away, and the space had subsequently become filled up with the mixture of manganese and iron oxides, along with some silica.

138. Sharks' Teeth.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

Loss on ignition after drying at 230° Fahr.,	4·00
Alumina,	3·00
Ferric oxide,	6·50
Calcium phosphate,	75·00
Manganese oxide,	trace
Calcium sulphate,	trace
Calcium carbonate,	7·50
Magnesium carbonate,	1·50
General residue, consisting of soluble silica with the insoluble silicates,	2·50
	100·00

Note.—Two teeth, hollow but not so completely filled as the one used in Analysis 137. Total weight for analysis only 11 grains.

139 and 140. CARCHARODON TOOTH.—Station 285. Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Dittmar).

The tooth weighed 22 grms. The outer shell was readily detached from the inner portion.

139. The outside portion was found to contain 33·66 per cent. of phosphoric acid, equal to 73·48 per cent. of tricalcic phosphate, and 2·28 per cent. of fluorine. Ratio of equivalents of phosphoric acid to fluorine—

1 : 0·1

140. The inside portion was completely analysed, with the following results :—

	P.	E.	$\frac{P.}{E.}$
Silica and portion insoluble in hydrochloric acid,	13·34		
Moisture,	8·41		
Combined water,	6·93		
Manganous oxide (MnO),[1]	35·51	: 35·5	= 1
Loose oxygen,[1]	6·85	: 8	= 0·8562
Ferric oxide,[1]	12·47	: 80	= 0·1556
Alumina,	5·09		
Lime,	3·72		
Magnesia,	3·74		
Potash,	0·56		
Soda,	1·31		
Phosphoric acid,	0·83		
Carbonic acid,	1·19		
Silica in solution,	0·30		
Chlorine and copper,	traces		
	100·25		

[1] The extra oxygen in the ferric oxide, as the quotients show, is more than sufficient to convert the manganous oxide into binoxide.

141 and 142. OXYRHINA TEETH.—Station 286. Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

Colour, brownish black.

The teeth consisted of a tough outer shell filled up with a friable black mass.

Three of the teeth were taken, the inside portion separated from the shell, and the percentages of phosphoric acid determined, with the following results :—

	(141) Inside.	(142) Outside.
Per cent. of phosphoric acid,	7·97	32·58
Equal to tricalcic phosphate,	17·39	71·12

143. EARBONE.—Station 285. Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	4·60
Portion soluble in Hydrochloric Acid = 95·04	Alumina,	0·50
	Ferric oxide,	9·28
	Calcium phosphate,	67·72
	Manganese oxide,	2·85
	Calcium sulphate,	2·69
	Calcium carbonate,	10·95
	Magnesium carbonate,	0·75
	Silica,	0·30
Portion insoluble in Hydrochloric Acid = 0·36	Insoluble residue,	0·36
		100·00

NOTE.—Portion of earbone; total weight 244 grains. Beside the details given in the foregoing analysis, it evidently contained nitrogenous organic matter in small quantity. By comparative experiments it was found to contain more than the piece of bone used in Analysis 149, and about the same as the shark's tooth used in Analysis 137. From material left over from this specimen and the tooth of Analysis 137, a nitrogen determination was made and yielded 0·052 per cent. of nitrogen.

144 and 145. Half of Earbone of Balæna.—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

One corner of this specimen had a considerable cavity, which was pretty well filled with a brownish black friable substance. This substance was scraped out and constitutes Analysis No. 144. The remainder consisted of a black coating (which was separated as far as possible), and a very white siliceous looking core, which was used for Analysis No. 145.

144. *Contents of Cavity.*

Note.—The analysis of this substance was all but completed when it was found that it contained a small admixture of an "oil," which had no doubt become mixed with it accidentally in the cutting of the original specimen. The greater part of the substance dissolved readily in hydrochloric acid, with evolution of chlorine. Only the solution was analysed.

	P.	
Portion insoluble in hydrochloric acid,[1]	13·66	
Total water,	27·00	
Manganous oxide,	27·13 :	MnO = 0·764 ÷ 0·764 = 1
Loose oxygen,	3·13 :	O = 0·398 ÷ 0·764 = 0·52
Ferric oxide,	8·34	
Lime,	4·34	
Magnesia,	4·03	
Alumina,	6·54	
Silica,	1·31	
Phosphoric acid,	2·39	
Potash,	1·07	
Soda,	2·39	
Nickel and copper,	traces	
	101·33	

The bulk of the portion soluble in acids apparently consists of hydrated sesquioxides of manganese and iron and decomposible silicates.

[1] Apparently all amorphous silica.

145. *Central Portion of Earbone.*

	P.	$\frac{P.}{E.}$
Insoluble in acid,	0·06	
Moisture,	2·21	
Combined water,	2·22	
Phosphates of iron and alumina,[2]	0·42	
Phosphoric acid,[2]	34·13	1·4420
Carbonic acid,	6·01	0·3042
Fluorine $1·4 \sim F_2 - O$,	0·81	0·0736
Sulphuric acid,	0·81	
Chlorine,	trace	
Lime,	49·85	1·7801
Magnesia,	0·77	0·0385
Alkalies and loss,	2·11	
	100·00	

Ratio of equivalents of phosphoric acid, carbonic acid, and fluorine—

$(\frac{1}{3}P_2O_5)$		(CO_2)		(F_2)
1	:	0·211	:	0·051

[2] Total phosphoric acid found = 34·33 per cent. 34·13 per cent. of phosphoric acid = 74·5 per cent. of tricalcic phosphate.

146. Portion of Earbone (Balænoptera).—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

This specimen was very similar to that used in Analyses 144 and 145, having a cavity with brown incrustation, a black outer coating, the inside being almost uncoloured by iron or manganese.

Found in 100 parts of the inner portion—

Moisture,	1·60	
Combined water,	1·34	
Phosphoric acid,	31·21	= 68·13 per cent. tricalcic phosphate.
Fluorine,	1·89	

Ratio of equivalents of phosphoric acid and fluorine—

1 : 0·0753

147. Portion of Earbone (Ziphius).—Station 289.

Lat. 39° 41′ S., long. 131° 23′ W., 2550 fathoms (Dittmar).

This specimen resembled those used in Analyses 144 to 146, but was smaller, and the cavity, which in them was filled up with a brownish friable mass, contained in this case a hard black substance. The inner portion was brownish; it consisted of hard vitreous looking matter with a yellowish soft powder diffused through it.

Found in 100 parts of the inner portion—

Moisture,	1·61	
Phosphoric acid,	32·73	= 71·44 per cent. tricalcic phosphate.
Fluorine,	1·61	

Ratio of equivalents of phosphoric acid and fluorine—

1 : 0·061

148. Portion of Beak of Ziphius.—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

The body of the specimen looked pretty much like recent bone, but had veins of manganese running through it. The outer coating of the specimen was black.

Found in 100 parts of the inner portion—

Moisture,	1·14	
Combined water,	2·78	
Carbonic acid,	6·81	
Phosphoric acid,	33·30	= 72·69 per cent. tricalcic phosphate.
Fluorine,	1·65	

Ratio of equivalents of phosphoric acid, carbonic acid, and fluorine—

1 : 0·220 : 0·062

149. Piece of Bone.—Station 285.

Lat. 32° 36′ S., long. 137° 43′ W., 2375 fathoms (Brazier).

	Loss on ignition after drying at 230° Fahr.,	5·50
Portion soluble in Hydrochloric Acid = 93·40	Alumina,	9·50
	Ferric oxide,	5·33
	Calcium phosphate,	55·17
	Manganese oxide,	3·76
	Calcium sulphate,	1·75
	Calcium carbonate,	14·87
	Magnesium carbonate,	0·76
	Silica,	2·26
Portion insoluble in Hydrochloric Acid = 1·10	Insoluble residue, principally alumina with silica,	1·10
		100·00

150. Piece of Bone (Whale's).—Station 286.

Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

The specimen was brown in colour, very porous, and readily reducible to a powder.

	P.	P./E.	
Moisture,	3·06		
Combined water,	3·66		
Phosphoric acid,	27·49	1·162	1·387
Carbonic acid,	4·14	0·188	
Fluorine 0·71 = (F_2 − O),	0·41	0·037	
Lime,	39·00	1·392	
Magnesia,	2·01		
Ferrous oxide,[1]	1·04		
Ferric oxide,[1]	4·83		
Binoxide of manganese,[1]	1·61		
Alumina,	2·70		
Silica and substances insoluble in hydrochloric acid,	9·08		
Alkalies and loss,	0·97		
	100·00		

The insoluble residue consisted apparently of amorphous silica. The part soluble in hydrochloric acid seems to be a mixture of—

Phosphate of lime,	60·0	per cent. of the whole substance.	
Carbonate of lime,	9·4	,,	,,
Fluoride of calcium,	1·4	,,	,,
Binoxide of manganese,	1·6	,,	,,
Ferric oxide,	4·8	,,	,,

and minor constituents.

Ratio of equivalents of phosphoric acid, carbonic acid, and fluorine—

($\frac{1}{3}P_2O_5$)		(CO_2)		(F_2)
1	:	0·162	:	0·037

In the recent earbone (No. 153a.) we found :—

1	:	0·162	:	*nil.*

[1] Direct result of analysis—

Manganous oxide,	1·31
Ferric oxide,	5·98
Loose oxygen,	0·18

151. Central Portion of Whale's Bone much impregnated with Manganese.—Station 286.
Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

The outer portions of this specimen were perfectly black; most of the inner portion also was black, but a small portion in the centre had remained untinged with manganese. This comparatively uncoloured central portion was removed, prepared for analysis, and used for the following determinations:—

	P.	$\frac{P.}{E.}$
Moisture,	2·87	
Phosphoric acid,	29·13	1·231
Fluorine,	1·44	0·076
Lime,	36·05	1·287
Portion insoluble in hydrochloric acid,	2·91	

Ratio of equivalents of phosphoric acid and fluorine—

1 : 0·062

There was an appreciable quantity of manganese present, and also a trace of cobalt.

152. External Portion of Whale's Bone much impregnated with Manganese.—Station 286.
Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

The outer manganiferous portion of the specimen used in Analysis 151 was completely analysed, with the following results:—

	P.	$\frac{P.}{E.}$
Portion insoluble in hydrochloric acid,	5·76	
Total water,	9·77	
Manganous oxide,	20·22	
Loose oxygen,	3·49	
Ferric oxide,	6·54	
Alumina,	1·66	
Lime,	19·71	0·7039
Magnesia,	7·42	0·3710
Potash,	0·55	
Soda,	1·12	
Phosphoric acid,	18·59[1]	0·7860
Carbonic acid,	3·87	0·1759
Traces of copper, chlorine, fluorine, and loss,	1·30	
	100·00	

The manganese is probably present mostly as binoxide, combined chemically with water and part of the protoxides.

[1] Equal to 40·90 per cent. tricalcic phosphate.

153. Portion of Whale's Bone much impregnated with Manganese.—Station 286.
Lat. 33° 29′ S., long. 133° 22′ W., 2335 fathoms (Dittmar).

The manganese was pretty well diffused through all the specimen.
Found in 100 parts—

Moisture,	5·49	
Combined water,	6·88	
Phosphoric acid,	13·05	= 28·48 per cent. tricalcic phosphate.
Fluorine,	0·65	

Ratio of equivalents of phosphoric acid and fluorine—

1 : 0·062

153A. Portion of Recent Earbone, Balæna Mysticetus (Dittmar).

	P.	E.	$\frac{P.}{E.}$	
Phosphoric acid,	31·66	: 23·67	= 1·3377	1·5612
Carbonic acid,	4·77	: 22	= 0·2168	
Chlorine 0·038 = ($Cl_2 - O$),	0·029	: 27·5	= 0·0011	
Sulphuric acid,	0·21	: 40	= 0·0053	
Fluorine,[1]	0·005	: 19	= 0·0003	
Lime,	41·52	: 28	= 1·4828	1·5758
Magnesia,	0·86	: 20	= 0·0430	
Potash,	0·14	: 47	= 0·0030	
Soda,	1·46	: 31	= 0·0470	
Phosphates of iron and alumina,	0·20			
Moisture,	7·31			
Organic matter,	11·14			
	99·30			

153B. Portion of Recent Mesorostral Bone of Ziphius, Cape of Good Hope (Dittmar).

Partly decayed; the undecayed portion was analysed.

	P.	$\frac{P.}{E.}$	
Phosphoric acid,	34·64	1·4635	1·7685
Carbonic acid,	6·35	0·2886	
Chlorine 0·14 = ($Cl_2 - O$),	0·11	0·0039	
Sulphuric acid,	0·05	0·0125	
Fluorine,	0·032		
Lime,	40·51	1·4467	1·6949
Magnesia,	3·59	0·1795	
Potash,	trace		
Soda,	2·13	0·0687	
Phosphates of iron and alumina,	0·36		
Moisture,	3·51		
Organic matter,	7·49		
	98·77		

From the numbers found for $\frac{P}{E}$ it would appear probable that this bone contains a hydric phosphate such as $MgHPO_4$, which I remember having seen reported in other bone analyses, but I am more inclined to think that there is an unobserved error somewhere. Taking the deficiency (1·7685 − 1·6949) in bases to mean a loss of magnesia, we have for the percentage of that base 3·59 + 1·47 = 5·06, which would bring up the total percentage to 100·21.

[1] Having found by preliminary experiments that the deep-sea specimens contained appreciable quantities of fluorine, I devoted particular attention to the exact determination of this element. The method adopted was as follows:—A sufficient quantity of ignited material (5 to 20 grms.) was heated with a large excess of pure quartz sand and pure oil of vitriol (previously charged with sulphate of silver to retain the bulk of the chlorine), and the fluoride of silicon formed, after having been filtered through dry asbestos to retain any sulphuric acid that might have come over, passed into water and determined titrimetrically by means of pure standard caustic soda. In the resulting mixture, the chlorine, if present, was determined and allowed for.

153c. Brain Case of Globiocephalus, European Seas (Dittmar).

	P.	$\frac{P.}{E.}$	
Phosphoric acid,	22·45	0·9485	1·1008
Carbonic acid,	3·18	0·1446	
Chlorine 0·085 = (Cl_2 - O) or muriatic acid,	0·066	0·0024	
Sulphuric acid,	0·21	0·0053	
Fluorine,	0·004		
Lime,	30·04	1·0727	1·1440
Magnesia,	0·38	0·0190	
Potash,	trace		
Soda,	1·62	0·0523	
Phosphates of iron and alumina,	1·25		
Moisture,	8·93		
Organic matter,	31·79		
	99·92		

The fluorine was determined in 8 grms. of the ash of the substance, and found to amount to 0·57 mgrms., that is to 0·007 per cent. of the ash, or 0·004 per cent. of the original substance.

From these analyses it would appear that the percentage of fluorine in recent marine bones is very minute. For the sake of comparison I determined the fluorine in a sample of ordinary bone ash, and found it 0·004 per cent., *i.e.*, almost *nil*. As it is stated that teeth contain more fluorine than ordinary bones, I procured a quantity of horses' teeth, ignited them, and determined the fluorine in the ash. It was found equal to 0·084 per cent., which, though decidedly higher than the number obtained with the bones, is still very minute. I have no doubt that the 1 or 2 per cent. of fluoride of calcium, which we find reported in the older analyses of bones, is based on utterly erroneous determinations. This, however, only confirms what Nicklès gave some years ago as the result of an extensive investigation on the subject.

For the number of equivalents of carbonate present per equivalent of phosphate, we have in :—

	No. 153A.	No. 153B.	No. 153C.
	0·162	0·197	0·153
or,	$\frac{1}{6·2}$	$\frac{1}{5·1}$	$\frac{1}{6·6}$

153d. Portion of Ziphius Beak from Red Crag, Suffolk (Dittmar).

A thin plate cut out of the beak, highly polished on one side; it was wholly petrified and homogeneous, and was completely soluble in hydrochloric acid.

	P.	$\frac{P.}{E.}$	
Moisture,	1·67		
Combined water,	2·31	0·2566	1·8647
Phosphoric acid,	33·83	1·4294	
Carbonic acid,	7·50	0·3409	
Fluorine 1·50 = (F_2 - O),	0·87	0·0789	
Sulphuric acid,	0·62	0·0155	
Chlorine and silica,	*nil.*		
Lime,	48·81	1·7431	
Magnesia,	1·08	0·0540	
Ferric oxide,	2·00	0·0577	
Alumina,	0·18	0·0105	1·9399
Potash,	0·52	0·0111	
Soda,	1·97	0·0635	
	101·36		

Ratio of equivalents—

($\frac{1}{3}P_2O_5$)	(CO_2)	(F_2)
1	0·239	0·055

In recent *Ziphius* bone (153b.) they were—

1 : 0·197 : *nil.*

153E. OTOLITHS OF COD (ROSS).

Lime,	53·08
Carbonic acid,	43·85
Magnesia,	2·71
Phosphoric acid,	trace
Alumina,	0·22
Silica,	0·33
	100·19

INDEX.

The more important references are indicated by heavier figures.

PLATE I.

Fig. 1. Large rounded fragment of pumice (one-fourth natural size). This is a characteristic specimen belonging to the light porous and filamentous liparitic variety; only a few minerals are visible to the naked eye. The surface is but slightly altered, and the pores are filled with small *Globigerina* shells, and other materials of the deposit in which it was imbedded. Station 246; 2050 fathoms. North Pacific.

Fig. 2. Smaller rounded specimen (natural size) belonging to the same variety as the preceding, showing Brachiopods (*Discina*) and Hydroids (*Stephanoscyphus*) attached. The surface has a brownish coating of altered material, and in some places there are depositions of the hydrated peroxide of manganese. Station 246; 2050 fathoms. North Pacific.

Fig. 3. Rounded specimen of the acid variety of pumice (natural size), out of which a section has been cut to show the altered zone of argillaceous matter in all the external parts, while the central parts are but slightly altered by decomposition. Station 246; 2050 fathoms. North Pacific.

Fig. 4. Section of another specimen of the same variety as the preceding (natural size), showing a decomposed brown zone surrounding the relatively little decomposed centre. Station 246; 2050 fathoms. North Pacific.

All the above specimens floated in water a few months after they had been dredged from the bottom.

Figs. 5 and 6. Pumice stones surrounded by layers of the hydrated peroxide of manganese, so that they may be called manganese nodules (natural size). The pumice is here very much decomposed, especially in the zone nearest the layers of manganese. In fig. 5 the layer of manganese is only about 1 mm. in thickness, while in fig. 6 it is fully 1 cm.; in the former the structure of the pumice is well preserved, but in the latter it is obliterated, the pumice being for the most part soft and earthy. The pores of the pumice are often filled with reddish earthy or clayey matter. In some samples from this station the structure of the nuclei of pumice is almost wholly lost, and can with difficulty be recognised. Station 248; 2900 fathoms. North Pacific.

Fig. 7. An irregular, white, fibrous fragment of liparitic pumice, with the central portions more or less altered, the fissures being often filled with the mud of the bottom (natural size). A zone of manganese, mingled with earthy matter, is often sharply marked off from the central parts, then follow concentric zones of the peroxide of manganese, covered with the clay of the deposit. Station 241; 2300 fathoms. North Pacific.

Fig. 8. Black-brown scoriaceous fragment of basaltic pumice, with numerous circular vesicles (natural size). Crystals of plagioclase, occasionally 4 to 6 mm. in diameter, can be seen with the naked eye, and other minerals are recognised in microscopic slides. The vesicles shown in the figure are like those in the interior, which are filled with the infiltrated clay, giving the fragment an oolitic appearance. Station 241; 2300 fathoms. North Pacific.

PLATE II.

Fig. 1. A very characteristic manganese nodule as regards shape and general appearance (natural size). Over thirty nodules more or less like this one were procured at this station. The general form is round, and the mammillæ are not prominent, but run the one into the other without forming marked reliefs. The upper and under surfaces present a sensible difference of aspect. The inferior surface, here figured, we believe to have been plunged into the ooze; it is covered with an immense number of rugosities,—little rounded points 1 or 2 mm. in diameter, and the same in height,—which, being scattered over the whole surface, render the nodule rough to the touch, and somewhat like shagreen. These asperities are not so abundant on the upper surface, which is on the whole much smoother. Station 248; 2900 fathoms. North Pacific.

Fig. 2. Similar nodule (natural size), in the interior of which were found the remains of a siliceous Sponge (*Farrea*). A portion of the skeleton of the Sponge is represented, more highly magnified, in fig. 2*a*; the minute canals of the Sponge are seen to be filled with manganese. Some portions of the siliceous skeleton appear to have been removed by solution. The nodule has probably been formed round a fragment of a Sponge. Station 248; 2900 fathoms. North Pacific.

Fig. 3. Irregular pyramidal-shaped variety of nodule (natural size). The nodule is wedge-shaped, and the entire surface is mammillated. The reliefs are more or less pronounced in two directions, the first being parallel to the lateral edges of the wedge, along radii, the second being more or less parallel to the superior surface of the figure, and following a curved direction. Station 160; 2600 fathoms. Southern Ocean.

Fig. 3*a*. Section showing the internal structure of a nodule similar to the preceding (natural size). The alternating zones, from 1 to 2 mm. in diameter, are yellowish white and black-brown. The light coloured bands are traversed by dendritic depositions of manganese, which is in greater abundance in the dark layers. Station 160; 2600 fathoms. Southern Ocean.

Fig. 3*b*. Portion of one of these nodules from which the manganese has been removed by concentrated hydrochloric acid. An examination of these clayey skeletons shows that the yellowish white matter extends also into the black bands in the interior of the nodule. Station 160; 2600 fathoms. Southern Ocean.

Fig. 4. Section of one of the larger nodules from the North Pacific (natural size). The external surface is similar to that of fig. 1. The several white nuclei are found on examination to be highly-altered fragments of pumice, around which layers of manganese have been deposited, the whole being ultimately formed into one nodule. Station 248; 2900 fathoms. North Pacific.

Fig. 5. One of the larger nodules from the South Pacific (natural size). The interior of these nodules consists of light brown concentric layers arranged round small altered volcanic fragments, or sharks' teeth and their fragments. The outer layers, for a depth of about 5 mm., are of a much darker colour than the inner ones. Station 285; 2375 fathoms. South Pacific.

Fig. 6. Five instances of small sharks' teeth, and little pellets of pumice, surrounded and cemented together by depositions of the hydrated peroxide of manganese (natural size), showing, as it were, the nodules in process of formation around various nuclei, and their agglomeration into larger nodules. Station 286; 2335 fathoms. South Pacific.

Fig. 7. Four small nodules (natural size) in a later stage of growth, so to speak, than those represented in fig. 6. The nuclei in both cases are of the same nature. Station 285; 2375 fathoms. South Pacific.

PLATE III.

Fig. 1. Portion of a large flattened fragment of manganese from the North Atlantic (natural size). The original fragment was over a foot in diameter, and was evidently a piece torn from a much larger mass by the action of the dredge. The upper surface shows the usual rough mammillated appearance, being black and shining, while the interior is black-brown. To this nodule was attached a large branching Coral; at the upper right hand side of the figure a portion of the base of this Coral is seen to be attached to the nodule, and to be again covered by a slight coating of manganese. Station 3; 1525 fathoms. North Atlantic.

Figs. 2 and 3. Fragments of the Coral (*Pleurocorallium johnsoni*) attached to the above nodule (natural size). The Coral was all dead, and in some places much corroded; it was everywhere coated and permeated by depositions of manganese, sometimes 0·1 mm. in thickness. The axis in some places was 2 cm. in diameter; it was pure white with black rings, took a high polish, and contained a considerable quantity of organic matter. Amidst the arms of the Coral was seated a large living siliceous Sponge (*Poliopogon amadou*). Station 3; 1525 fathoms. North Atlantic.

Fig. 4. Pyramidal nodule from the South Pacific (natural size). The upper parts and upper surface are smoother and more compact than the lower ones, which are mammillated and covered with asperities resembling in many respects the nodule figured in Plate II. fig. 3. Station 299; 2160 fathoms. South Pacific.

Fig. 5. One of a large number of nodules of similar size and external appearance from the North Pacific (natural size). Its dimensions were $7 \times 7 \times 5$ cm. The specimen is broken to show that in the centre there is a large *Carcharodon* tooth about 4 cm. in length. The tooth is surrounded by concentric layers of manganese 1·5 cm. in thickness, and the whole nodule takes roughly the form of the tooth. The outer layers, 6 mm. in thickness, are of a lighter colour than the deeper ones, and the same is the case with other nodules from this station. Only the hard dentine of the tooth remains, the external surface being black and shining; the vaso-dentine has entirely disappeared, and the whole tooth is impregnated with manganese. Station 252; 2740 fathoms. North Pacific.

Fig. 6. Nodule similar to the preceding, shown in section (natural size). Three zones may be distinguished: first, in the centre an elongated yellowish white nucleus, penetrated by dendrites of manganese, and in some places sharply separated from the second zone of dark layers of manganese, in which no concentric arrangement can be observed, the third zone being composed of concentric layers of manganese, the outer ones of a lighter colour than the inner ones. As shown in the figure, there is a thin layer of clay of varying continuity immediately below the concentric layers. The manganese has always a semi-metallic lustre on a broken and polished surface. Station 252; 2740 fathoms. North Pacific.

Fig. 7. Section of a nodule from the South Pacific (natural size). In the centre there is a light-coloured nucleus, probably of volcanic origin, surrounded by layers which are denser and blacker than usual. The outer surface is extremely irregular. Station 289; 2550 fathoms. South Pacific.

Figs. 8 and 9. Nodules from the South Pacific, one showing the external form, and the other in section (natural size). The external surface has a mammillated and rough appearance similar to that of the majority of nodules, but the internal portions are quite different, remarkable, and exceptional. Nearly all the nodules from this station have yellowish white or greenish nuclei. In general the nuclei are soft, and contain numerous casts of Foraminifera, but none of the carbonate of lime of the shells remains; there is a dendritic arrangement of manganese throughout the nucleus. The nodules are from a deposit of Globigerina Ooze, and seem to have been formed round aggregations of the bottom. Station 297; 1775 fathoms. South Pacific.

PLATE IV.

Fig. 1. External form and appearance of a typical nodule from the North Pacific (natural size). The little knob on the top is a small piece of pumice cemented to the nodule by enveloping layers of manganese, and the swellings on the side have a similar structure and origin. The nodules from this station looked like a lot of potatoes when rolled out of the dredge. Station 252; 2740 fathoms. North Pacific.

Fig. 2. Typical manganese nodule from the Central Pacific (natural size). All the nodules taken at this station (about one hundred) have the same general form, and are the most compact of all the nodules dredged during the cruise. The upper surface is smooth, and very different in aspect from the under surface, which is covered with little rough mammillæ, having spaces between them, giving this face a scoriaceous aspect. The whole nodule has a discoidal form. Station 274; 2750 fathoms. Mid Pacific.

Fig. 3. One of several large slabs dredged among the nodules from the South Pacific, in section, and showing part of the upper surface (natural size). About the middle of the section there is a dark line which appears to represent the upper surface of an old sea-bottom, with manganese nodules imbedded or partially imbedded in the clay. A fall of ashes would appear to have taken place, covering the floor of the ocean in some places to the depth of an inch. The coarser particles lie immediately on the clay, and contain much black mica, then follow layers of finer and finer particles. Subsequently the bottom was apparently, after consolidation, rent by cracks, and layers of manganese were deposited over the upper surface and down the cracks, binding the whole into a compact mass. Station 281; 2385 fathoms. South Pacific. (For microscopical description of this slab see Plate XXI. fig. 2).

Fig. 4. Round nodule from the same station, in section (natural size). On one side there is a whitish layer of volcanic ashes, over which, as in the case of the slabs, there is a layer of manganese. The side with the layer of ashes had evidently been the upper surface of the nodule when resting on the bottom of the sea. Station 281; 2385 fathoms. South Pacific.

Fig. 5. Another nodule from the same station (natural size), broken to show the *Carcharodon* tooth in the centre. Station 281; 2385 fathoms. South Pacific.

Fig. 6. Upper surface of rather rare and irregular form of nodule from the South Pacific (natural size). It is more or less flattened, and presents a scoriaceous aspect, with a rugged appearance on the upper surface. The interior contains a yellowish earthy matter. Station 276; 2350 fathoms. South Pacific.

Fig. 7. Section of another nodule from the same station (natural size). The interior does not present any concentric structure, but there is an outer zone of concentric layers from 2 to 3 mm. in diameter. The nucleus was probably originally a piece of pumice. Station 276; 2350 fathoms. South Pacific.

Fig. 8. External surface of the same nodule (natural size), showing the scaly structure of the outer zones.

PLATE V.

Figs. 1 and 1*a*. Tooth of *Carcharodon megalodon*, outer surface and profile (natural size). This is the largest specimen taken during the cruise. Station 281; 2385 fathoms. South Pacific.

Figs. 2, 3 and 3*a*, 4, 5 and 5*a*. Other specimens of *Carcharodon*, slightly coated with manganese, from the same station (natural size). Station 281; 2385 fathoms. South Pacific.

Figs. 6, 7 and 7*a*. Teeth of *Carcharodon* (natural size). Station 285; 2375 fathoms. South Pacific.

Figs. 8 and 9. Small serrated teeth (*Hemipristis ?*) (natural size). Station 286; 2335 fathoms. South Pacific.

Figs. 10 and 11. Small serrated teeth (*Hemipristis ?*) (natural size). Station 285; 2375 fathoms. South Pacific.

Fig. 12. Small serrated tooth (*Carcharodon ?*) (natural size). Station 276; 2350 fathoms. South Pacific.

Fig. 13. Small serrated tooth (*Carcharias ?*) (natural size). Station 281; 2385 fathoms. South Pacific.

PLATE VI.

Figs. 1 and 1*a*. Large tooth of *Oxyrhina* (*Oxyrhina trigonodon?*), about the largest specimen taken during the cruise (natural size). Station 276; 2350 fathoms. South Pacific.

Figs. 2 and 2*a*, 3 and 3*a*, 4 and 4*a*, 5 and 5*a*, 6 and 6*a*, 7 and 7*a*. Other specimens of *Oxyrhina* (natural size). Station 285; 2375 fathoms. South Pacific.

Fig. 8. Tooth of *Oxyrhina* or centre fang of *Otodus* (natural size). Station 274; 2750 fathoms. Mid Pacific.

Figs. 9 and 9*a*, 10 and 10*a*. Teeth of *Oxyrhina* or centre fangs of *Otodus* (natural size). Station 281; 2385 fathoms. South Pacific.

Figs. 11 and 11*a*. Tooth of *Oxyrhina* or centre fang of *Otodus* (natural size). Station 274; 2750 fathoms. Mid Pacific.

Figs. 12 and 12*a*. Tooth of *Oxyrhina* or *Lamna*, from about the mesial line of the upper or lower jaw (natural size). Station 285; 2375 fathoms. South Pacific.

Figs. 13 and 13*a*. Tooth of *Oxyrhina* (natural size). Station 281; 2385 fathoms. South Pacific.

Figs. 14 and 14*a*. Tooth of *Lamna* (natural size). Station 286; 2335 fathoms. South Pacific.

Figs. 15 and 15*a*. Tooth of *Lamna* (natural size). Station 281; 2385 fathoms. South Pacific.

Figs. 16 and 16*a*. Tooth of *Lamna* (natural size). Station 274; 2750 fathoms. Mid Pacific.

Fig. 17. Tooth of *Oxyrhina* (natural size). Station 281; 2385 fathoms. South Pacific.

Fig. 18. Tooth of *Oxyrhina* or *Lamna*, from about the mesial line of the upper or lower jaw (natural size). Station 285; 2375 fathoms. South Pacific.

Fig. 19. Small tooth of *Lamna* (natural size). Station 276; 2350 fathoms. South Pacific.

Figs. 20 and 21. Teeth of *Oxyrhina* or *Lamna*, from about the mesial line of the upper or lower jaw (natural size). Station 285; 2375 fathoms. South Pacific.

Fig. 22. Tooth of *Oxyrhina* (?) (natural size). May be the form of tooth in the mesial line of an *Oxyrhina* jaw. Station 286; 2335 fathoms. South Pacific.

Fig. 23. Tooth of *Oxyrhina* or *Lamna*, from about the mesial line of the upper or lower jaw (natural size). Station 285; 2375 fathoms. South Pacific.

PLATE VII.

Fig. 1. Tympanic bone of a large species of *Balænoptera*, coated and impregnated with manganese (natural size). Station 285; 2375 fathoms. South Pacific.

Fig. 2. Section of bulla of *Balænoptera* (perhaps *Balænoptera antarctica*), similar to the preceding (natural size). Station 286; 2335 fathoms. South Pacific.

Fig. 3. Bulla of *Balænoptera* (perhaps *Balænoptera rostrata*), with a considerable coating of manganese (natural size). Station 286; 2335 fathoms. South Pacific.

Figs. 4 and 5. Right and left bullæ of a whale belonging to the Balænidæ, upper and under surfaces (natural size). The markings shown in fig. 5 were found on both of the bones and are of the same character; these are the only bones taken during the cruise with such marks, and they differ from all the other earbones in other respects as well as in the markings. Station 286; 2335 fathoms. South Pacific.

Figs. 6 and 7. Tympano-periotic bones of *Mesoplodon* (*Mesoplodon layardi?*), outer and inner surfaces (natural size). The bones were coated with manganese and attached when brought up, but in the majority of cases the petrous and tympanic bones were separate. Station 276; 2350 fathoms. South Pacific.

PLATE VIII.

Fig. 1. Petrous and tympanic bones of *Mesoplodon* (species allied to *layardi*), outer surfaces covered with manganese (natural size). Station 286; 2335 fathoms. South Pacific.

Fig. 2. Section through petrous and tympanic bones similar to the preceding (natural size), showing the spaces filled with depositions of manganese and iron, with malleus and incus, &c. Station 286; 2335 fathoms. South Pacific.

Fig. 3. Petrous bone, and portion of elongated mastoid element continuous with it, belonging to one of the Baleen whales (natural size). Several such bones were obtained at this station, some very deeply imbedded in manganese depositions. Station 286; 2335 fathoms. South Pacific.

Figs. 4 and 5. Tympano-periotic bones of a *Globiocephalus* (natural size). Station 274; 2750 fathoms. Mid Pacific.

Fig. 6. Tympanic bone of *Globiocephalus* (?) (natural size). Station 286; 2335 fathoms. South Pacific.

Fig. 7. Tympanic bone of *Kogia* (natural size). Station 286; 2335 fathoms. South Pacific.

Figs. 8, 9 and 9*a*. Petrous bones of Cetaceans (Ziphioid) (natural size). Fig. 9*a* under surface to compare with fig. 14*a*. Station 286; 2335 fathoms. South Pacific.

Fig. 10. Petrous bone of *Globiocephalus* (?) (natural size). Station 160; 2600 fathoms. Southern Ocean.

Fig. 11. Tympanic bone of *Mesoplodon* (?) very deeply imbedded in depositions of manganese (natural size). Station 160; 2600 fathoms. Southern Ocean.

Figs. 12 and 13. Tympano-periotic bones belonging to one of the Delphinidæ (natural size). Station 274; 2750 fathoms. Mid Pacific.

Figs. 14 and 14*a*. Doubtful Cetacean bone (natural size). Fig. 14*a* under surface to compare with fig. 9*a*. Station 286; 2335 fathoms. South Pacific.

PLATE IX.

Fig. 1. Fourth part of a large nodule from the North Pacific (natural size); the nodule when dredged measured 31 × 20 × 6 centimetres. There is a great difference between the two large faces, the one figured being the upper surface. The under surface, that which rested on the clay of the bottom, is rough and consists of numerous closely-set mammillæ, which are more numerous towards the outer edges. The upper surface is much smoother, and the reliefs of the mammillæ rounded and softened. Small pieces of pumice that have fallen on the upper surface are cemented to it by manganese depositions, and in the same way a specimen of *Nodosaria* can be seen cemented to it by layers of manganese. In addition, there were attached to the upper surface: four specimens of *Stephanoscyphus*, a Tubularian, two Actinians, a *Serpula*, two Polyzoons, and many Rhizopod tubes or rhizomes of a Hydroid. Attached to the under surface at the edge was an Annelid with a muddy tube. The white central part may be regarded as an elongated nucleus with hollow spaces filled by clayey matter; it is hard, but can be scratched with a knife. It is impossible to suggest with any certainty its original nature. The layers of manganese above the nucleus are much thicker than those below. Station 253; 3125 fathoms. North Pacific.

Fig. 1*a*. End portion of the same nodule, from which the manganese has been removed by concentrated hydrochloric acid (natural size). The way in which some of the inner layers terminate at the edge suggests that this fragment may at one time have been part of a larger mass.

Fig. 2. Under surface of nodule from the Central Pacific (natural size). It is formed on a large *Carcharodon* tooth, and takes roughly the form of that triangular body; it might be said that there are three centres of concretion, one at each corner of the triangle. The upper surface is much smoother than the under. Station 274; 2750 fathoms. Mid Pacific.

Fig. 3. Compact nodule from the South Pacific (natural size). It is deeply mammillated, and in the hollows between the mammillæ there is a rough, irregular Rhizopod tube. The upper part of the figure shows how the nodule breaks into concentric zones. Station 289; 2550 fathoms. South Pacific.

Fig. 4. Sections of manganese nodule from the North Pacific, one half being demanganesed to show the structure (natural size). The nucleus is yellowish, and apparently was originally a piece of pumice; this is surrounded by concentric layers, some of which contain much more manganese than others. It will be noticed that, with the growth of the nodule, secondary nuclei have been embraced by the concentric layers. There is an indication of radial as well as concentric structure. Station 248; 2900 fathoms. North Pacific.

Figs. 5 and 6. Sections of nodules from the Central Pacific (natural size). The nucleus is small and surrounded by black undulating zones or lines superposed the one upon the other. In fig. 6 the face is demanganesed by concentrated hydrochloric acid to bring out the structure. Station 274; 2750 fathoms. Mid Pacific.

Fig. 7. Section of a round nodule from the North Pacific (natural size). In this case the cut face of the nodule has been demanganesed by concentrated hydrochloric acid, which leaves a clayey skeleton showing well the structure of the nodule. Three zones can be recognised: first, the nucleus; second, a zone around this without definite structure; and third, an external zone of concentric layers. Station 252; 2740 fathoms. North Pacific.

Fig. 7*a*. Portion of the same, showing the external zone with concentric layers (magnified 25 diameters). Here the intimate structure is seen; the empty spaces are those that were occupied by the manganese, and the figure shows the interpenetration of earthy and clayey matters.

Fig. 8. Section of nodule from the South Pacific, the face of which has been demanganified to show the structure (natural size). There is a hard nucleus of volcanic rock, surrounded by a zone without any alternating layers, around which are concentric layers of the usual form. Station 276; 2350 fathoms. South Pacific.

Fig. 9. Nodule from the South Pacific (natural size). The surface has been treated with concentrated hydrochloric acid to remove the manganese; the clayey skeleton that remains is very areolar in structure. Station 297; 1775 fathoms. South Pacific.

Fig. 10. Portion of nodule from the Central Pacific (natural size), in which tubes apparently of Rhizopods are seen between two of the layers of the clayey skeleton that remains after treatment with concentrated hydrochloric acid. Station 274; 2750 fathoms. Mid Pacific.

PLATE X.

Fig. 1. Mezorostral bone or beak of a Ziphioid whale (natural size). The whole bone is coated and impregnated with manganese. Station 286; 2335 fathoms. South Pacific.

Fig. 1*a*. Section of the same (natural size), showing canals as in recent species.

Fig. 1*b*. Longitudinal vertical section of the same (magnified 50 diameters), showing the Haversian canals and lacunæ filled or partially filled with peroxide of manganese.

Fig. 2. Portion of the brain-case of a Cetacean, much impregnated and covered by depositions of peroxide of manganese (natural size). Station 286; 2335 fathoms. South Pacific.

Fig. 2*a*. Transverse vertical section of the same (magnified 40 diameters), showing that the bone is partially removed, depositions of manganese having taken place in the Haversian canals and lacunæ.

Fig. 3. Portion of very light spongy bone, probably a portion of the expanded wing of a superior maxilla, covered and impregnated with manganese (natural size). Station 286; 2335 fathoms. South Pacific.

Fig. 4. Transverse section of *Carcharodon* tooth (natural size). The vaso-dentine is entirely removed from the interior, its place being occupied by depositions of manganese; only the hard dentine remains. Station 286; 2335 fathoms. South Pacific.

Fig. 4*a*. Portion of the dentine of the same (magnified 120 diameters); even the dental tubes are filled or partially filled with manganese depositions.

Fig. 5. Longitudinal vertical section of *Oxyrhina* tooth (natural size), showing the centre filled with manganese depositions. Station 286; 2335 fathoms. South Pacific.

PLATE XI.

Fig. 1. Section of Globigerina Ooze from Station 176; 1450 fathoms, South Pacific. The preparation shows numerous sections of shells of pelagic Foraminifera, some of which are filled with an argillaceous substance of a darker colour than the surrounding mass; others, however, are filled with substances of a lighter tint. Some of the Foraminifera from this station yield, after treatment with dilute hydrochloric acid, external and internal silicated casts (see Plate XXIV. fig. 3). Among the mineral particles, colourless splinters of pumice can be recognised. The black particles scattered over the figure are peroxide of manganese (magnified 104 diameters).

Fig. 2. Mineral particles of Blue Mud from Station 237; 1875 fathoms, North Pacific. These are almost all of volcanic nature: brown scoriaceous lapilli, fragments of palagonite, and numerous elongated fibrous splinters of pumice. Colourless crystals of felspar, among which are plagioclases, may be recognised; they contain brown or black and opaque inclusions of glass. Around these crystals of felspar there is at some points vitreous matter of the same colour as the inclusions, being the remains of the vitreous matter to which these clastic fragments were attached. In addition there are fragments of hornblende, with characteristic cleavages, pale green splinters of augite, grains of magnetite, minute particles of other volcanic substances, together with amorphous matter and organic remains (magnified 37 diameters).

Fig. 3. The minuter calcareous particles of Globigerina Ooze from Station 166; 275 fathoms, South Pacific. Here the Coccoliths and Coccospheres are of a large size, and the Rhabdoliths are relatively rare (magnified 500 diameters).

Fig. 4. The finer portions of Globigerina Ooze from Station 338; 1990 fathoms, South Atlantic, chiefly made up of Coccoliths, Rhabdoliths, and the primordial chambers of *Globigerinæ*, together with fragments of other calcareous organisms. Coccospheres are not here represented (magnified 500 diameters).

Fig. 5. General appearance of Globigerina Ooze, as seen by reflected light, after some of the finer amorphous particles have been washed away. It consists chiefly of various species of pelagic Foraminifera, together with a few fragments of worm-tubes, Pteropods, and Ostracode valves. Station 13; 1900 fathoms. North Atlantic (magnified 25 diameters).

Fig. 6. General appearance of Pteropod Ooze as seen by reflected light, after some of the finer amorphous particles have been washed away. It consists principally of Pteropod, Heteropod, and other Molluscan shells, together with numerous shells of pelagic Foraminifera. Station 22; 450 fathoms. North Atlantic (magnified 5 diameters).

PLATE XII.

Fig. 1. Section of Globigerina Ooze from Station 338; 1990 fathoms, South Atlantic (magnified 50 diameters). The mud, just as it was obtained from the dredge, was hardened and then cut into thin sections, so as to be seen by transmitted light. It is almost entirely composed of shells of pelagic Foraminifera, among which species of *Globigerina* and *Pulvinulina* are the most abundant.

1. Longitudinal section of *Globigerina rubra.*
2. ,, ,, *Nonionina umbilicatula.*
3. Fragment of shell of *Orbulina universa.*
4. Part section of *Sphæroidina dehiscens.*
5. Part of shell of *Orbulina universa*, showing foramina.
6. Longitudinal section of *Pulvinulina crassa.*
7. *Globigerina bulloides.*
8. ,, ,,
9. Median section of *Orbulina universa.*
10. ,, ,, ,, ,,
11. Part ,, ,, ,,
12. Small *Globigerina* shells.
13. Section of *Pulvinulina menardii.*

Fig. 2. Section of rock dredged at Station 192; 129 fathoms, off Ki Islands (magnified 50 diameters). This rock is composed principally of pelagic Foraminifera, similar to those now living in the tropical waters of the Pacific and Atlantic Oceans. It was probably not formed of the mud from which it was dredged, but belongs to an older formation (see page 171).

1. Section of portion of test of Echinoderm.
2. Part section of *Pullenia obliquiloculata.*
3. Section of *Globigerina bulloides.*
4. ,, ,, ,,
5. Longitudinal section of *Uvigerina* sp. (?).
6. ,, ,, *Pulvinulina micheliniana.*
7. ,, ,, *Pullenia obliquiloculata.*
8. ,, ,, *Pulvinulina menardii.*
9. Section of *Globigerina rubra.*
10. Section across one lobe of *Globigerina rubra.*
11. Fragment of test of Echinoderm.
12. Transverse section of spine of Echinoderm.
13. Longitudinal section of *Globigerina rubra.*
14. Part section of *Nodosaria communis.*
15. ,, *Orbulina universa.*
16. *Bulimina* sp. (?).
17. Transverse section of *Pulvinulina micheliniana.*

Fig. 3. Section of Globigerina Ooze from Station 348; 2450 fathoms, Tropical North Atlantic (magnified 50 diameters). The ooze consists principally of the large shells of pelagic *Pulvinulina*, *Sphæroidina*, and *Globigerina.*

1. *Pulvinulina menardii.*
2. Part section of *Sphæroidina dehiscens.*
3. Transverse section of *Truncatulina* sp. (?).
4. Part of final lobe of *Pulvinulina menardii.*
5. Part section of *Pullenia obliquiloculata.*
6. Radiolarian.
7. Longitudinal section of *Pulvinulina menardii.*
8. *Globigerina sacculifera.*
9. Superior aspect of *Globigerina inflata.*
10. Longitudinal median section of *Pulvinulina menardii.*
11. *Globigerina dubia.*
12. Part section of *Orbulina universa.*
13. ,, *Pulvinulina menardii.*
14. Radiolarian.

Fig. 4. Section of Globigerina Ooze from Station 158; 1800 fathoms, Southern Indian Ocean (magnified 50 diameters). The ooze here consists principally of *Globigerinæ*, the more tropical forms being absent.

1. Part section of *Globigerina bulloides.*
2. Radiolarian.
3. *Globigerina bulloides.*
4. ,, ,,
5. ,, ,,
6. Radiolarian (?).
7. *Globigerina rubra.*
8. Radiolarian.
9. Longitudinal section of *Pullenia obliquiloculata.*
10. ,, ,, *Pulvinulina crassa.*
11. Section of *Sphæroidina dehiscens.*
12. Radiolarian.

PLATE XIII.

The figures on this plate represent the changes in the composition and appearance of the calcareous deposits around the island of Bermuda, at different depths and distances from the outer edge of the reef.

Fig. 1. Section of the mud from 200 fathoms, about a mile from the reef (magnified 15 diameters), consisting principally of fragments of Molluscs, Polyzoa, Corals, calcareous Algæ, and bottom-living Foraminifera.

1. Fragment of Polyzoon.
2. ,, Millepore (?).
3. ,, calcareous Alga.
4. Longitudinal section of *Amphistegina cumingii.*
5. Gasteropod shell surrounded with calcareous Alga.
6. Shell of Echinoderm cemented to other fragments — Foraminifera, Radiolaria, &c.—by deposition of carbonate of lime.
7. Part section of *Textularia barrettii.*
8. Calcareous Alga.
9. Calcareous Alga.
10. Transverse section of *Amphistegina cumingii.*
11. Section of *Textularia* sp. (?).
12. Longitudinal section of *Textularia conica.*
13. Fragment of calcareous Alga.
14. Conglomeration of deposit showing section of Coral.
15. Longitudinal section of *Amphistegina cumingii* (young).
16. Fragment of Polyzoon (*Lepralia* sp.?).

Fig. 4. Section of the mud from 380 fathoms, about 2½ miles from the reef (magnified 50 diameters). The fragments are all of much smaller size than in 200 fathoms, although consisting of fragments of nearly the same organisms. The shells of Pteropods and pelagic Foraminifera are, however, more abundant than in the shallower depths.

1. Fragment of calcareous Alga.
2. Sponge spicule.
3. Fragment of section of *Orbitolites complanata.*
4. Part section of *Pulvinulina canariensis.*
5. Transverse section of *Heterostegina depressa.*
6. ,, ,, *Patellina corrugata.*
7. ,, ,, *Planorbulina mediterranensis.*
8. Longitudinal section of *Sagrina columellaris* (?).
9. Fragment of Polyzoon.
10. ,, shell of *Pulvinulina* sp. (?).
11. Calcareous Alga.
12. Basal portion of Sponge spicule.
13. Fragment of Pteropod shell.
14. Transverse section of *Discorbina* sp. (?).
15. Fragment of test of Echinoderm.
16. Longitudinal section of *Lingulina carinata* (?).
17. Fragment of test of Echinoderm.
18. Part section of *Sphæroidina dehiscens.*
19. Longitudinal section of *Bulimina* sp. (?).
20. Transverse section of *Rotalia soldanii.*
21. Fragment of Polyzoon.
22. *Rotalia* sp. (?).
23. Fragment of calcareous Alga.
24. Transverse section of Echinoderm spine.
25. Section of *Globigerina rubra.*
26. Ostracode valve.
27. Section of Heteropod shell.
28. ,, *Miliolina* sp. (?).
29. Part of test of Lituolid.
30. Fragment of calcareous Alga.
31. Longitudinal section of *Bulimina* sp. (?).
32. Fragment of calcareous Alga.

Fig. 2. Sections representing the appearance of the mud in 950 fathoms, still further (about 5 miles) from the reef (upper half magnified 50 diameters, lower half 100 diameters). The particles are much smaller in size, while the pelagic shells are more numerous, and the reef fragments less numerous than in the shallower depths.

1. Fragment of calcareous Alga.
2. Transverse section of Alcyonarian spicule.
3. Fragment of Polyzoon (*Lepralia* sp.?).
4. Longitudinal section of *Bolivina dilatata.*
5. Fragment of calcareous Alga.
6. Section of Heteropod shell.
7. ,, Pteropod shell.
8. ,, fragment of *Orbitolites* sp. (?).
9. *Globigerina* sp. (?).
10. Section of Ostracode valve.
11. Part section of *Pulvinulina micheliniana.*
12. Radiolarian.
13. *Bulimina* sp. (?).
14. Sponge spicule.
15. Pteropod shell with *Cornuspira* sp. (?).
16. Transverse section of *Discorbina vilardeboana* (?).
17. Basal portion of Sponge spicule.
18. Part section of *Sphæroidina dehiscens.*
19. ,, ,,
20. Longitudinal section of *Miliolina* sp. (?).
21. Alcyonarian spicule.
22. *Globigerina bulloides* (young).
23. Ostracode valve.
24. *Globigerina bulloides.*
25. Basal portion of Echinoderm spine.
26. Sponge spicule.
27. Fragment of Mollusc shell.
28. ,, ,,
29. Transverse section of Echinoderm spine.
30. Calcareous Alga.
31. Fragment of test of Echinoderm.
32. Fragment of outer edge of transverse section of Echinoderm spine.
33. Fragment of Sponge spicule.
34. Calcareous Alga.
35. Radiolarian.
36. Sponge spicule.
37. ,, ,, (*Geodia* ?).
38. Part section of *Orbitolites complanata.*
39. Fragment of Mollusc shell.
40. ,, calcareous Alga.

Fig. 3. Section representing the appearance of the mud in 1950 fathoms, and still further (about 7½ miles) from the reef edge (magnified 50 diameters). Here the deposit is chiefly made up of the shells of pelagic Foraminifera, and might be called a Globigerina Ooze.

1. Longitudinal section of Gasteropod shell.
2. Fragment of section of *Orbitolites complanata.*
3. Longitudinal section of *Pulvinulina canariensis.*
4. Transverse section of Echinoderm spine.
5. Longitudinal section of *Bulimina textilarioides.*
6. *Orbulina universa.*
7. Longitudinal section of *Globigerina inflata.*
8. ,, ,, *Spiroloculina* sp. (?).
9. ,, ,, *Globigerina bulloides.*
10. ,, ,, *Pulvinulina menardii.*
11. Surface of shell of *Orbulina universa.*
12. *Globigerina rubra.*
13. Fragment of Sponge spicule.
14. Radiolarian.
15. Long. section of *Pulvinulina micheliniana.*
16. Transverse section of *Rotalia* sp. (?).
17. ,, ,, *Truncatulina pygmæa.*
18. Fragment of Pteropod shell.
19. Longitudinal section of *Bulimina* sp. (?).
20. *Globigerina rubra.*
21. Sponge spicule (?).
22. Longitudinal section of *Bulimina textilarioides* (?).
23. *Globigerina rubra.*
24. Longitudinal section of Echinoderm spine.
25. Part section of marginal ring of *Pulvinulina menardii.*
26. Part section of *Globigerina* sp. (?).

PLATE XIV.

This plate represents the general appearance of the calcareous deposits at different depths and distances from the reefs at the Fiji and Friendly Islands in the South Pacific.

Fig. 2. Section of the mud from 18 fathoms inside the reefs at Tongatabu (magnified 15 diameters), consisting principally of fragments of Molluscs, calcareous Algæ, Polyzoa, and large bottom-living Foraminifera.

1. Fragment of calcareous Alga.
2. Part section of *Orbitolites* sp. (?).
3. Transv. section of *Operculina complanata* (young).
4. Fragment of test of Echinoderm (?).
5. Longitudinal section of *Alveolina boscii*.
6. Transverse ,, ,, ,,
7. Calcareous Alga.
8. Fragment of calcareous Alga.
9. Alcyonarian spicule.
10. Longitudinal section of *Cymbalopora poeyi*.
11. ,, ,, *Textularia trochus*.
12. Fragment of calcareous Alga.
13. Longitudinal section of *Nonionina scapha*.
14. Part section of *Amphistegina cumingii*.
15. Transverse section of *Truncatulina* sp. (?).
16. Longitudinal section of *Cycloclypeus* sp. (?).
17. Longitudinal section of *Spiroloculina crenata*.
18. Fragment of test of Echinoderm.
19. Fragment of calcareous Alga, with *Polytrema miniaceum* attached.
20. Section of *Orbitolites*.
21. Longitudinal section of Gasteropod shell.
22. Fragment of calcareous Alga.
23. *Globigerina bulloides*.
24. Longitudinal section of *Textularia conica*.
25. Fragment of calcareous Alga.
26. Longitudinal section of *Clavulina communis*.
27. Section of *Orbitolites complanata*, showing primordial chamber.
28. Fragment of Polyzoon.
29. Transverse section of *Orbitolites complanata*, var. *laciniata*.

Fig. 1. Section representing the appearance of the mud in 240 fathoms, about three miles from the reefs off Tongatabu (magnified 50 diameters); the particles are of the same nature as in fig. 2, but of smaller size, and there is a considerable admixture of pelagic species.

1. Fragment of *Orbulina universa*.
2. Longitudinal section of Gasteropod shell.
3. Section of *Globigerina rubra*.
4. Heteropod shell.
5. Section of *Orbitolites complanata*, showing primordial chamber.
6. Part section of *Polystomella* sp. (?).
7. ,, *Polytrema miniaceum*.
8. Calcareous Alga.
9. Fragment of calcareous Alga.
10. Longitudinal section of *Bolivina beyrichi*.
11. Transverse section of Echinoderm spine.
12. Fragment of calcareous Alga (?).
13. Part section of *Heterostegina* sp. (?).
14. Transverse section of *Nummulites* sp. (?).
15. Longitudinal section of *Orbitolites complanata*.
16. *Truncatulina* sp. (?).
17. Fragment of Mollusc shell.
18. Part section of *Calcarina spengleri*.
19. Fragment of test of Echinoderm.
20. Transverse section of *Spiroloculina crenata*.
21. Section of *Globigerina rubra*.
22. Fragment of calcareous Alga.
23. Fragment of pumice.
24. Part section of *Textularia trochus*.
25. Transverse section of *Spiroloculina* sp. (?).
26. Fragment of Polyzoon.
27. Part section of *Orbitolites* sp. (?).
28. ,, *Amphistegina cumingii*.
29. Fragment of calcareous Alga.
30. Transverse section of *Rotalia soldanii*.
31. Section of *Globigerina rubra*.
32. Calcareous Alga.
33. Fragment of calcareous Alga.
34. Longitudinal section of Echinoderm spine.
35. Transverse section of *Rotalia* sp. (?).
36. Longitudinal section of *Bulimina* sp. (?).
37. ,, ,, *Miliolina subrotunda*.
38. Part section of *Carpenteria monticularis*.
39. Fragment of Mollusc shell, with *Carpenteria* attached.
40. Transverse section of *Tritaxia* sp. (?).

Fig. 3. Sections representing the appearance of the deposit in 610 fathoms, about 3½ miles from the reefs at Kandavu, Fijis (fig. 3*a* magnified 50 diameters, fig. 3*b* 200 diameters), where there is a large admixture of pelagic shells among the minute calcareous fragments derived from the reefs and shallower waters.

1. Part section of *Rotalia soldanii*.
2. Section of *Globigerina bulloides*.
3. Radiolarian.
4. ,,
5. Section of Heteropod shell.
6. Longitudinal section of *Bulimina pygmæa*.
7. *Globigerina rubra*.
8. Long. section of *Clavulina communis* (young).
9. *Globigerina dubia*.
10. Fragment of calcareous Alga.
11. ,, Sponge spicule.
12. ,, *Globigerina* shell.
13. Portion of test of *Rhabdammina* (?).
14. Fragment of shell of *Orbulina universa*.
15. Section of *Spiroloculina crenata*.
16. *Globigerina sacculifera*.
17. Transverse section of *Truncatulina* sp. (?).
18. Fragment of Mollusc shell.
19. Fragment of Pteropod shell.
20. ,, ,, ,,
21. Longitudinal section of *Miliolina* sp. (?).
22. Section of *Globigerina rubra*.
23. ,, *Globigerina bulloides*.
24. Fragment of Mollusc shell.
25. Part section of Gasteropod shell.
26. Fragment of *Orbiculina* shell.
27. Calcareous Alga.
28. Fragment of Sponge spicule.
29. ,, test of Echinoderm.
30. Sponge spicules.
31. ,, ,,
32. ,, ,,
33. ,, ,,
34. ,, ,,
35. Fragment of shell of *Globigerina rubra*.
36. *Globigerina bulloides* (young).

Fig. 4. Sections representing the appearance of the deposit, about 30 miles west of Ngaloa, Fijis, at a depth of 1350 fathoms (fig. 4*a* magnified 50 diameters, fig. 4*b* 200 diameters), where, it will be seen, the deposit is a Globigerina Ooze, principally made up of pelagic Foraminifera shells.

1. Part section of *Orbulina universa*.
2. *Truncatulina* sp. (?).
3. Fragment of test of Echinoderm.
4. Part section of *Pulvinulina crassa*.
5. Section of *Globigerina conglobata*.
6. Radiolarian.
7. Section of *Globigerina bulloides*.
8. ,, *Globigerina conglobata*.
9. Part of shell of *Orbulina universa*.
10. Section of *Globigerina conglobata*.
11. *Globigerina rubra*.
12. Part of shell of *Pulvinulina menardii*.
13. *Globigerina rubra*.
14. Fragment of test of Echinoderm.
15. Part section of *Globigerina* sp. (?).
16. Radiolarian.
17. *Globigerina rubra* (young).
18. Fragment of section of *Globigerina conglobata*.
19. *Globigerina bulloides* (young).
20. *Globigerina conglobata*, showing spines remaining on an inner cell.

PLATE XV.

This plate represents the appearance of various deposits in which siliceous organisms play an important rôle.

Fig. 1. Sections of Diatom Ooze from Station 157; 1950 fathoms, Southern Indian Ocean (fig. 1*a* magnified 50 diameters, fig 1*b* 300 diameters). Although the deposit is principally made up of the frustules of Diatoms, there are numerous shells of *Globigerina* in the deposit.

1. Radiolarian.
2. Diatoms.
3. Section of *Globigerina dutertrei.*
4. Radiolarian.
5. *Globigerina bulloides.*
6. Radiolarian.
7. Section of *Globigerina bulloides.*
8. Part section of *Globigerina bulloides.*
9. *Globigerina* (?).
10. Radiolarian.
11. Diatom.
12. ,,
13. ,, (*Fragilaria*).
14. ,, (*Coscinodiscus*).
15. ,, (*Thalassiothrix*).
16. ,, (*Navicula*).
17. ,, (*Actinocyclus*).
18. ,, (*Coscinodiscus* fragment).
19. ,,

Fig. 2. Sections of Globigerina Ooze from Station 271; 2425 fathoms, Central Pacific (fig. 2*a* magnified 50 diameters, fig. 2*b* 200 diameters). In this deposit, while tropical species of pelagic Foraminifera predominate, the shells and skeletons of Radiolaria make up a very large part of the deposit.

1. Part section of *Pulvinulina menardii.*
2. Cyrtoidean.
3. Portion of Foraminiferous shell (?).
4. Double-shelled Sphæroidean.
5. *Globigerina bulloides* (young).
6. Double-shelled Sphæroidean.
7. *Lychnocanium sigmopodium.*
8. Section of Discoidean; unnumbered figure to the right, *Stylodictya arachnia.*
9. *Globigerina bulloides* (young).
10. ,, ,,
11. Part section of *Globigerina conglobata.*
12. *Panartus tetrathalamus.*
13. Median section of *Pullenia obliquiloculata.*
14. Coccodiscidean.
15. Section of double-shelled Cubosphæridean (?).
16. Section of Phacodiscidean.
17. Part section of *Globigerina conglobata.*
18. Section of Spongodiscidean.
19. Stylosphæridean.
20. Section of double-shelled Sphæroidean or Prunoidean.
21. Part section of *Pulvinulina menardii.*
22. Spongiose Prunoidean.
23. *Lychnosphæra regina.*
24. Section of fragment of shell of *Pullenia obliquiloculata.*
25. Cyrtoidean.
26. Diatom (*Coscinodiscus* ?).
27. Radiolarian.
28. *Lithomitra eruca* (?).
29. Cyrtoidean.
30. *Carposphæra melitomma.*
31. Portion of Porodiscidean.

Fig. 3. Section of Radiolarian Ooze from Station 225; 4475 fathoms, Western Pacific, where the deposit is principally made up of the remains of Radiolaria and other siliceous organisms.

1. Sponge spicule (*Geodia* ?).
2. Portion of Radiolarian skeleton.
3. Sponge spicules.
4. *Rhopalodictyum* sp. (?).
5. Stichocyrtidean (*Dictyomitra caltanisettæ* ?).
6. (?).
7. Portion of section of Porodiscidean.
8. Portion of shell of a Porodiscidean or Spongodiscidean.
9. Tricyrtidean.
10. *Pipettaria fusaria.*
11. Stichocyrtidean.
12. *Anthocyrtium*, n. sp. (same form as in fig. 4, No. 20).
13. *Lychnocanium sigmopodium.*
14. Sponge spicule.
15. Sponge spicule (?).
16. *Carposphæra waltheri* (small specimen).
17. Prunoidean.
18. Fragment of Stylosphæridean (?).
19. Young stage or defective specimen of *Carpocanium petalospyris.*
20. *Carposphæra waltheri.*
21. Sponge spicules.
22. *Dictyomitra caltanisettæ.*
23. Spyroidean.
24. *Druppula nucula* (?).
25. *Archicapsa quadriforis* (?).
26. Tricyrtidean (same as No. 9).
27. Radiolarian.
28. Sponge spicule.
29. Cyrtoidean.
30. *Sethodiscus phacoides.*
31. Tricyrtidean (same as Nos. 9 and 26).
32. *Spongodiscus florealis.*
33. *Entympanium musicantum.*
34. Cyrtoidean.

Fig. 4. Section of Radiolarian Ooze from Station 268; 2900 fathoms, Central Pacific, where the deposit is principally made up of the shells and skeletons of Radiolaria.

1. Fragment of skeleton of Phæodarian.
2. (?)
3. *Cenosphæra compacta.*
4. *Akanthosphæra clavata* (?).
5. Section of Cyrtoidean.
6. *Stylodictya heliospira.*
7. Portion of *Cenosphæra* sp. (?).
8. *Siphonosphæra socialis.*
9. Spyroidean.
10. *Cenosphæra mellifica.*
11. Cyrtoidean.
12. *Dictyomitra caltanisettæ.*
13. Section of Phacodiscidean or Prunoidean (?).
14. *Siphonosphæra patinaria.*
15. Stylosphæridean (?).
16. Fragment of Radiolarian skeleton.
17. *Dorcadospyris antilope.*
18. Section of Cyrtoidean.
19. *Thecosphæra zittelii.*
20. *Anthocyrtium*, n. sp. (same as No. 12 in fig. 3).
21. Section of shell of Cyrtoidean.

PLATE XVI.

Fig. 1. Section of fragment of sideromelan, or unaltered basic volcanic glass, forming the nucleus of a manganese nodule from Station 276 ; 2350 fathoms, South Pacific. In this preparation there is seen a skeleton crystal of olivine, and single and elongated grains of metallic oxides. At the upper part of the figure the commencement of alteration into palagonite can be observed (magnified 37 diameters).[1]

Fig. 2. Section of nucleus of nodule from Station 160 ; 2600 fathoms, Southern Indian Ocean. It is an unaltered fragment of sideromelan filled with little crystals of olivine, some of which contain inclusions of glass similar to that forming the mass of the rock. There are also skeletons of crystals forked at the two extremities. All the olivine crystals are surrounded by trichites (magnified 37 diameters).

Fig. 3. Section of nucleus of nodule from Station 285 ; 2375 fathoms, South Pacific. It is formed of a greenish grey sideromelan represented in the lower part of the figure, and of brownish yellow palagonite represented in the upper part of the figure. This section shows that the palagonite must be produced by the decomposition of the sideromelan, as it encloses crystals of olivine similar to those observed in the unaltered glass in the lower part of the figure (magnified 37 diameters).

Fig. 4. Section of nucleus of manganese nodule from Station 302 ; 1450 fathoms, South Pacific. This nucleus of sideromelan has been partly transformed into red palagonite along the borders of fissures. The glass contains colourless crystals of olivine, some of which are of considerable size, but the great majority appear as microliths scattered throughout the mass (magnified 37 diameters).

[1] The following coloured figures of minerals and rocks were drawn by M. E. de Munck, viz.:—Pl. XVI. fig. 1; Pl. XVII. figs. 1, 2; Pl. XVIII. figs. 1, 3; Pl. XIX. figs. 1, 3, 4; Pl. XXI. fig. 1; Pl. XXII. figs. 1, 2, 3; Pl. XXVIII. fig. 3; Pl. XXIX. figs. 1, 2, 3. Several figures on Pl. XXIII. were drawn by M. W. Prinz.

PLATE XVII.

Fig. 1. Section of nucleus of manganese nodule from Station 285; 2375 fathoms, South Pacific. This section shows two fragments of grey coloured sideromelan or unaltered basic glass, the one in the centre of the figure, and the other on the left hand side, containing little crystals of olivine. Around these two centres extends a yellowish mass, which contains similar crystals of olivine, and is derived from the alteration of the sideromelan. The preparation shows a phase of decomposition in which the palagonite still preserves a certain homogeneity. Manganese has infiltrated into the characteristic fissures of the rock in the form of dendrites, especially in the upper part of the figure (magnified 145 diameters).

Fig. 2. Section of nucleus of manganese nodule from Station 293; 2025 fathoms, South Pacific. This figure represents a frequent mode of decomposition of vitreous basic rocks; the vitreous matter has been entirely transformed into reddish palagonite, but it shows, like the preceding figure, a certain homogeneity of structure, no fissures being visible in some parts. Among the mineralogical elements, crystals of plagioclase are to be observed in the form of rhombic tables, completely encased in the palagonite, as seen in the lower part of the figure. In the fractures there are abundant infiltrations of manganese (magnified 145 diameters).

Fig. 3. Section of nucleus of nodule from Station 160; 2600 fathoms, Southern Indian Ocean. This nucleus is formed of a brownish basaltic volcanic glass, surrounded by products of decomposition. The unaltered glass is represented by the greenish grey patch across the middle of the figure; it is perfectly isotropic, and contains little crystals of plagioclase, olivine, and augite. Similar minerals are found in the yellowish brown altered zones at the upper and lower parts of the figure. These yellowish zones are traversed by undulating lines, along which the substance breaks; these zones present between crossed nicols spherolithic polarisation, as observed in some zeolites (magnified 37 diameters).

Fig. 4. Section of nucleus of manganese nodule from Station 302; 1450 fathoms, South Pacific. This section represents a fragment of palagonite, with the perlitic structure and fissures usually accompanying the advanced decomposition of this substance; the parallel lines of the convex and concave zones are highly characteristic, being rendered more distinct by the penetration of peroxide of manganese (magnified 280 diameters).

PLATE XVIII.

Fig. 1. Section of nucleus of manganese nodule from Station 285; 2375 fathoms, South Pacific. In the manganese forming the ground-work of the preparation, there are embedded irregular, triangular, elongated, or quadrilateral fragments, having a yellowish tint, and formed of successive zones of different shades of colour; very often there is a hollow centre, in which crystals of zeolites are sometimes formed. In polarised light these fragments are birefrangent, like palagonite, and are believed to be altered fragments of basic volcanic glass (magnified 145 diameters).

Fig. 2. Section of nucleus of manganese nodule from Station 276; 2350 fathoms, South Pacific. This nucleus is formed by an aggregation of greenish, vesicular, volcanic lapilli, enclosing little lamellæ of plagioclase and sections of olivine almost entirely replaced by limonite mixed with manganese, and in addition some grains of augite. These are splinters of basaltic rock, with an altered vitreous base, the different lapilli being cemented by fibro-radiate bands of zeolites, forming a mammillated coating around each splinter (magnified 145 diameters).

Fig. 3. Section of nucleus of nodule from Station 276; 2350 fathoms, South Pacific. This nucleus is composed of volcanic fragments of a vitreous nature, transformed into palagonite. There are numerous areolar cavities lined or filled with zeolites, besides numerous lamellæ of plagioclase. The two lapilli partially represented in the figure are surrounded by zeolitic zones, the interspace being filled with earthy matters and peroxide of manganese (magnified 50 diameters).

Fig. 4. Section of nucleus of nodule from Station 276; 2350 fathoms, South Pacific. This nucleus consists of a fragment of palagonite of a red colour, in which there are some lamellæ of plagioclase. The vesicles are everywhere occupied by fibro-radiate colourless zeolites, in a thick layer towards the interior, but in concentric zones towards the external border, the empty space in the centre being frequently filled by manganese or muddy matters. The characteristic fractures depending on the perlitic structure are in this specimen more circular than is usually the case (magnified 145 diameters).

PLATE XIX.

Fig. 1. Section of nucleus of nodule from Station 276; 2350 fathoms, South Pacific. This represents a portion of a lapilli, principally formed of an aggregation of extremely thin crystals of plagioclase in the form of rhombic tables. From the optical properties this plagioclase appears to be bytownite. The fundamental mass of the rock, now transformed into palagonite, was originally a blackish glass. The dark colour at some points of the figure is due to the presence of manganese. This rock is profoundly altered, the felspars alone having resisted decomposition. In some parts there are sections of augite and of olivine entirely transformed into a red substance, with a fibrous appearance. The rock is a felspathic basalt with a vitreous base (magnified 50 diameters).

Fig. 2. Section of nucleus of manganese nodule from Station 276; 2350 fathoms, South Pacific. This especially represents the decomposition of olivine. The fragment belongs to a basaltic rock in which porphyritic crystals of olivine are imbedded. The fundamental mass, which is highly altered and penetrated by manganese, is filled with little crystals of plagioclase, as seen in the upper and lower parts of the figure. In the crystal of olivine occupying the centre of the figure the optical properties are almost effaced; it presents a more or less pronounced fibrous structure. The mineral is in part transformed into hematite, and manganese penetrates into all the fissures traversing the crystal in an irregular manner (magnified 37 diameters).

Fig. 3. Section of nucleus of manganese nodule from Station 293; 2025 fathoms, South Pacific. This figure represents the nucleus as seen by reflected light. The centre is composed of a black and homogeneous volcanic glass (sideromelan or tachylite), which is still unaltered. All around this are successive zones, like those of an agate, which correspond to different phases of decomposition. Those nearest the centre are colourless or tinged with yellow, succeeded by others in which the tints are brown or green, the fractures being irregular. Beyond these altered zones are successive layers of peroxide of manganese (magnified 20 diameters).

Fig. 4. Section of nucleus of manganese nodule from Station 276; 2350 fathoms, South Pacific. The fundamental mass of this fragment, which was formerly vitreous, is transformed into yellowish palagonite. In this altered mass are embedded large and small crystals of plagioclase, the larger ones having undergone but little alteration, and sections of olivine transformed into a reddish material with a fibrous structure, like the crystal represented in fig. 2. These crystals of olivine have inclusions of the vitreous base of the rock at the centre. Augite is rare in this preparation; there are some crystals of magnetite. The rock is a felspathic basalt with a vitreous base (magnified 50 diameters).

PLATE XX.

PHOSPHATIC CONCRETIONS.

Fig. 1. Section of phosphatic concretion from Green Sand, Station 142; 150 fathoms, on the Agulhas Bank, off the Cape of Good Hope. The most abundant particles are rounded greenish grains of glauconite, associated with numerous little fragments of quartz, generally angular but sometimes rounded, distinguished in the figure by colourless sections. Towards the centre a large fragment of plagioclase is seen. All these mineral fragments are enclosed in a mass of amorphous, dirty yellowish brown, phosphate of lime (magnified 37 diameters).

Fig. 2. Section of phosphatic concretion from Globigerina Ooze, Station 143; 1900 fathoms, Southern Indian Ocean. The most distinct bodies imbedded in the phosphate of lime are the shells of Globigerinidæ and Pulvinulinidæ. In the nodule represented in fig. 1 the phosphate plays simply the role of a cement for the glauconite and sandy particles; in the nodule represented in this figure the phosphate is more abundant, penetrating into all the hollow spaces of the Foraminifera, where it is present with a clearer tint than in the fundamental enveloping mass. It may be perceived infiltrating by the foramina, but generally the pseudomorphism of the calcareous shells into phosphate is not complete, the characteristic colourless appearance of the shells being preserved in many of the sections. In some of the internal casts of the shells the phosphate is brown, owing to the presence of iron or organic matters (magnified 37 diameters).

Fig. 3. Section of nodule from the same station presenting a more advanced phase of phosphatisation; almost all the carbonate of lime of the Foraminifera shells is pseudomorphosed into phosphate, which has assumed a concretionary form, and in certain points gives the black cross of spherolithic aggregates (magnified 37 diameters).

Fig. 4. Section of another nodule from Station 143. Not only is the phosphatisation here complete, but it is no longer possible to recognise the presence of the pseudomorphosed organic remains nor the internal casts of phosphate of lime. The whole field of the microscope presents a concretionary structure. The section does not extinguish uniformly between crossed nicols, but presents vague tints like concretionary minerals, and the black cross may be observed in some zones. Certain deeper coloured patches are filled with inclusions of heterogeneous particles, but on their borders a clearer zone may be observed, which follows all the contours and presents the characters of concretionary phosphate (magnified 37 diameters).

PLATE XXI.

Fig. 1. Section of nucleus of an elongated manganese nodule from Station 276; 2350 fathoms, South Pacific. This preparation offers an excellent example of the abundance and variety of volcanic products at the sea-bottom. The fragments of minerals and rocks have been enveloped by depositions of the peroxide of manganese, and form a veritable tufa composed of many species of rocks and minerals. Commencing at the top of the figure, there is a colourless crystal of plagioclase surrounded by altered vitreous matter, irregular colourless particles of volcanic glass, more or less vesicular, black and opaque fragments of volcanic rocks surrounded by a whitish zone of zeolites. Near the centre of the figure to the left is a particle of sideromelan, infiltrations of manganese, small volcanic fragments, basaltic lapilli with pores filled with zeolites and an external zeolitic zone. To the right, embedded in the manganese, is a rather large black and opaque basaltic lapilli, in part surrounded by zeolites. Beneath this there is a rather large greenish fragment of pumice, and alongside of it a fragment of sideromelan. Towards the lower part of the figure there are again lapilli and fragments of zeolites surrounding or detached from the fragments of rocks. The yellowish mass in which all the fragments are embedded is composed of muddy matters more or less coloured with iron and manganese, and the whole surrounded by concretionary layers of the peroxide of manganese (magnified 37 diameters).

Fig. 2. Section of volcanic tufa from Station 281; 2385 fathoms, South Pacific, the macroscopic appearance of which is represented on Pl. IV. fig. 3. The figure shows two parts sharply marked off from each other: that to the right a more or less homogeneous Red Clay, that to the left formed of an agglomeration of volcanic mineral particles representing a shower of volcanic ashes that had fallen upon the deposit. The whole has been surrounded by depositions of manganese, which have preserved the layers in their primitive position (see Pl. IV. fig. 3). In the Red Clay, near the lower part of the figure, a small manganese nodule is represented with a reddish centre; the brown colour of the Red Clay passes in the layer of volcanic minerals to a greenish colour, due to the presence of numerous individuals of augite and hornblende. All these minerals are clastic, have a sharp fracture, and give the impression that they belong to a volcanic ash. The largest and most numerous are fragments of hornblende with a brown or greenish colour, and about 0·5 mm. in diameter; augite is much less abundant, and the crystals are less deeply coloured. Felspars, especially fragments of plagioclase, can be observed, but they are generally altered and decomposed into a zeolitic substance. Finally, there are some little fragments of volcanic rocks, in which the principal elements are microliths of augite, as well as fragments of magnetite, vitreous basaltic lapilli, and peroxide of manganese (magnified 37 diameters).

PLATE XXII.

Fig. 1. Fine washings of a Red Clay from Station 276; 2350 fathoms, South Pacific. The little, colourless, prismatic crystals are simple or grouped microliths of phillipsite, and are associated with more or less circular grains of manganese and argillaceous substance (magnified 280 diameters).

Fig. 2. Section of a spherule formed by crystals of phillipsite from Station 276; 2350 fathoms, South Pacific. The spherule is entirely enveloped by the clay and penetrated by manganese. The section shows the form of the crystals towards the periphery of the spherule, more or less inclined to the longer axis. These spherules are about 0·1 mm. in diameter (magnified 60 diameters).

Fig. 3. Section of a spherule of crystals of phillipsite forming the nucleus of a manganese nodule from Station 276; 2350 fathoms, South Pacific. The section passes through the centre of the spherule, which is about 0·1 mm. in diameter. It seems to be formed by a more or less regular grouping of the little crystals following approximately the radii of a circle, and they increase in size as they approach the periphery. In several crystals the zones of increase are indicated by lines of inclusions, and in others these zones are shown to be grouped concentrically. The crystals of phillipsite forming the spherule are surrounded by a thin layer of manganese, beyond which is a muddy deposit, containing particles of volcanic minerals and manganese (magnified 60 diameters).

Fig. 4. Crystals of phillipsite of considerable size found free in the clay at Station 276; 2350 fathoms, South Pacific. They are generally grouped in an irregular manner, or show a tendency to form twins. They are covered with manganese depositions or form the centres of little concretions of that substance (magnified 37 diameters).

PLATE XXIII.

Fig. 1. Magnetic spherule of cosmic origin from Station 285; 2375 fathoms, South Pacific. This spherule was extracted from a manganese nodule, and has a coating of black magnetic iron, with a brilliant and shagreened surface (magnified 90 diameters).

Fig. 2. Magnetic spherule from Station 276; 2350 fathoms, South Pacific. It is regular in form, but has not a central nucleus. The figure shows a broken surface, which is blue-black, with a dull aspect. The structure presents many somewhat regular cleavages. Although presenting some of the characters of chondres of bronzite, somewhat like that shown in fig. 11, the origin of this spherule must be regarded as doubtful (magnified 90 diameters).

Fig. 3. Spherule composed of crystals of phillipsite from Station 276; 2350 fathoms, South Pacific. The crystals are terminated by the faces of domes or pyramids. This shows the external aspect of the spherules seen in section in Plate XXII. figs. 2 and 3 (magnified 90 diameters).

Fig. 4. Cosmic magnetic spherule from Station 285; 2375 fathoms, South Pacific. The external aspect of this spherule is similar to that shown in fig. 1, but the figure exhibits the characteristic cupule present in nearly all these cosmic spherules (magnified 90 diameters).

Fig. 5. Cosmic magnetic spherule from interior of nodule from Station 276; 2350 fathoms, South Pacific. A part of the external layer has been removed to show the grey metallic nucleus of native iron (magnified 90 diameters).

Fig. 6. Cosmic magnetic spherule from Station 276; 2350 fathoms, South Pacific, embedded in a mass of little crystals of zeolites (magnified 90 diameters).

Fig. 7. Metallic nucleus of a cosmic spherule from the same station. This nucleus has a grey metallic lustre; it has taken a discoidal form under pressure in an agate mortar. When placed in an acid solution of sulphate of copper, no copper was precipitated, and it is probably an alloy of iron, nickel, and cobalt (magnified 90 diameters).

Fig. 8. Cosmic spherule from Station 285; 2375 fathoms, South Pacific, a portion of the crust having been removed to show the metallic nucleus (magnified 90 diameters).

Fig. 9. Metallic nucleus of cosmic spherule from Station 276; 2350 fathoms, South Pacific. The black coating has been removed, and the particle has assumed a discoidal appearance under pressure in an agate mortar. When placed in an acid solution of sulphate of copper, the copper was at once precipitated over the whole surface, which indicates that the nucleus was composed of native iron (magnified 90 diameters).

Fig. 10. (*See* fig. 13.)

Fig. 11. Chondre from Globigerina Ooze, Station 338; 1990 fathoms, South Atlantic. This chondre is about 1 mm. in diameter. In reflected light under the microscope it has a bronze metalloid reflection. It is formed by the juxtaposition of a great number of lamellæ, which start from an excentric point, where there is a depression in the form of a cupule. The characters are quite analogous to those of chondres of meteorites (magnified 37 diameters).

Figs. 13 and 10. Microstructure of one of the lamellæ of the chondre represented in fig. 11. These are formed of an accumulation of little colourless prisms, about 0·05 mm. in diameter. The prisms follow two directions, cutting each other at an angle of 70°. The lamellæ have many dark-coloured inclusions in the form of crystallites, which are probably magnetite, arranged regularly following the direction of the little prisms (magnified 390 diameters).

Fig. 12. Appearance of the magnetic particles extracted from Radiolarian Ooze, Station 274; 2750 fathoms, Mid Pacific, after being broken down in an agate mortar, and treated with an acid solution of sulphate of copper. The black particles are fragments of magnetite and coatings of the cosmic spherules, while those on which copper has been deposited are malleable particles of native iron (magnified 37 diameters).

PLATE XXIV.

This Plate is intended to represent as nearly as possible the appearance of the casts which are formed in and on the Foraminiferous shells and other calcareous organisms in different varieties of marine deposits.

Fig. 1. Glauconitic particles that remain after the removal of the carbonate of lime from a deposit on the Agulhas Bank, off the Cape of Good Hope (magnified 35 diameters). The grains have an average diameter of about 1 millimetre, and are isolated or agglomerated into nodules. They are often mammillated, and always more or less rounded; some are hard and black or dark green, others softer and pale green or yellow. The surface of the grains is often shining. The casts of Foraminifera, and other organisms, are pale green or brown, rarely dark green, although many of the dark green grains appear to have the form of the Foraminifera rudely displayed. Station 142; 150 fathoms. Southern Ocean.

Fig. 2. Similar deposit from off the coast of Australia (magnified 35 diameters). On the removal of the carbonate of lime there is seen to be a very much larger number of casts of the calcareous organisms than in the Agulhas Bank formation. The chambers of the shells are filled, or partially filled, with red, yellow, brown, and pale green casts in various stages of consolidation. Where these casts are not opaque they give aggregate polarisation. Besides the casts, there are many grains in the deposit, similar to those described by mineralogists under the name of glauconite, which in many cases show roughly the form of the Foraminifera. Station 164B; 410 fathoms. South Pacific.

Fig. 3. Casts obtained by removing the carbonate of lime from a large quantity of Coral Sand from off the Great Barrier Reef of Australia (magnified 25 diameters). They are all of a brick-red colour; one or two had a greenish tinge, but there was no true glauconite. These casts have a porous aspect, arising from the presence in the cast of carbonate of lime, which has been dissolved by the action of the acid. The red substance of these casts gives aggregate polarisation. Station 185B; 155 fathoms. Torres Strait.

Fig. 4. Red casts of Foraminifera from the South Pacific (magnified 25 diameters). This is one of the few instances in which numerous perfect casts of these organisms have been found in a deep-sea deposit far from land. There is frequently an external as well as an internal cast, and the two are united by numerous little pillars which had occupied the foramina of the shells. There is no glauconite in the deposit. When the colour is discharged by concentrated hydrochloric acid, colourless globules of the original forms remain, showing that we are not here dealing with an infiltration of fine mud or clay, but with a chemical combination that has taken place in the interior and on the external surface of the shells. Station 176; 1450 fathoms. South Pacific.

PLATE XXV.

Illustrates various phases assumed by glauconite in existing oceans.

Fig. 1. Glauconitic casts and particles from off the coast of Australia, as seen between crossed nicols, showing aggregate polarisation. Little green and blue points form a very fine mosaic on a brownish-coloured ground. Station 164B; 410 fathoms. South Pacific (magnified 50 diameters).

Fig. 2. Glauconite-like particle of a brown-green colour. The mammillated surface is quite like a typical glauconitic grain, but this particular grain appears to be an altered rock fragment.

Fig. 3. Particle of a lighter colour than the preceding, but having apparently a similar origin.

Fig. 4. Specimen of *Globigerina bulloides* filled with a glauconitic cast.

Fig. 5. Specimen of *Truncatulina refulgens* filled with glauconitic cast.

Fig. 6. Specimen of *Miliolina seminulum* filled with cast.

Fig. 7. Specimen of *Uvigerina pygmæa* filled with cast.

Figs. 8 and 9. Casts of *Orbulina universa.*

Fig. 10. Cast of *Anomalina coronata.*

Fig. 11. Cast probably formed in the interior of *Orbulina universa.*

Fig. 12. Specimen of *Globigerina pachyderma* filled with cast.

Fig. 13. Cast of *Polystomella arctica.*

Fig. 14. Cast of *Anomalina coronata.*

PLATE XXVI.

Fig. 1. Mineral particles in the residue of a Globigerina Ooze. Station 300; 1375 fathoms, South Pacific. These are essentially of a volcanic nature: in addition to fragments of pumice, easily recognised by their structure and the absence of colour, there are homogeneous red-brown particles, vitreous fragments altered into palagonite, and also fragments of felspars, augite, and grains of magnetite (magnified 90 diameters).

Fig. 2. Mineral particles of a Red Clay. Station 282; 2450 fathoms, South Pacific. All the particles are of volcanic origin. Fragments of felspar may be recognised by the homogeneity and regular fracture. There are numerous fragments of pumice. The brown grains are particles of palagonite or other mineral particles coated with deposits of manganese and iron (magnified 175 diameters).

Fig. 3. Mineral particles from a Red Clay. Station 165A; 2600 fathoms, South Pacific. In addition to fragments of pumice, splinters of felspar, and little green prisms of augite, which are the usual minerals in a Red Clay, there are represented in the figure many rounded granules of quartz, for the most part covered with limonite. The mineralogical nature and form of these granules show that they are not a normal element in the Red Clay deposit; they are believed to be particles borne by atmospheric currents from the Australian continent (magnified 175 diameters).

Fig. 4. Mineral particles from a Globigerina Ooze. Station 303; 1325 fathoms, South Pacific. This figure shows abundance of glassy volcanic particles, belonging for the most part to the acid and filamentous variety of pumice, although there are also fragments of the basic variety with rounded pores and of a yellow or red-brown colour (magnified 175 diameters).

Fig. 5. Mineral particles of a Beach Sand from Diamond Point, Honolulu, Sandwich Islands. These are almost exclusively formed of unaltered crystals of olivine, along with some vitreous particles. Similar particles are widely distributed in the Coral Muds and Sands of the neighbouring coasts (magnified 37 diameters).

Fig. 6. Mineral particles of a Beach Sand from the Admiralty Islands. Among these may be recognised large colourless fragments of felspar (plagioclase), prismatic green fragments, more or less irregular, of augite, brown fragments of hornblende, dirty brown basaltic lapilli, fragments of palagonite, olivine, magnetite, and particles of volcanic glass (magnified 37 diameters).

PLATE XXVII.

Fig. 1. Microscopic mineral particles from a Volcanic Mud. Station 262; 2875 fathoms, North Pacific. The particles are principally brown splinters of volcanic glass, showing in typical form the irregular outlines and conchoidal fracture, as well as the elongated fibrous structure of some varieties of pumice (magnified 175 diameters).

Fig. 2. Mineral particles and fine washings of a Red Clay. Station 178; 2650 fathoms, South Pacific. The little colourless angular particles scattered over the figure are microscopic splinters of volcanic glass, or of minerals from eruptive rocks. Among these are vitreous fragments of a larger size as well as crystalline particles. The red-brown particles are palagonite. There are felspars and green particles of augite (magnified 175 diameters).

Fig. 3. Mineral particles of a Red Clay. Station 240; 2900 fathoms, North Pacific. These are essentially volcanic products. Among them may be recognised numerous fragments of pumice and other glassy volcanic particles, plagioclase, and palagonitic grains of a red colour (magnified 175 diameters).

Fig. 4. Mineral particles of a Red Clay. Station 294; 2270 fathoms, South Pacific. As in the preceding figure, these are almost wholly composed of volcanic products, in which pumice fragments are the most abundant; there are also felspar, plagioclase, green fragments of augite, red palagonitic particles, and small crystals of quartz. The last are hexagonal prisms terminated by two pyramids; two individuals at the top of the figure are united together with their vertical axes parallel. The brown-black particles are peroxide of manganese (magnified 175 diameters).

Fig. 5. Fine washings of a Radiolarian Ooze. Station 225; 4475 fathoms, Western Pacific. This figure represents the exceedingly fine grains or flocculent matter, mixed with particles of volcanic glass, felspars, palagonitic and manganese grains, together with minute fragments of Radiolarians and other siliceous organisms (magnified 175 diameters).

Fig. 6. Mineral particles of a Green Mud. Station 189; 28 fathoms, Arafura Sea. This figure shows the difference in a mineralogical composition and in the dimensions and form of the grains in a terrigenous deposit compared with pelagic deposits, which are represented in the five preceding figures on this plate. Rounded fragments of quartz, sometimes covered with a reddish deposit of limonite, are the most numerous. Some colourless particles terminated by cleavages are felspar; the rounded green grains are glauconite. There are also crystals of tourmaline and zircon (magnified 37 diameters).

PLATE XXVIII.

Fig. 1. Section of manganese nodule from Station 160; 2600 fathoms, Southern Indian Ocean. This microscopic preparation shows, besides the zonary arrangement, a dendritic structure of the manganese. These dendrites are arranged along the radii of the nodule, and the manganese is, as it were, imbedded in a yellowish brown mass of clayey and earthy matters (magnified 37 diameters).

Fig. 2. Section of manganese nodule from Station 160; 2600 fathoms, Southern Indian Ocean. Around the indefinite white-coloured nucleus there is a concretionary arrangement of the manganese in the form of dendrites; the radiate structure is not, however, well marked. The large ovoid body occupying most of the figure was probably the primary form of the original nucleus (magnified 37 diameters).

Fig. 3. Section of manganese nodule from Station 285; 2375 fathoms, South Pacific. This figure shows a nodule with several concretionary centres, consisting of organic particles or fragments of palagonite or other volcanic rocks. The depositions which had commenced around these several centres ultimately became united into a single nodule by the formation of successive layers of manganese (magnified 37 diameters).

Fig. 4. Section of manganese nodule from Station 160; 2600 fathoms, Southern Indian Ocean. This figure shows the dendritic and zonary arrangement of the manganese (magnified 37 diameters).

Fig. 5. Section of manganese nodule from the same station, showing a dendritic arrangement of the manganese, in which the radiate structure is not well marked, but presenting zones in which the colouring matter has accumulated (magnified 37 diameters).

PLATE XXIX.

Fig. 1. Section of manganese nodule from Station 285; 2375 fathoms, South Pacific. It shows a zonary arrangement of the concretion around a fragment of a shark's tooth. The alternate zones consist of lighter and darker layers, the manganese being accumulated in the dark, and the clayey matters more abundant in the light, bands (magnified 37 diameters).

Fig. 2. Section of manganese nodule from the same station. This concretion contains several nuclei. Near the upper part of the figure there is a section of a shark's tooth, and portions of other teeth may be seen in different parts of the figure. Near the lower part there is a volcanic lapilli, containing green augite and plagioclase. Around each of these centres the manganese has been deposited in a concentric manner, and during the growth of the nodule the numerous other particles have been enveloped by the manganese (magnified 37 diameters).

Fig. 3. Section of manganese nodule from the same station. This preparation shows the arrangement of the manganese under a higher power, the manganese being more abundant in the dark patches, while the lighter colour represents the spaces for the most part made up of clayey and earthy matters (magnified 145 diameters).

Fig. 4. Section of manganese nodule from the same station. This figure shows the zonary arrangement of the manganese around two principal centres, and their subsequent envelopment in one nodule by the continuous deposition of layers of manganese, which have enclosed at the same time the clayey matters with their fragments of minerals and organisms (magnified 37 diameters).

Geo. West, Lith. ad Nat.

W. & A.K. Johnston, Lithographers.

FRAGMENTS OF PUMICE AND MANGANESE-IRON NODULES.

Geo West, Lith. ad Nat.

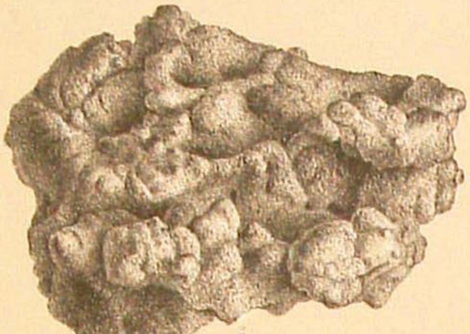
W. & A.K. Johnston, Lithographers.

MANGANESE-IRON NODULES.

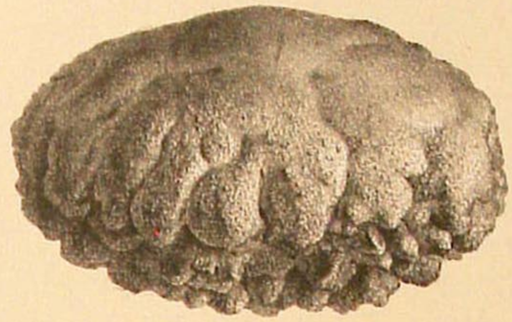
Geo. West, Lith. ad Nat.

W. & A.K. Johnston, Lithographers.

MANGANESE-IRON NODULES.

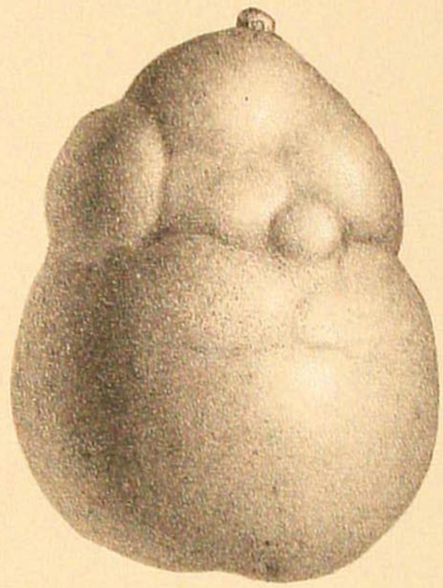


6

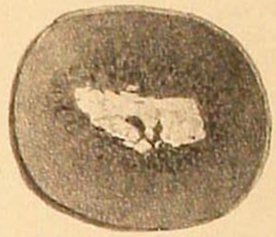


2

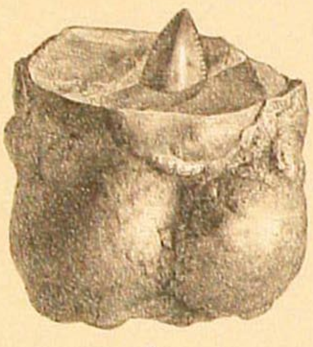
4



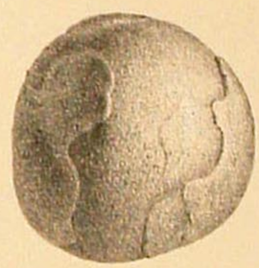
1



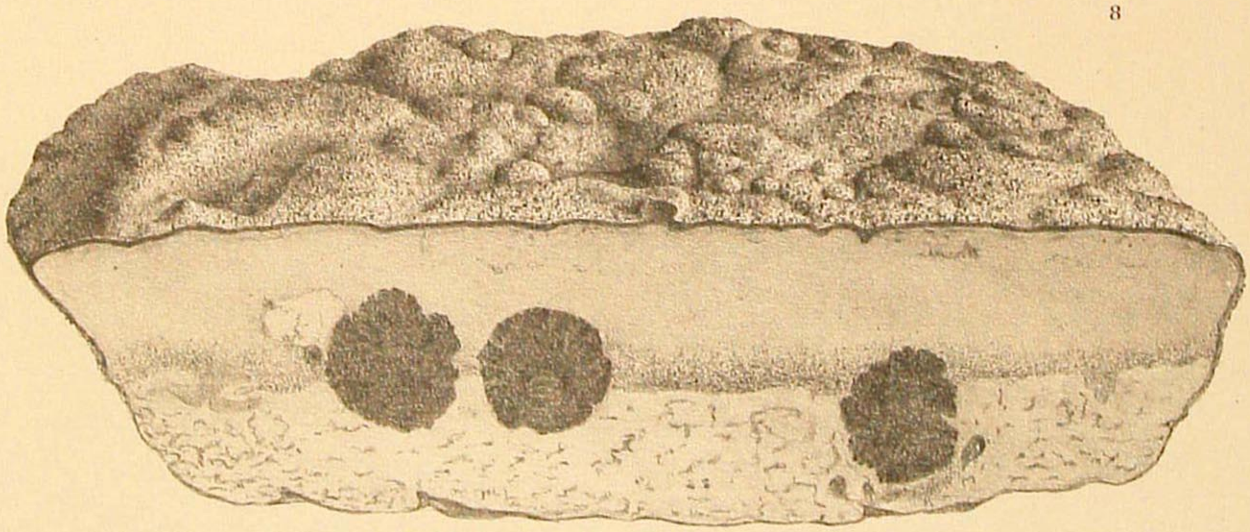
7



5



8

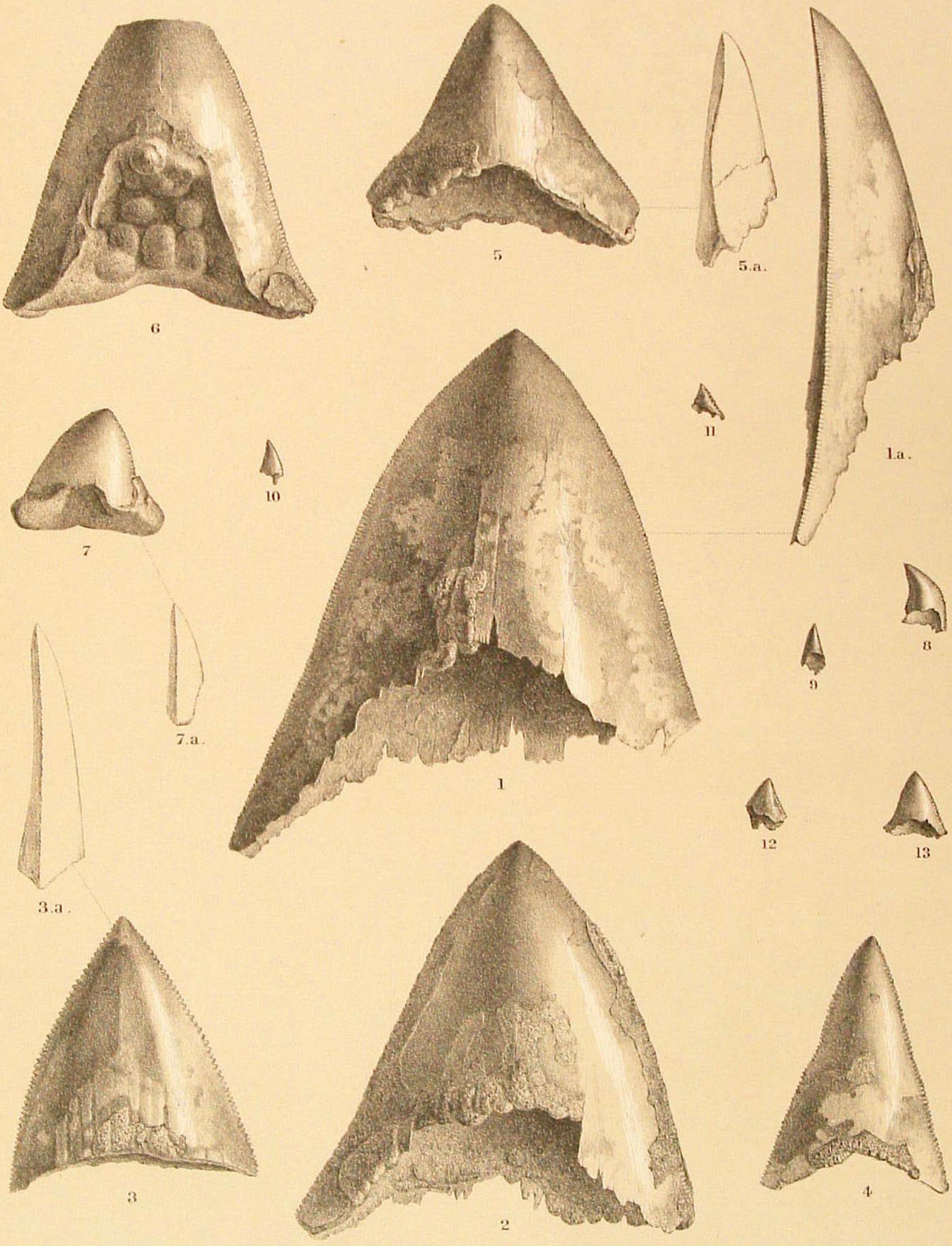


3

Geo West, Lith ad Nat.

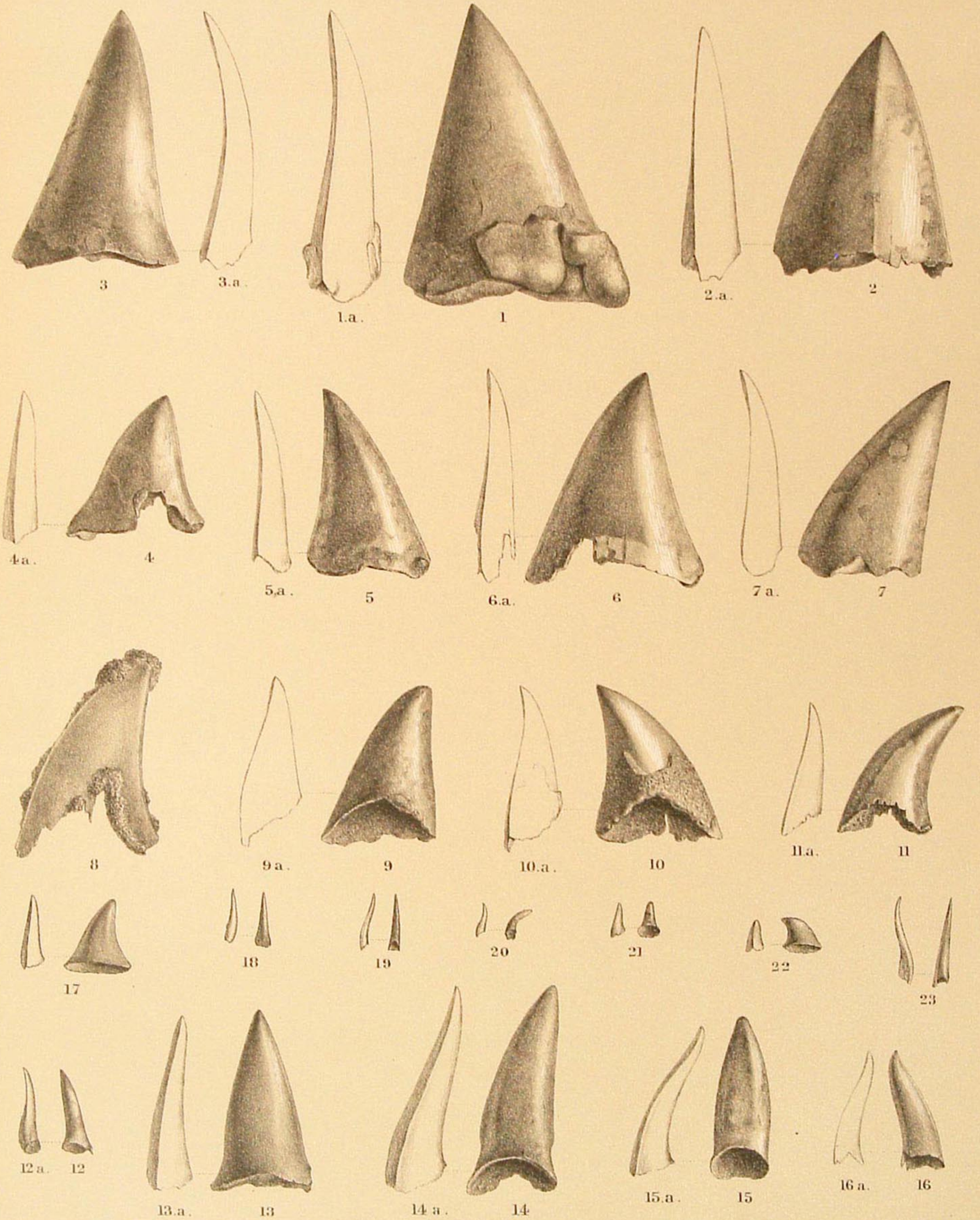
W & A K Johnston, Lithographers

MANGANESE-IRON NODULES.



Geo. West, Lith. ad Nat.
W & A.K. Johnston, Lithographers.

SHARK'S TEETH.
(Carcharodon, Carcharias, &c.)



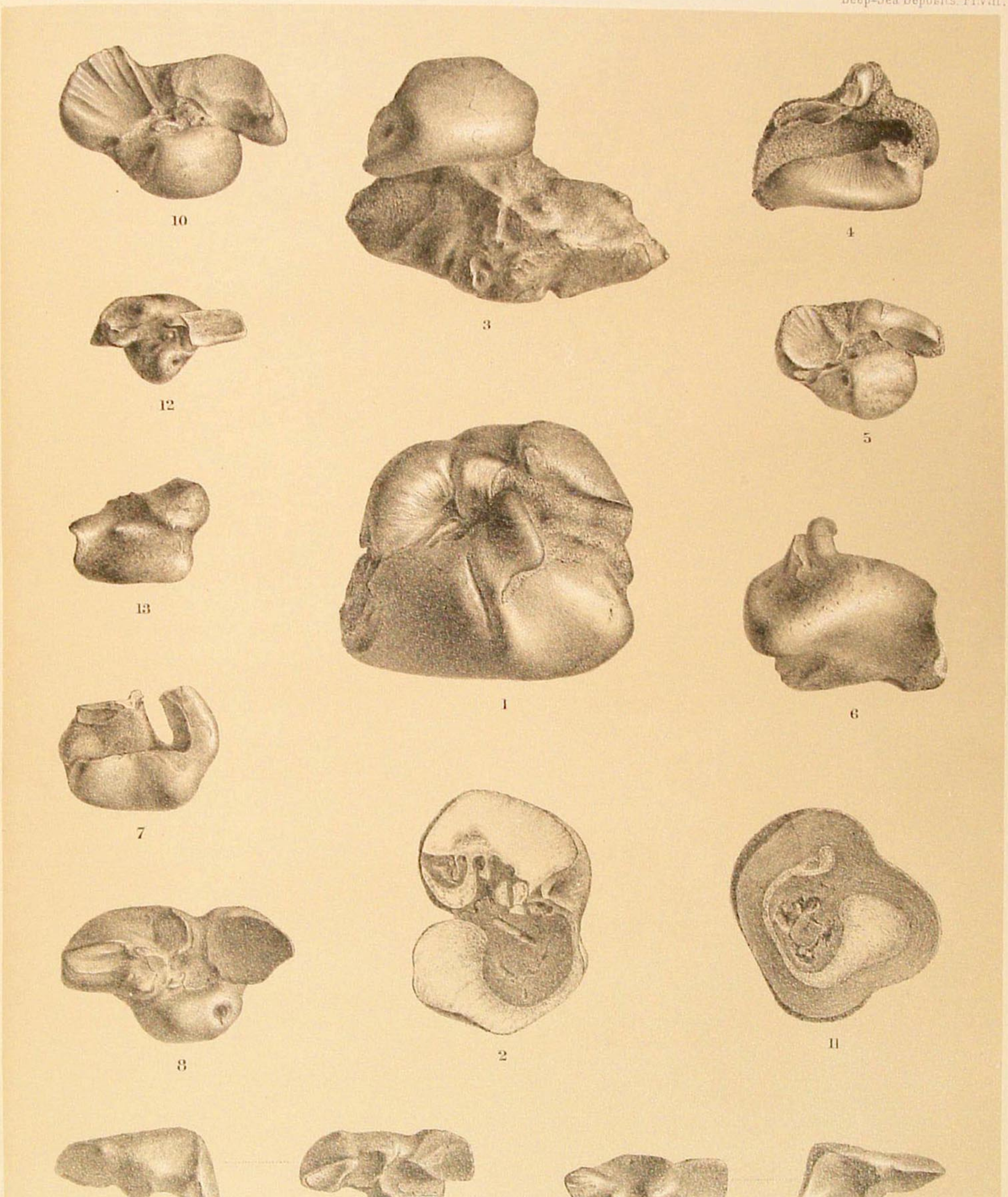
Geo. West, Lith. ad Nat.

W. & A.K. Johnston, Lithographers

SHARK'S TEETH.
(Oxyrhina. Lamna, &c.)

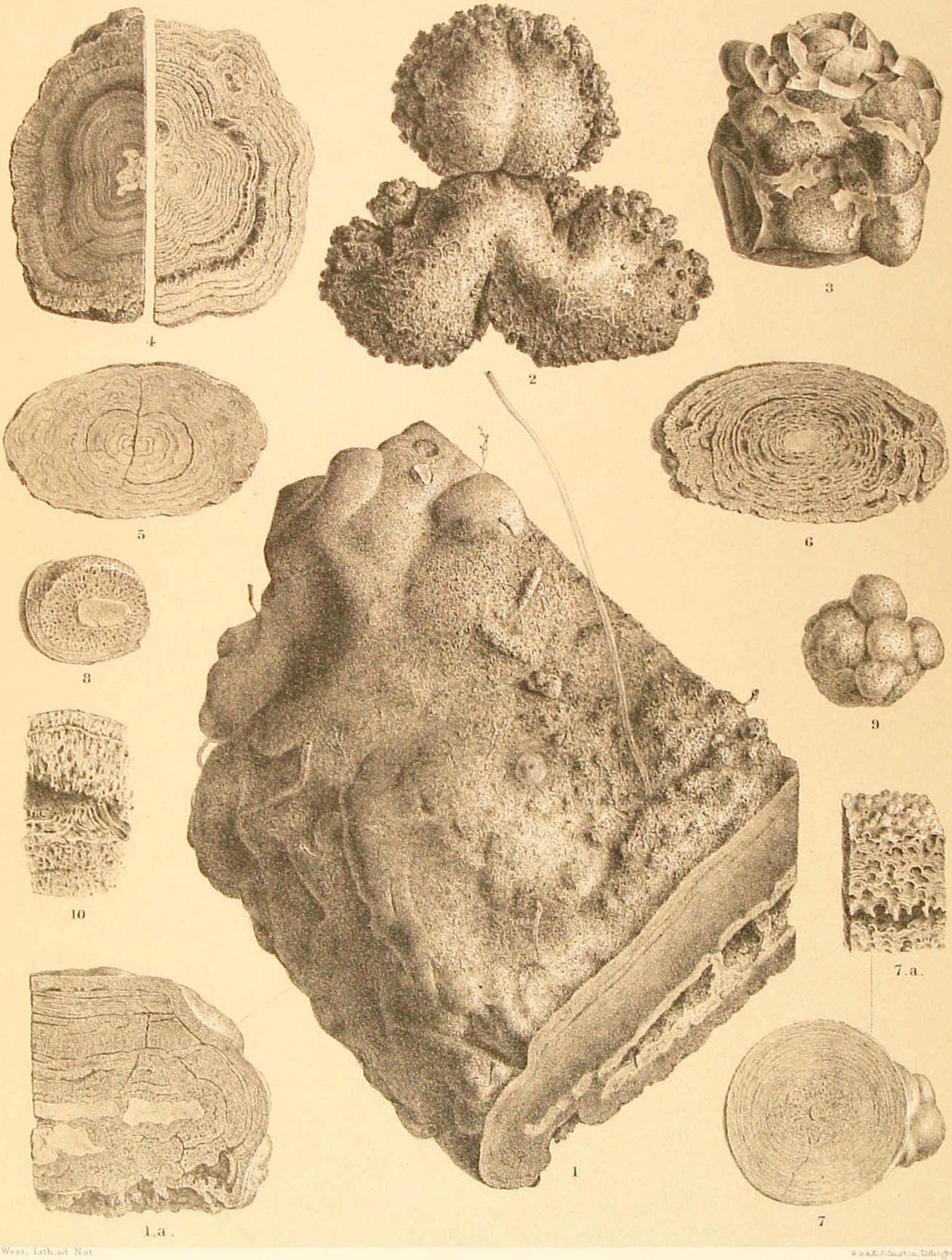
Geo. West, Lith. ad Nat. W. & A.K. Johnston, Lithographers.

EAR BONES OF CETACEA.
(Balænoptera. Balæna. Mesoplodon. &c)



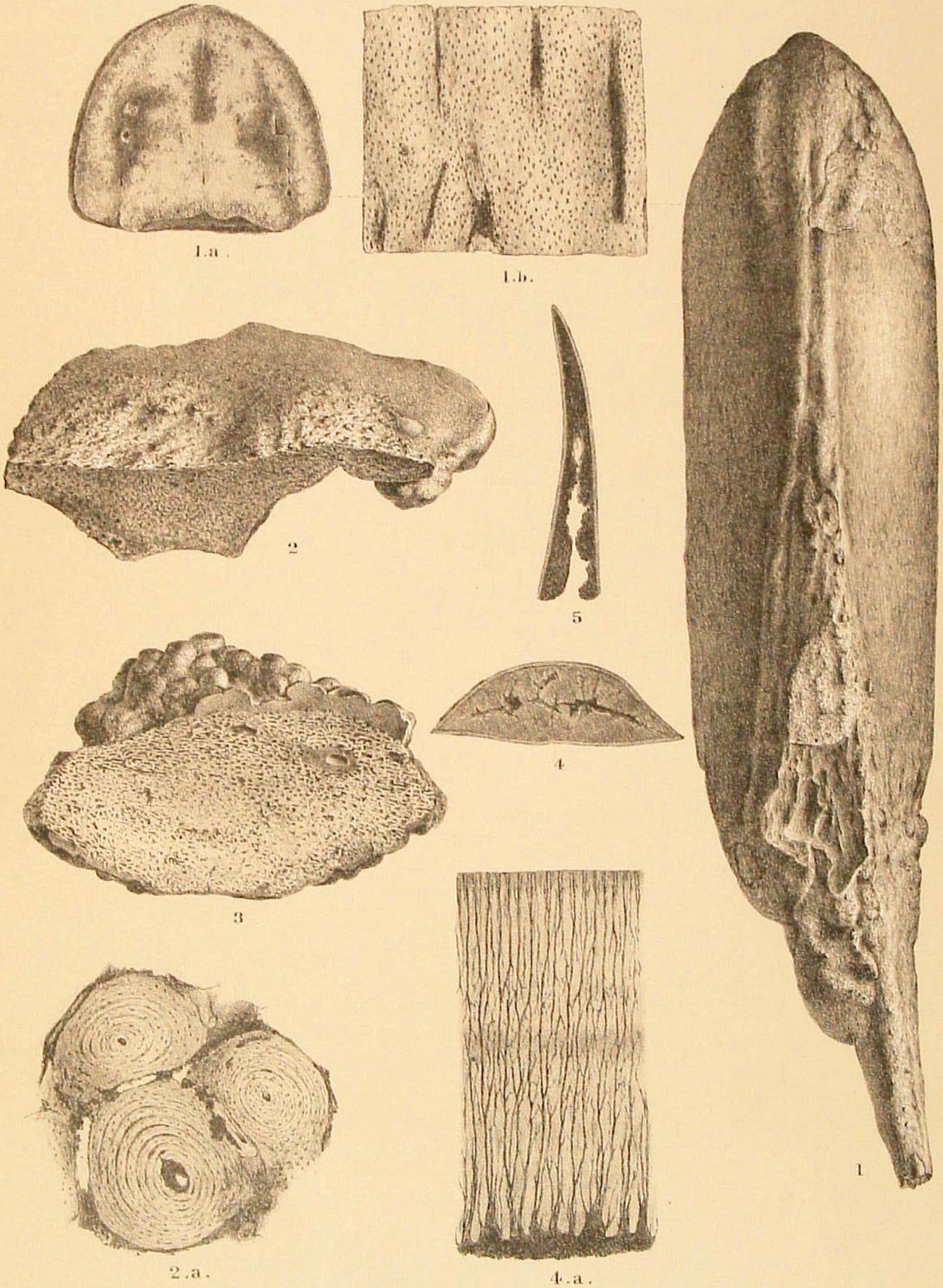
Geo. West, Lith. ad Nat.

EAR BONES OF CETACEA.
(Ziphius. Megaptera. Delphinus. &c)



Geo West, Lith. ad Nat. W. & A.K. Johnston, Lithographers.

MANGANESE-IRON NODULES.



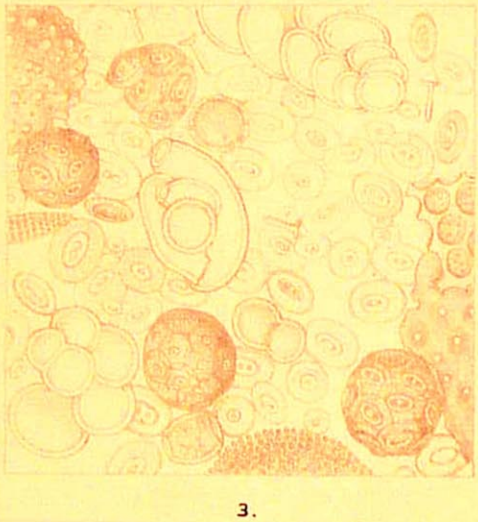
Geo West, Lith. ad Nat.

W & A.K. Johnston, Lithographers.

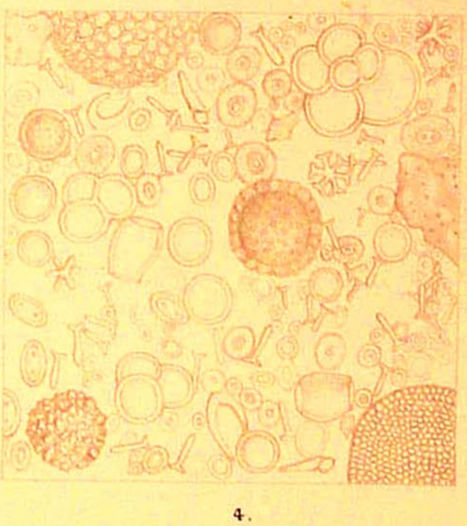
ZIPHIUS' BEAK. STRUCTURE OF BONE AND TEETH.

1.

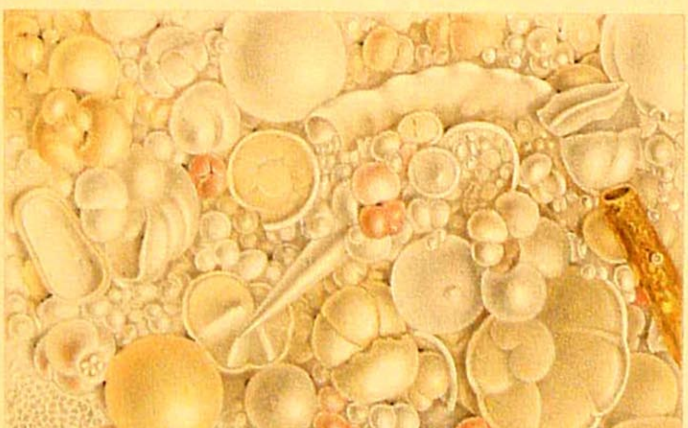
2.



3.



4.



5.

6.

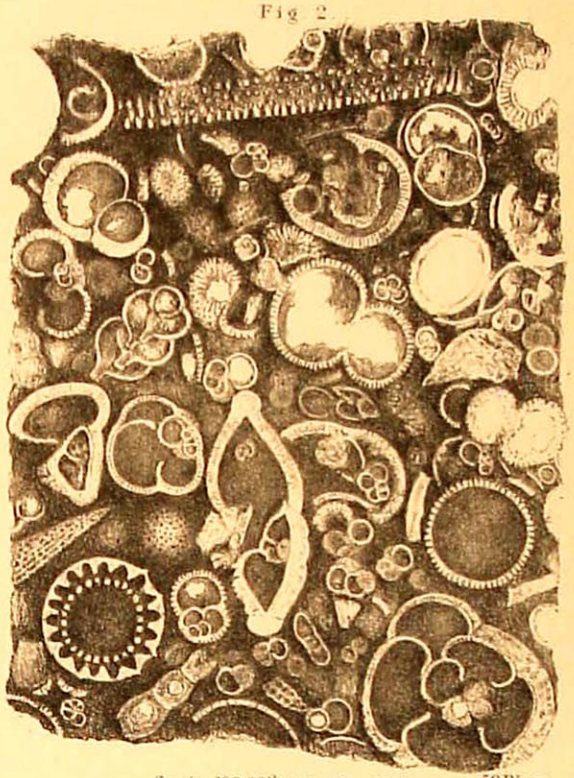
F. Huth, Lith^r Edin^r

Fig. 1.

50 Diam.

Station 338. 21st March 1876.
Lat. 21° 15' S. Long. 14° 2' W.
1990 Fathoms.

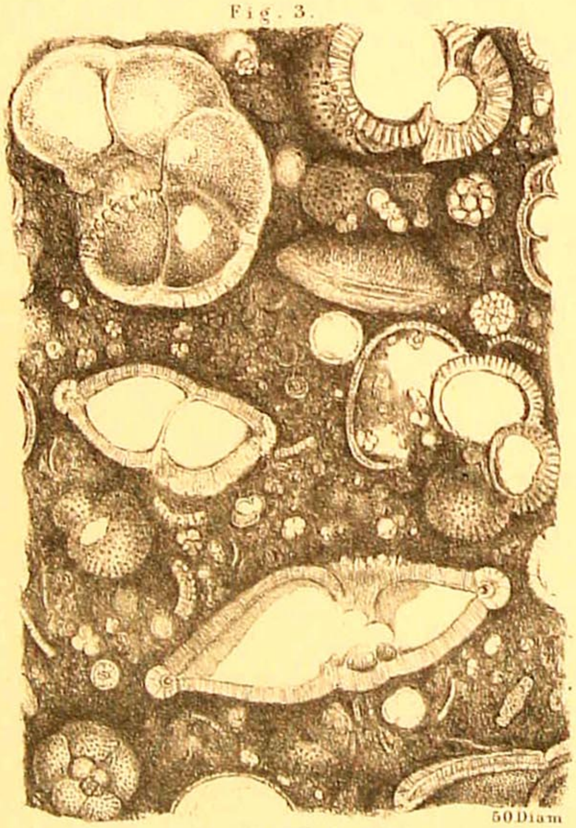
Fig. 2.



50 Diam.

Station 192. 26th September 1874.
Off Ki Islands. Lat. 5° 42' S. Long 132° 25' E.
129 Fathoms.

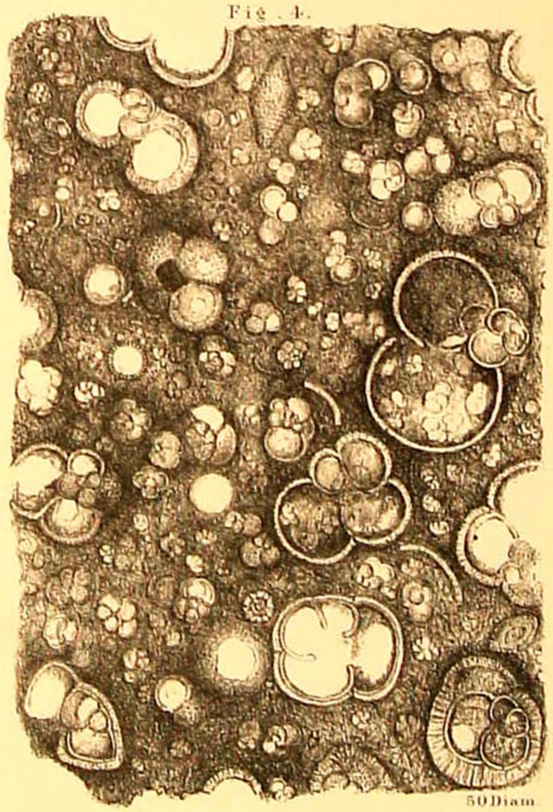
Fig. 3.



50 Diam.

Station 348. 9th April 1876.
Lat. 3° 10' N. Long 14° 51' W.
2450 Fathoms.

Fig. 4.



50 Diam.

Station 158. 7th March 1874.
Lat. 50° 1' S. Long 123° 4' E.
1800 Fathoms.

Geo. West, Lith. ad Nat.

CALCAREOUS DEPOSITS.

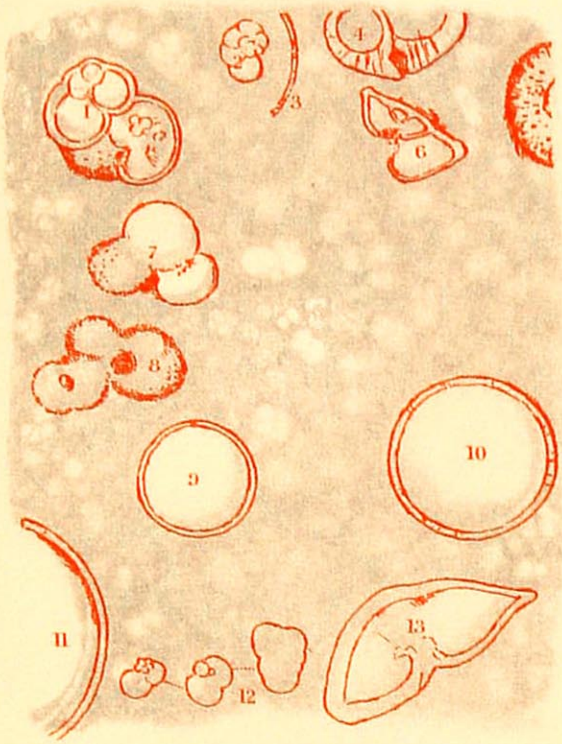
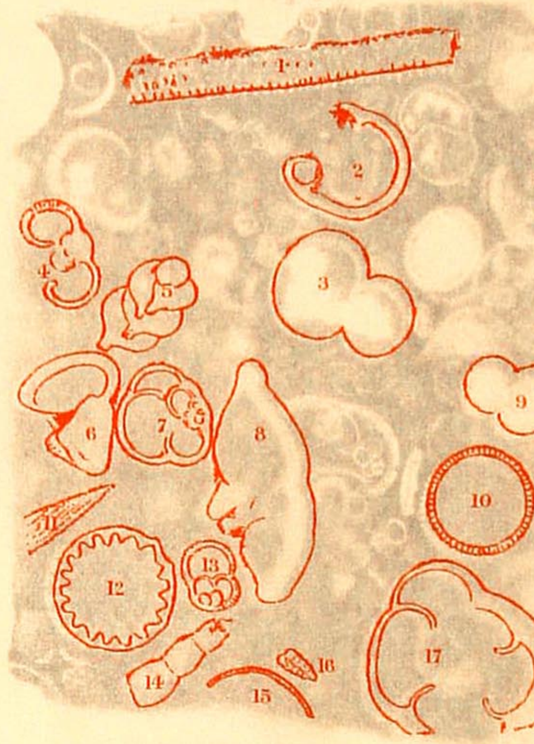
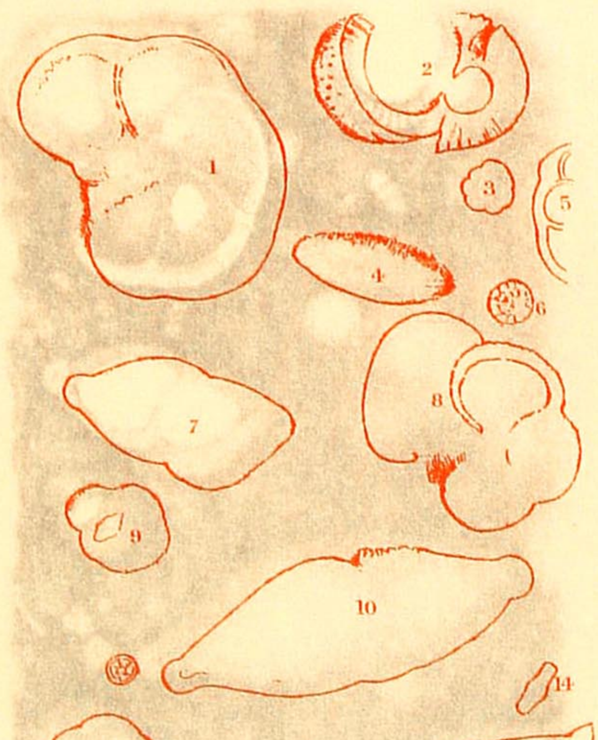
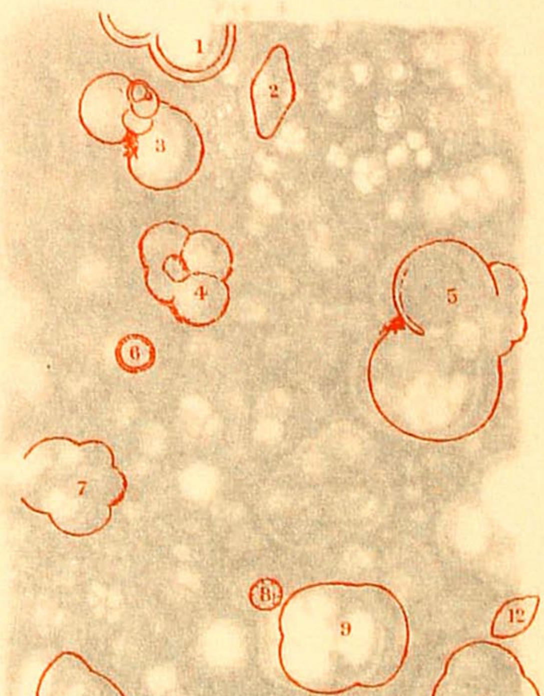


Fig. 2







Station 158, 7th March 1874.
Lat. 50° 1' S. Long. 123° 4' E.
1800 Fathoms.

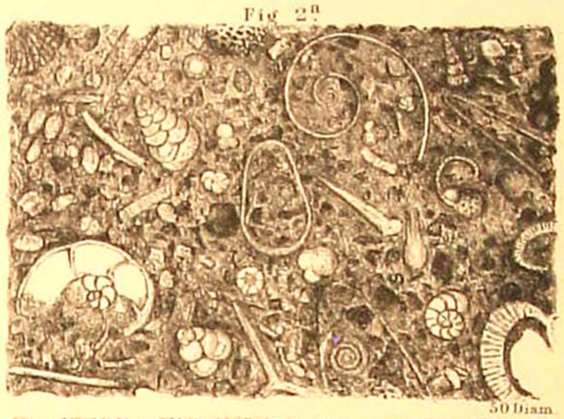
CALCAREOUS DEPOSITS

Fig 1.

15 Diam.

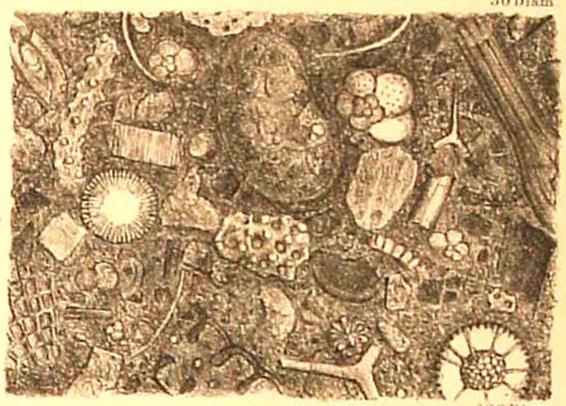
17th April 1873.
South of Bermuda.
200 Fathoms.

Fig 2a.



50 Diam.

Fig 2b.



100 Diam.

Station 32b. 3rd April 1873.
Off Bermuda. Lat. 32° 10' N. Long. 64° 52' W.
950 Fathoms.

Fig 3.

50 Diam.

Station 35c. 22nd April. 1873.
Off Bermuda. Lat. 32° 15' N. Long. 65° 8' W.
1950 Fathoms.

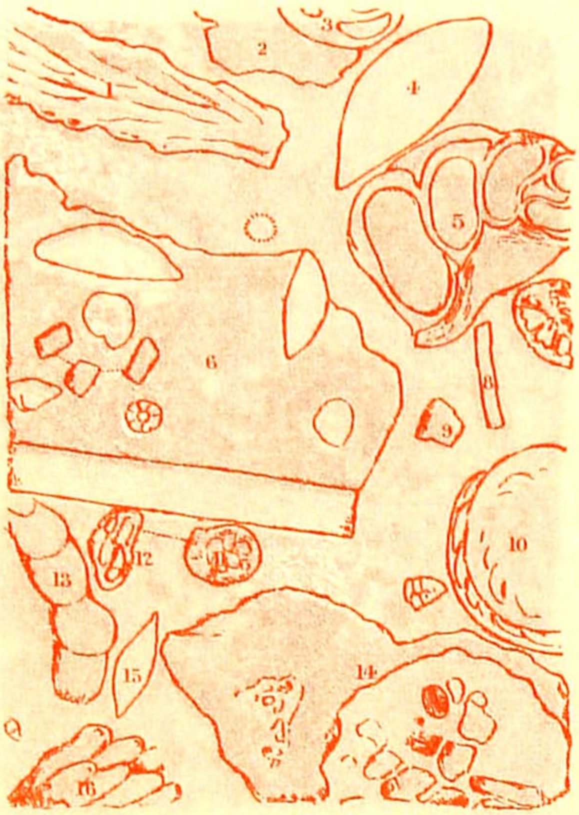
Fig. 4.

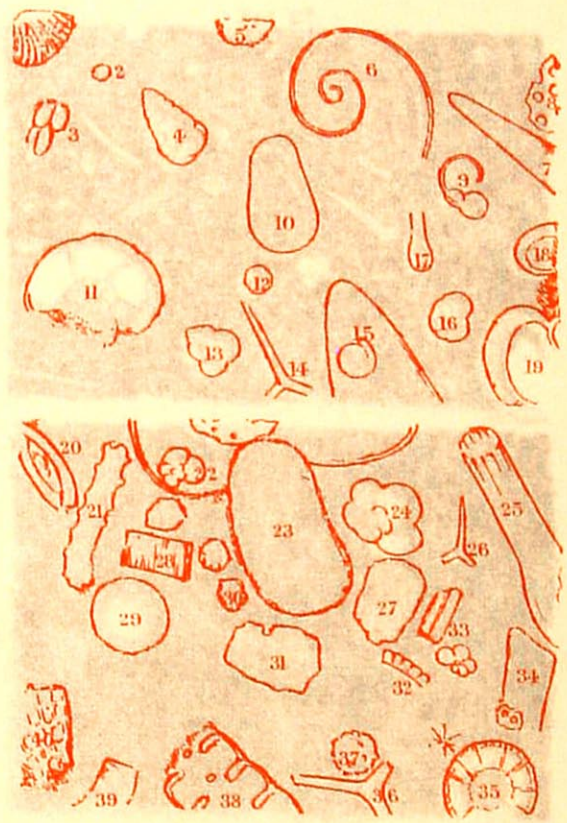
50 Diam.

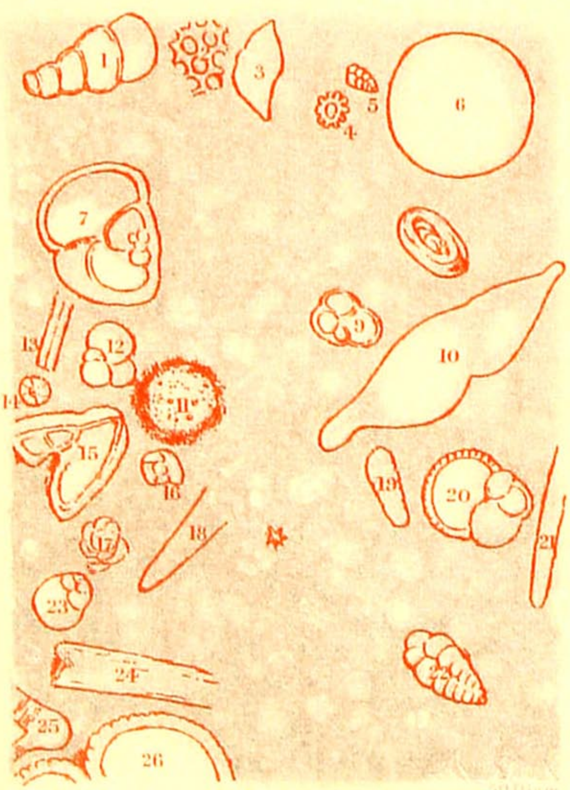
Station 32d. 4th April. 1873.
Off Bermuda. Lat. 32° 19' N. Long. 64° 40' W.
380 Fathoms.

Geo. West, Lith. ad Nat. W. & A.K. Johnston, Lithographers.

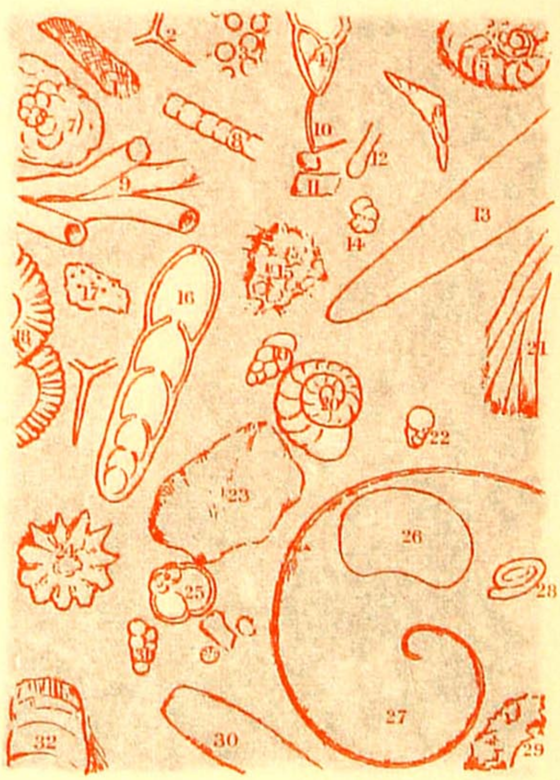
CALCAREOUS DEPOSITS.







500 Diam.



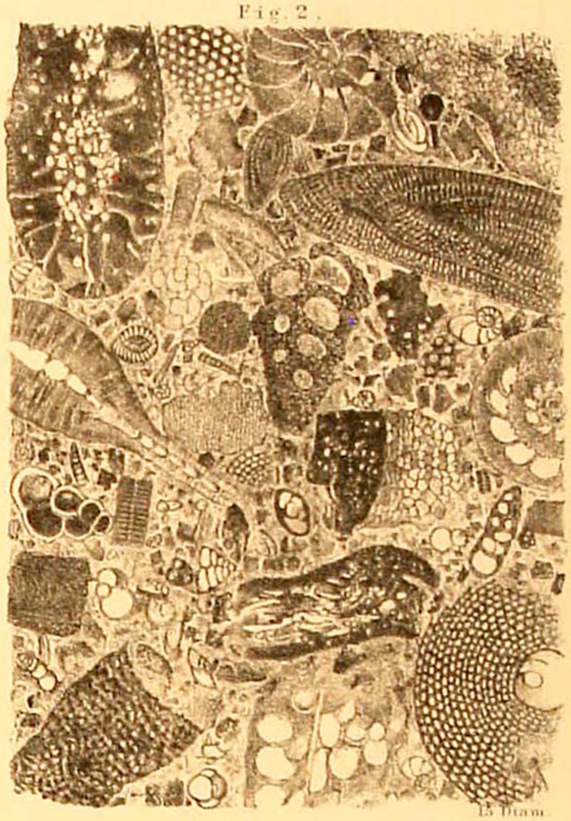
CALCAREOUS DEPOSITS

Fig. 1.

50 Diam.

Station 172a. 22nd July 1874.
Outside Reefs, Tongatabou Lat. 20° 56' S. Long. 175° 11' W.
240 Fathoms.

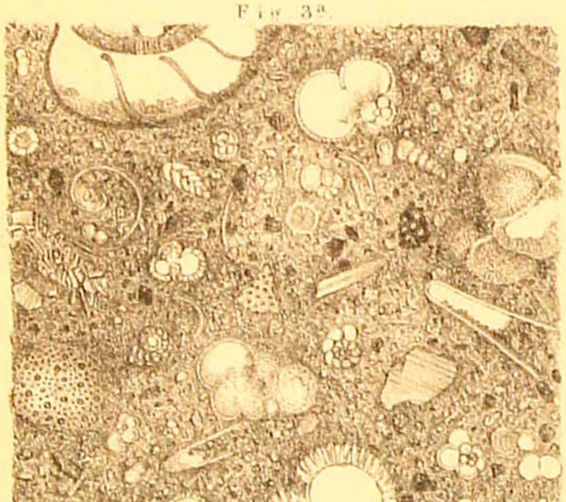
Fig. 2.



15 Diam.

Station 172. 22nd July 1874.
Inside Reefs, Tongatabou Lat. 20° 58' S. Long. 175° 9' W.
18 Fathoms.

Fig. 3a.



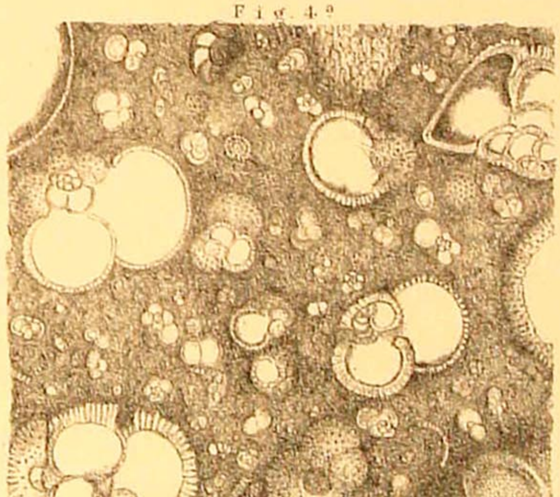
50 Diam.

Fig 3b

200 Diam.

Station 174c. 3rd August 1874.
Outside Reefs, Off Kandavu Fiji. Lat. 19° 7' 50" S. Long. 178° 19' 35" E.
610 Fathoms.

Fig. 4a.



50 Diam.

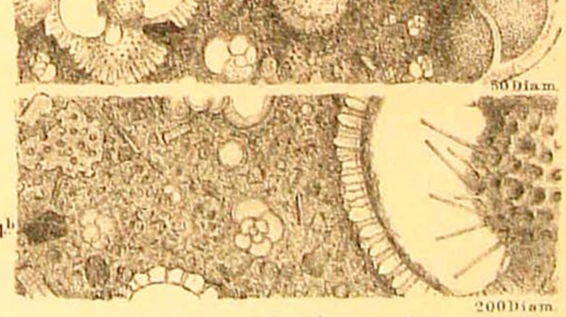


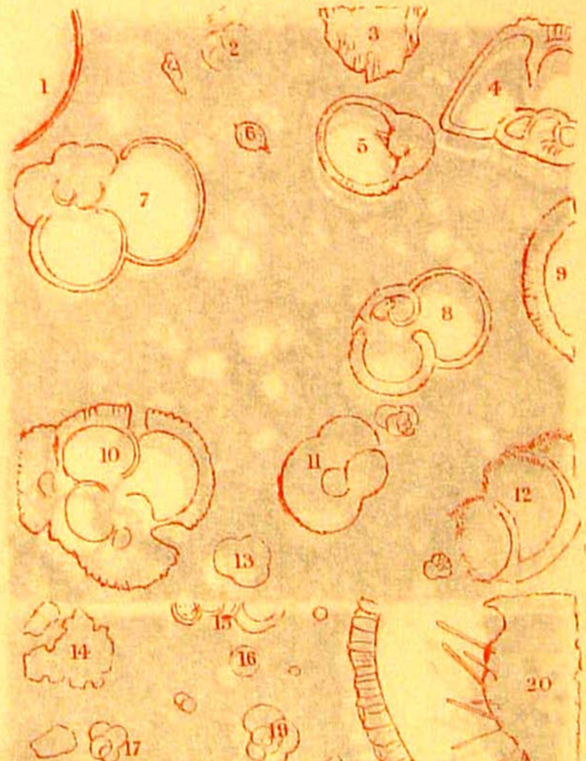
Fig 4b

200 Diam.

Station 175. 12th August 1874.
Lat. 19° 2' S. Long. 177° 10' E.
1350 Fathoms.

Geo. West, Lith. ad Nat. | W. & A. K. Johnston, Lith.

CALCAREOUS DEPOSITS.



1350 Fathoms

Fig 1a.

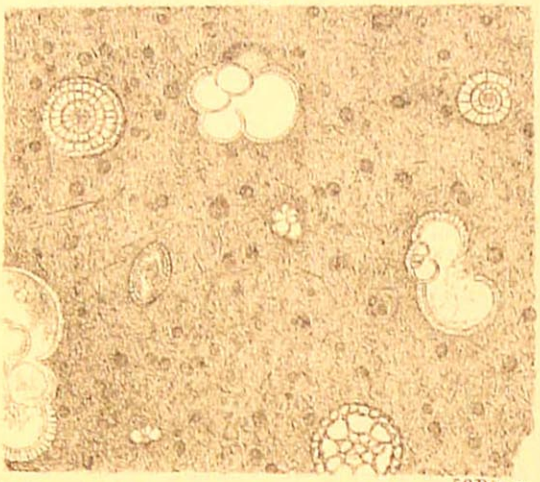


Fig 1b

Station 157. 3rd March 1874.
Lat. 53°. 55′. S. Long. 108°. 35′. E.
1950 Fathoms.

Fig 2a.

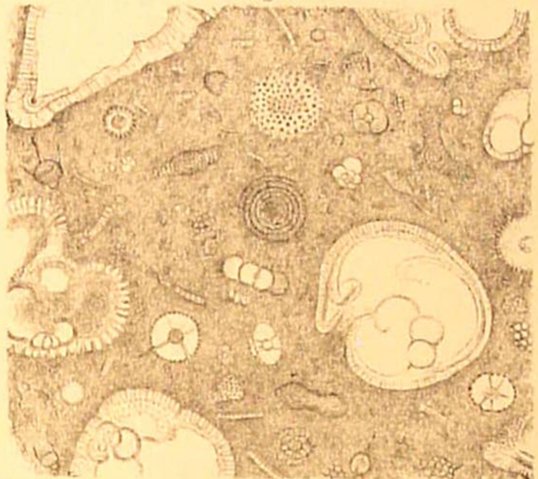


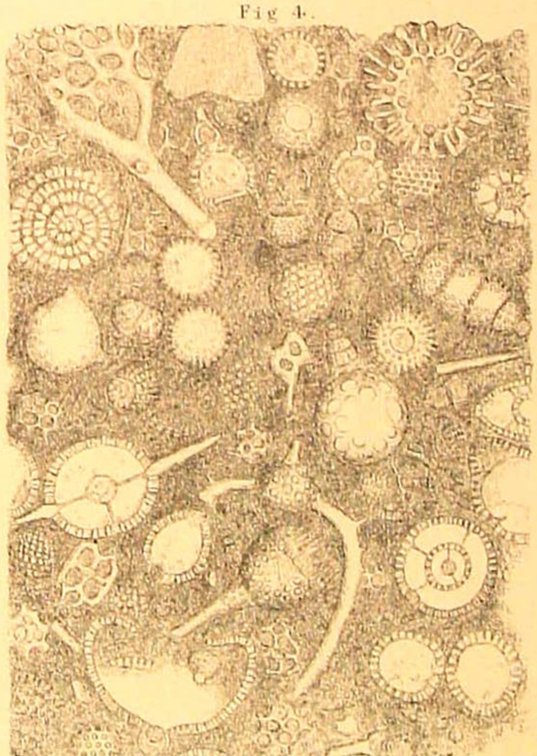
Fig 2b

Station. 271. 6th September 1875.
Lat. 0°. 33′. S. Long. 151°. 34′. W.
2425 Fathoms.

Fig 3.

Station. 225. 23rd March. 1875.
Lat. 11°. 24′. N. Long. 143°. 16′. E.
4475 Fathoms.

Fig 4.

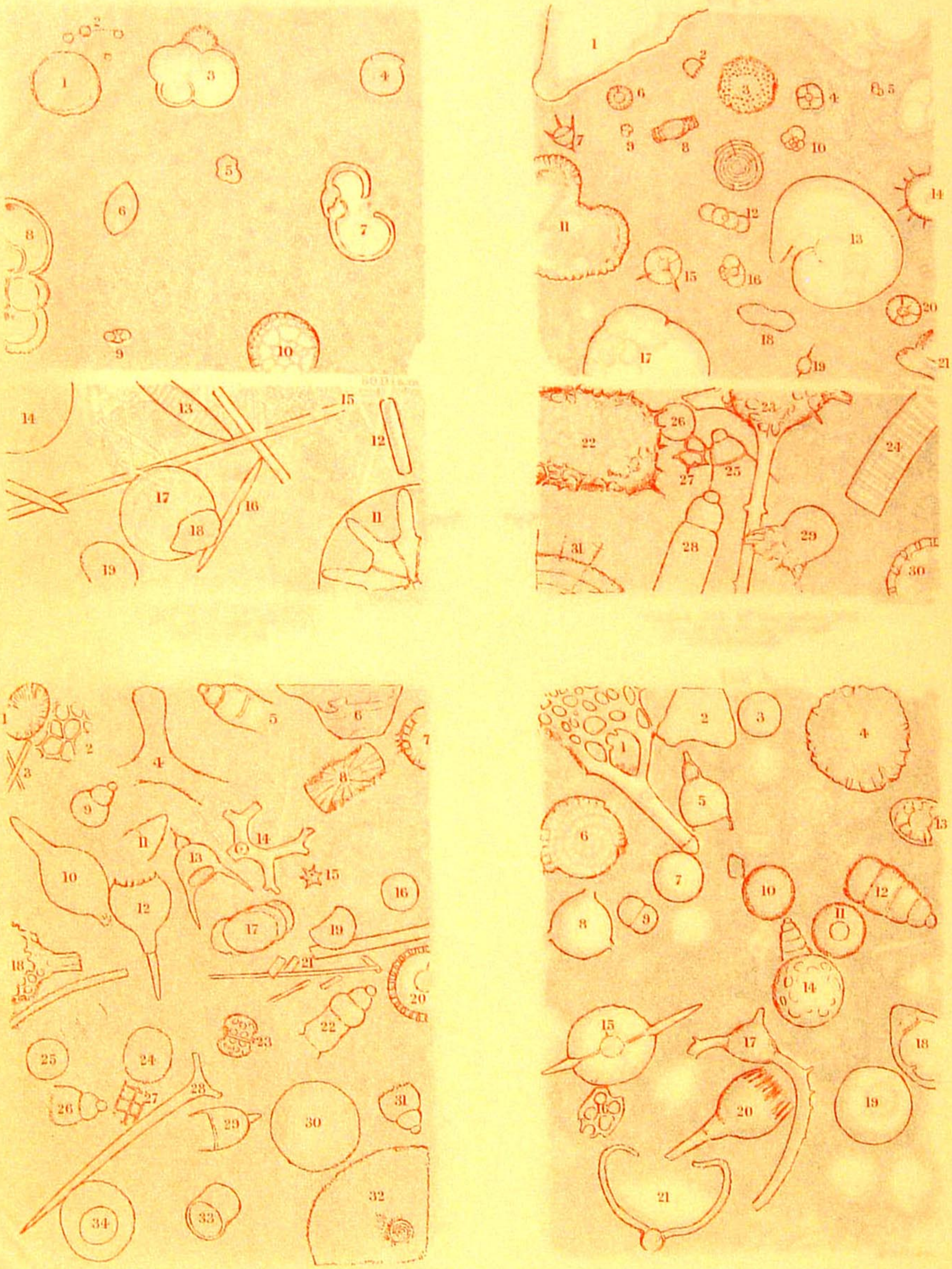


Station. 268. 30th August. 1875.
Lat. 7°. 35′. N. Long. 149°. 49′. W.
2900 Fathoms.

Lith.ad.Nat

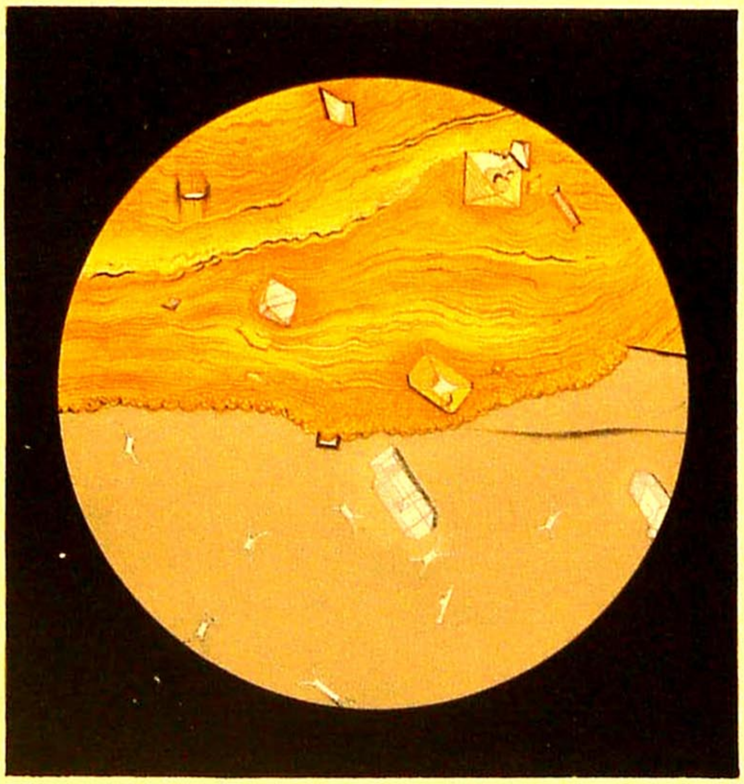
W & A.K. Johnston, Edinburgh

SILICEOUS DEPOSITS.

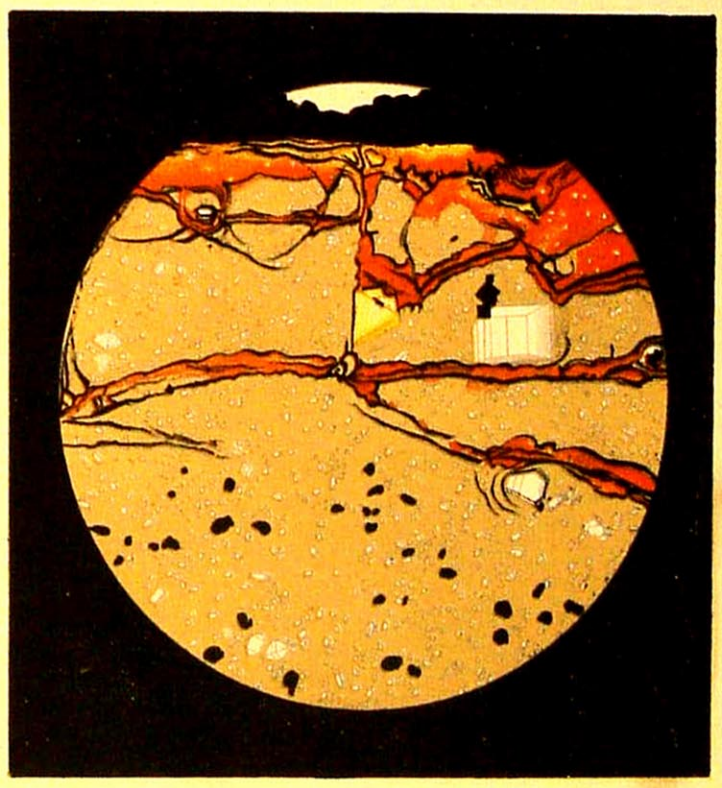


1

2



3



4

A. Renard & Dr. J. Heitzmann del.

Lith. v. Dr. J. Heitzmann.

K. k. Hof- u. Staatsdruckerei Wien

1

2

4

3

A. Renard & Dr. J. Heitzmann del. Lith. v. Dr. J. Heitzmann. K.k. Hof- u. Staatsdruckerei Wien

1

2

3

4

A. Renard & Dr. J. Heitzmann del.

Lith v Dr. J. Heitzmann.

K.K. Hof u. Staatsdruckerei Wien

1.

2.

3.

4.

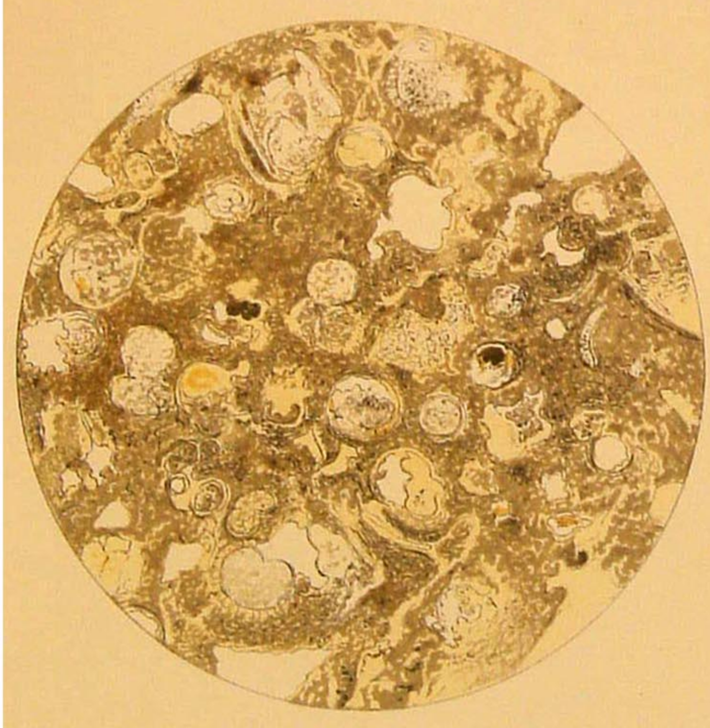
A. Renard del.

Lith v. Dr J. Heitzmann

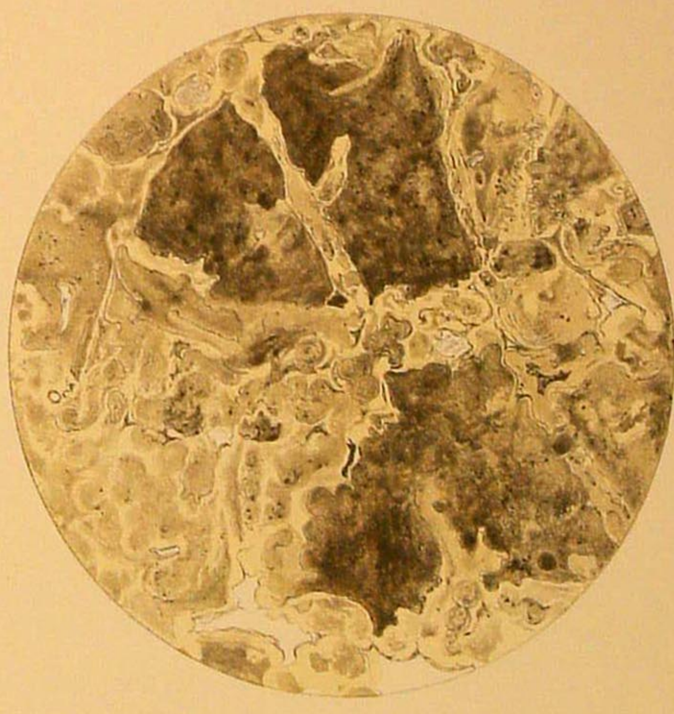
K.k.Hof u. Staatsdruckerei Wien

1.

2.



3.



4.

PHOSPHATIC CONCRETIONS.

F. Huth, Lith^{r} Edin^{r}

1

2

Rebard & Dr. J. Heitzmann del.

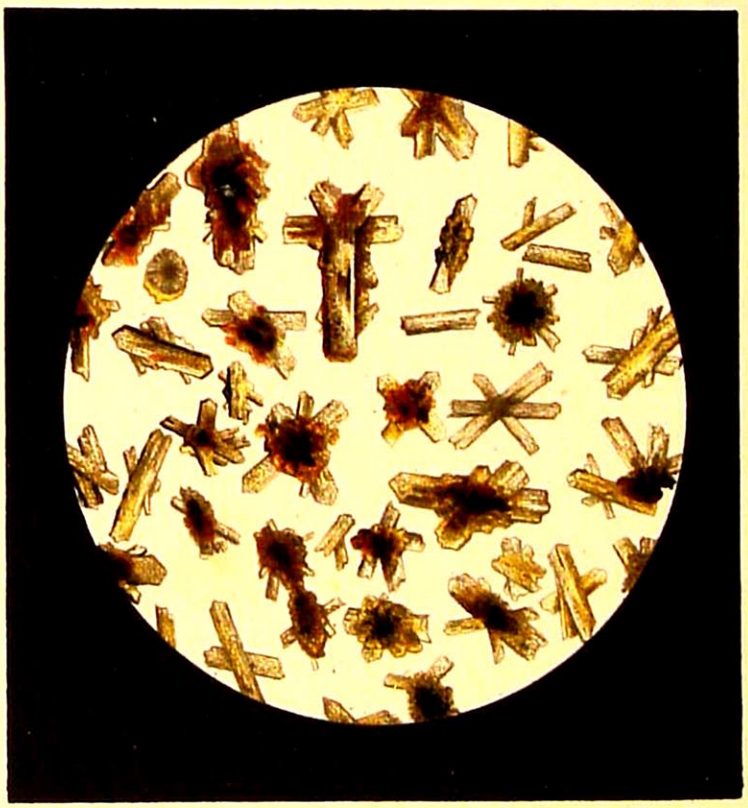
Lith. v. Dr. J. Heitzmann

K.k.Hof-u. Staatsdruckerei Wien.

1.

2.

3.



4.

A. Renard del.

Lith. v. Dr J. Heitzmann.

K.k. Hof-u. Staatsdruckerei Wien.

A. Renard del.

Lith. v. Dr. J. Heitzmann.

K. k. Hof- u. Staatsdruckerei Wien.

Fig. 1.

35 Diam.

Station 142. 18th December 1873.
Lat. 34° 4′ S. Long 18° 37′ E.
150 Fathoms.

Fig. 2.

35 Diam.

Station 164B 13th June 1874.
Lat. 34° 13′ S. Long. 151° 38′ E.
410 Fathoms.

Fig. 3.

25 Diam.

Station 185B 31th August 1874.
Lat. 11° 35′ S. Long. 144° 3′ E.
155 Fathoms.

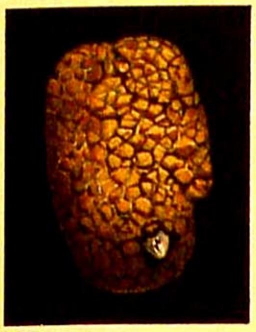
Fig. 4.

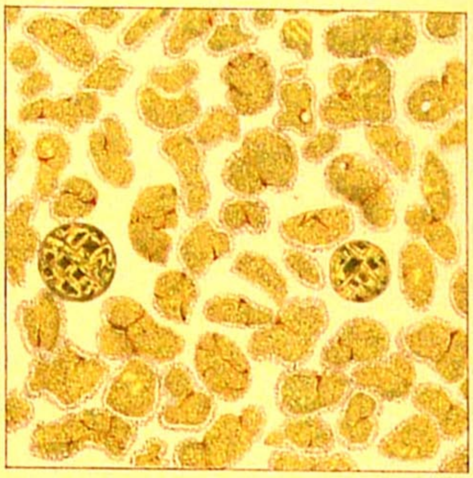
25 Diam.

Station 176. 15th August 1874.
Lat. 18° 30′ S. Long. 173° 52′ E.
1450 Fathoms.

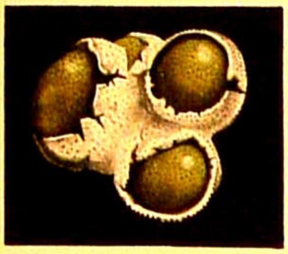
Geo. West. del. ad. Nat.

Chromo. G. Severeyns. Brussels.


2.


1.


3.


4.


5.


6.

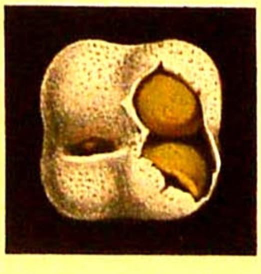

7.


8.


9.


10.

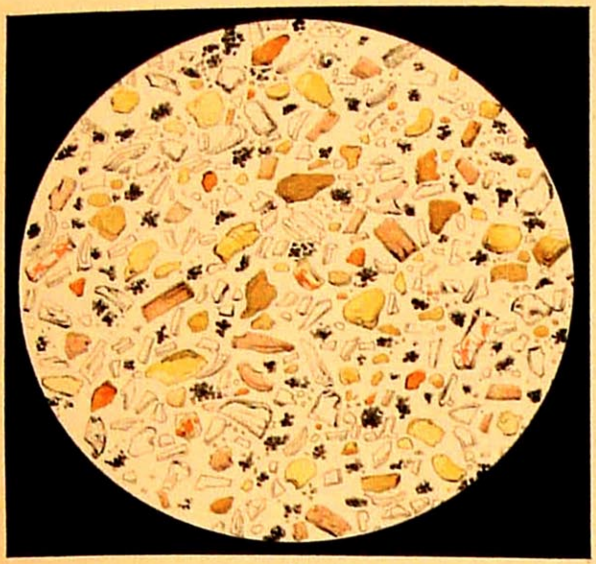

11.


12.


13.

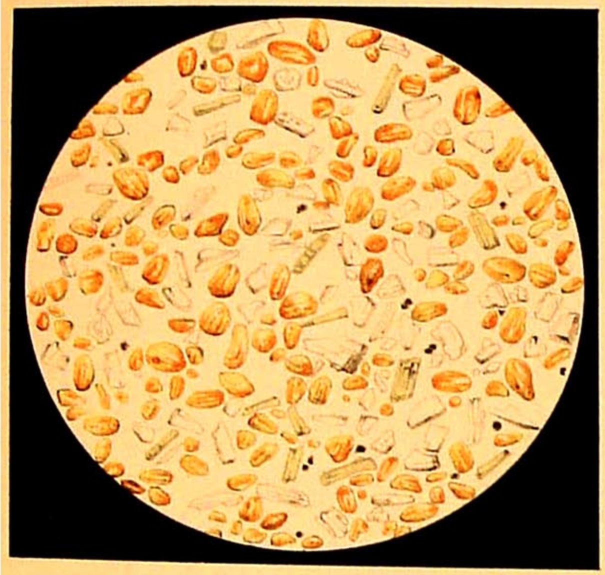

14.

F. Huth, Lith.r Edin.r



1.

2.



3.

4.

5.

6.

F. Huth, Lith^{r} Edin^{r}.

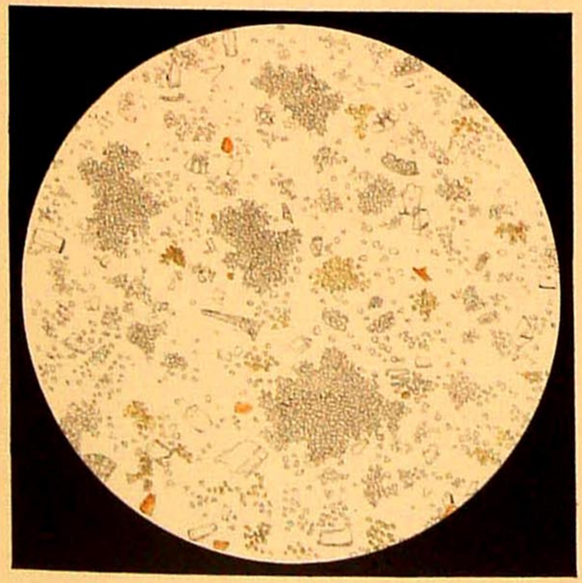
MINERAL PARTICLES.

1.

2.

3.

4.



5.

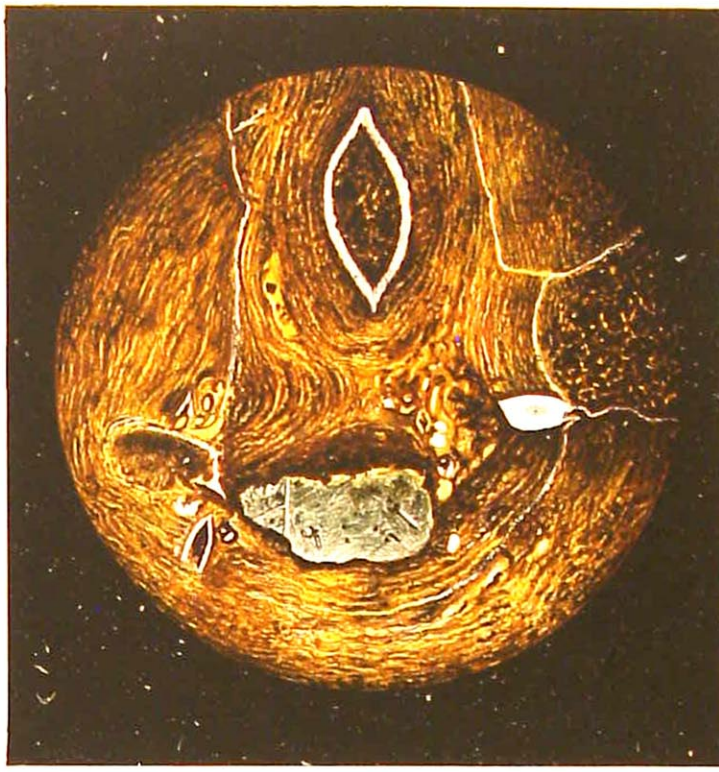
6.

F. Huth, Lith.r Edin.r

MINERAL PARTICLES AND FINE WASHINGS.

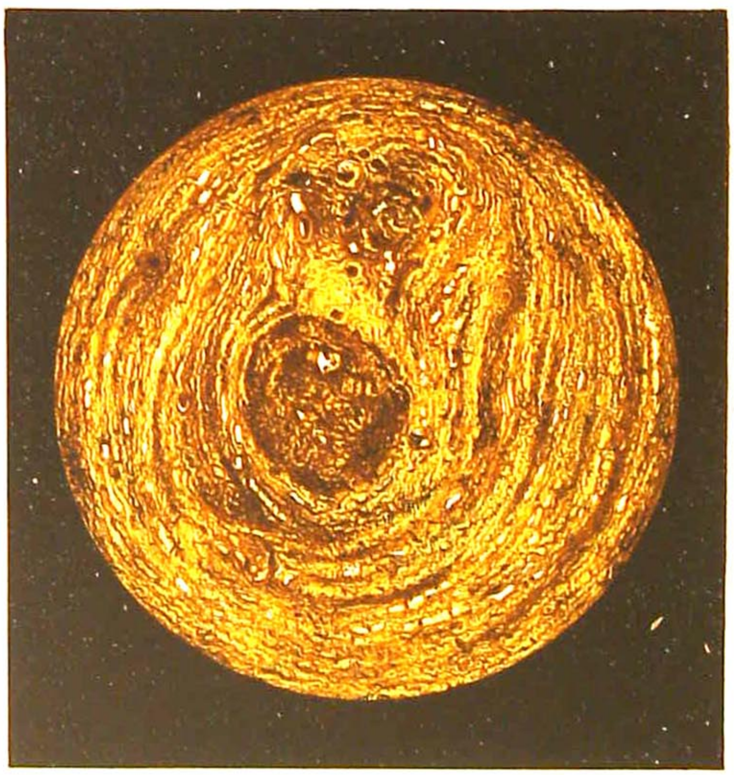

1.
2.
3.
4.
5.

1



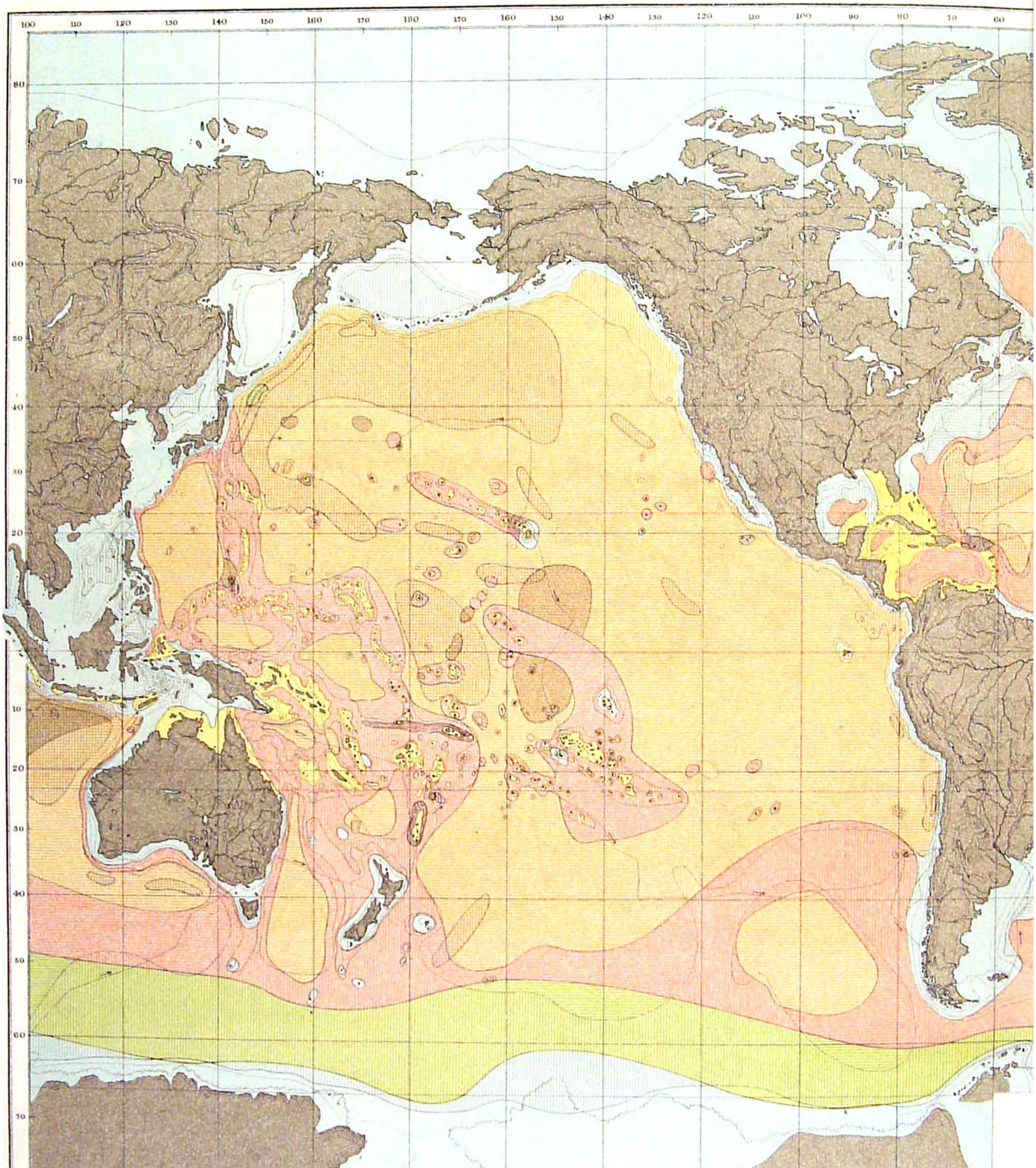
2

3



4

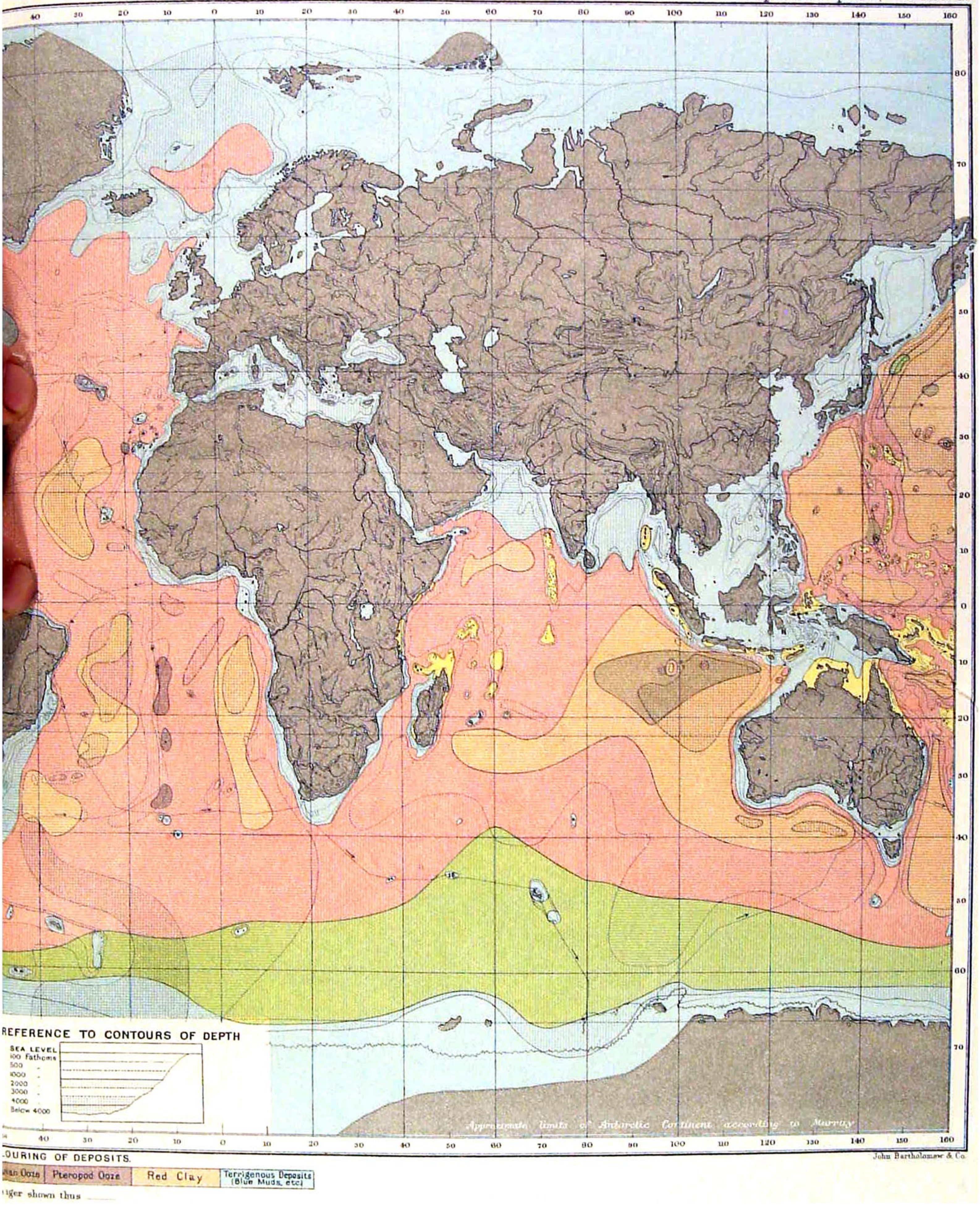
A. Renard & Dr. J. Heitzmann del. Lith v Dr. J. Heitzmann K.k.Hof u. Staatsdruckerei Wien

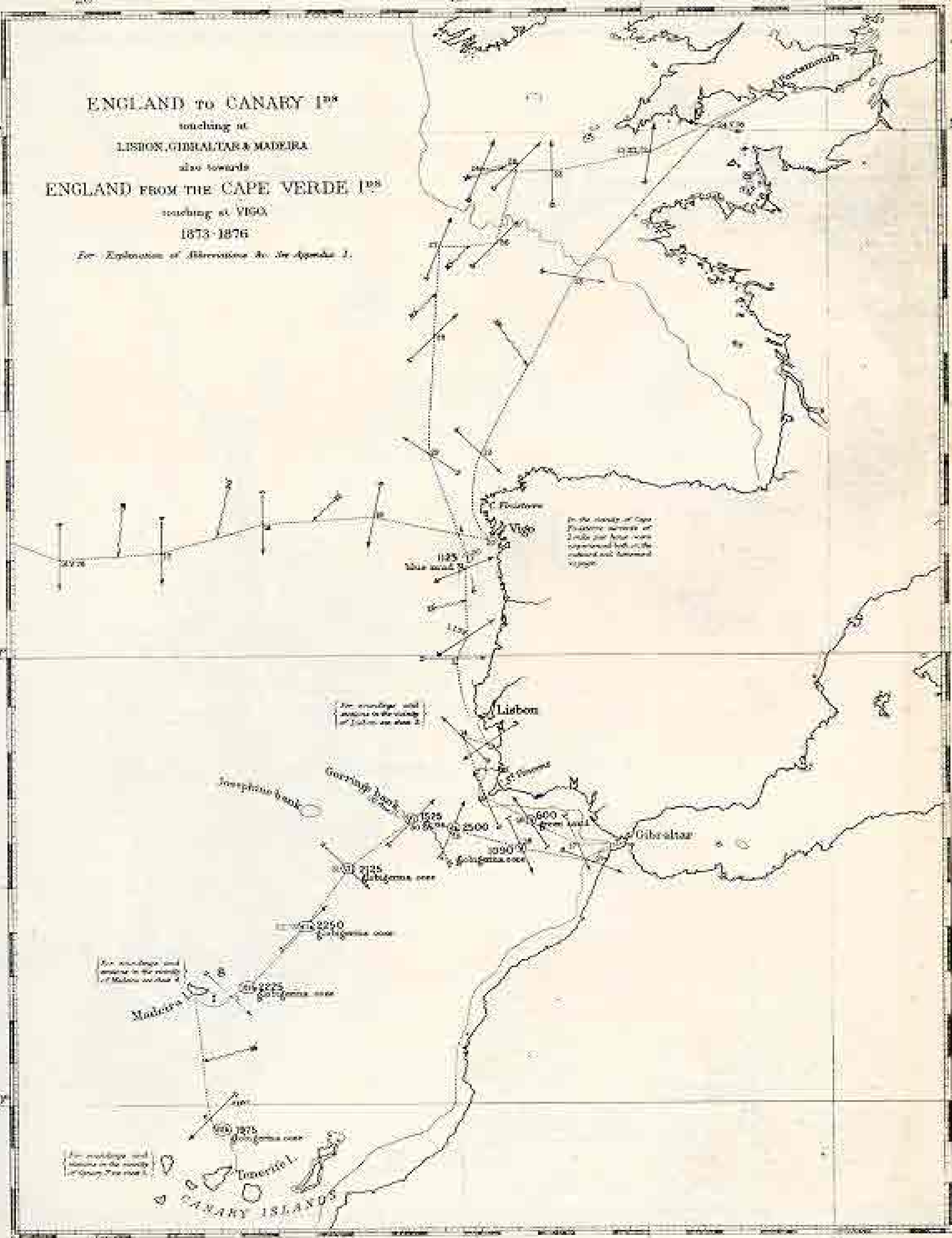


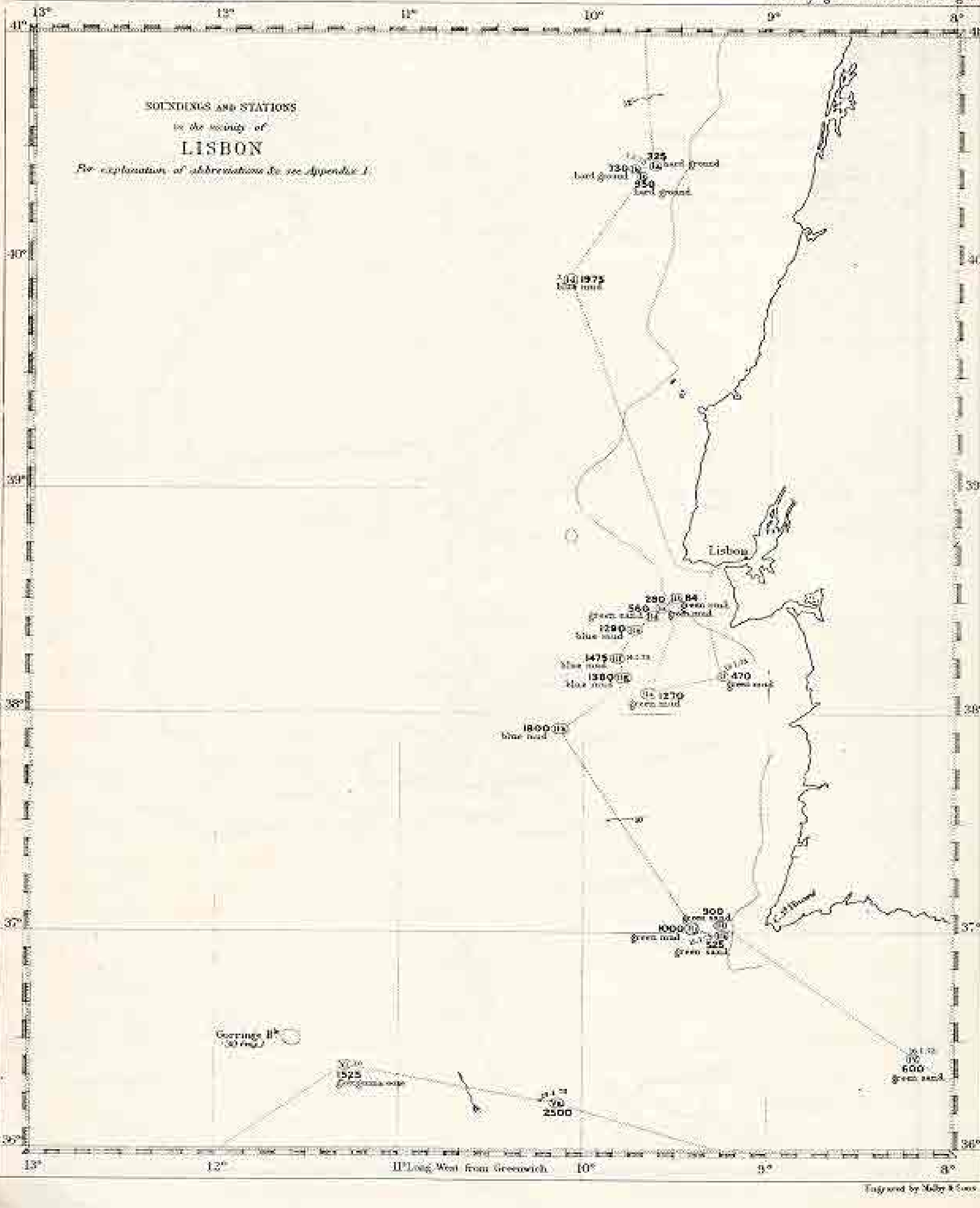
The Edinburgh Geographical Institute

REFERENCE TO CO

Coral Muds & Sands	Globigerina Ooze	Diatom Ooze	Radiola

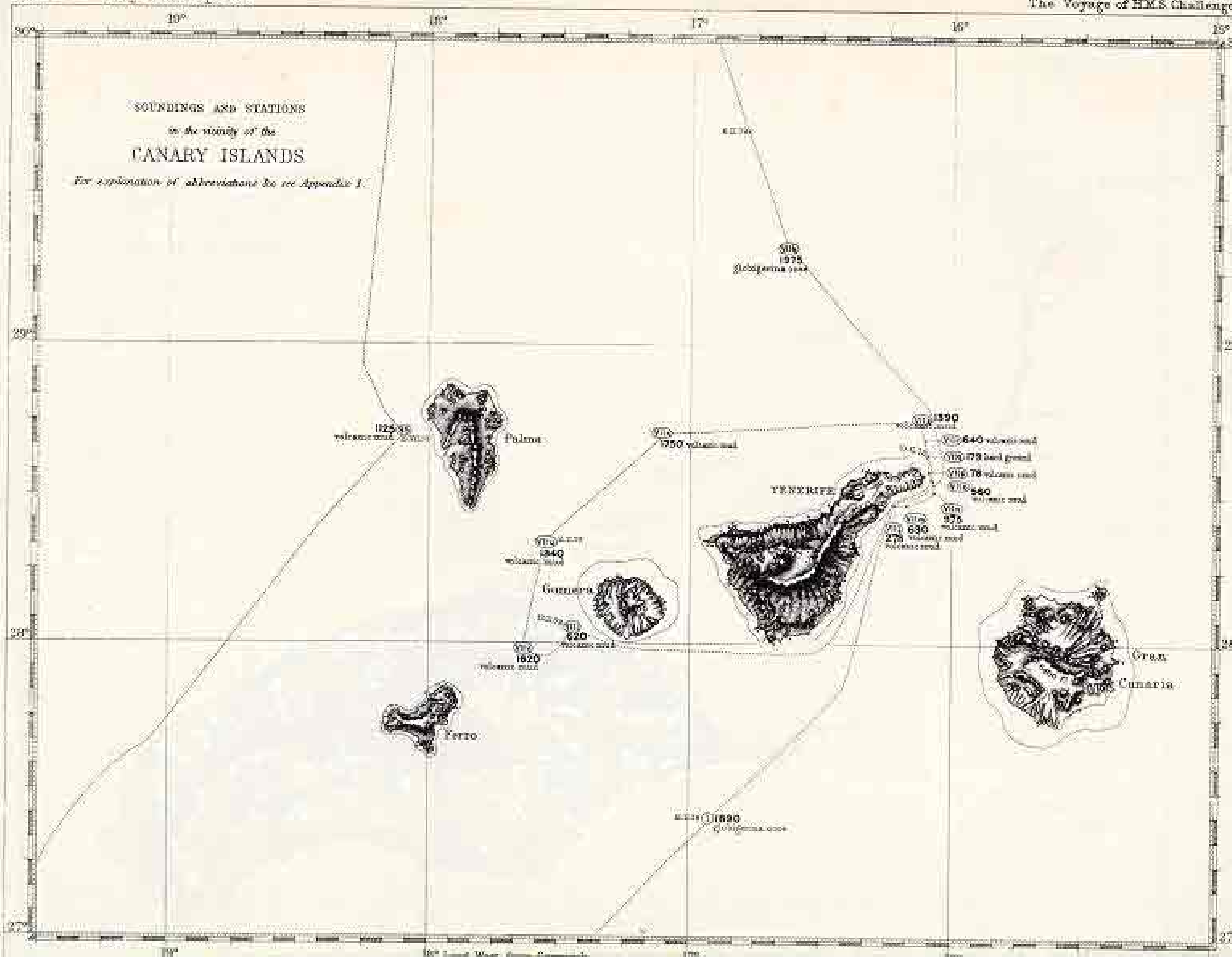

REFERENCE TO CONTOURS OF DEPTH
SEA LEVEL
100 Fathoms
500
1000
2000
3000
4000
Below 4000
Approximate limits of Antarctic Continent according to Murray
John Bartholomew & Co.
Pteropod Ooze
Red Clay
Terrigenous Deposits (Blue Muds, etc)

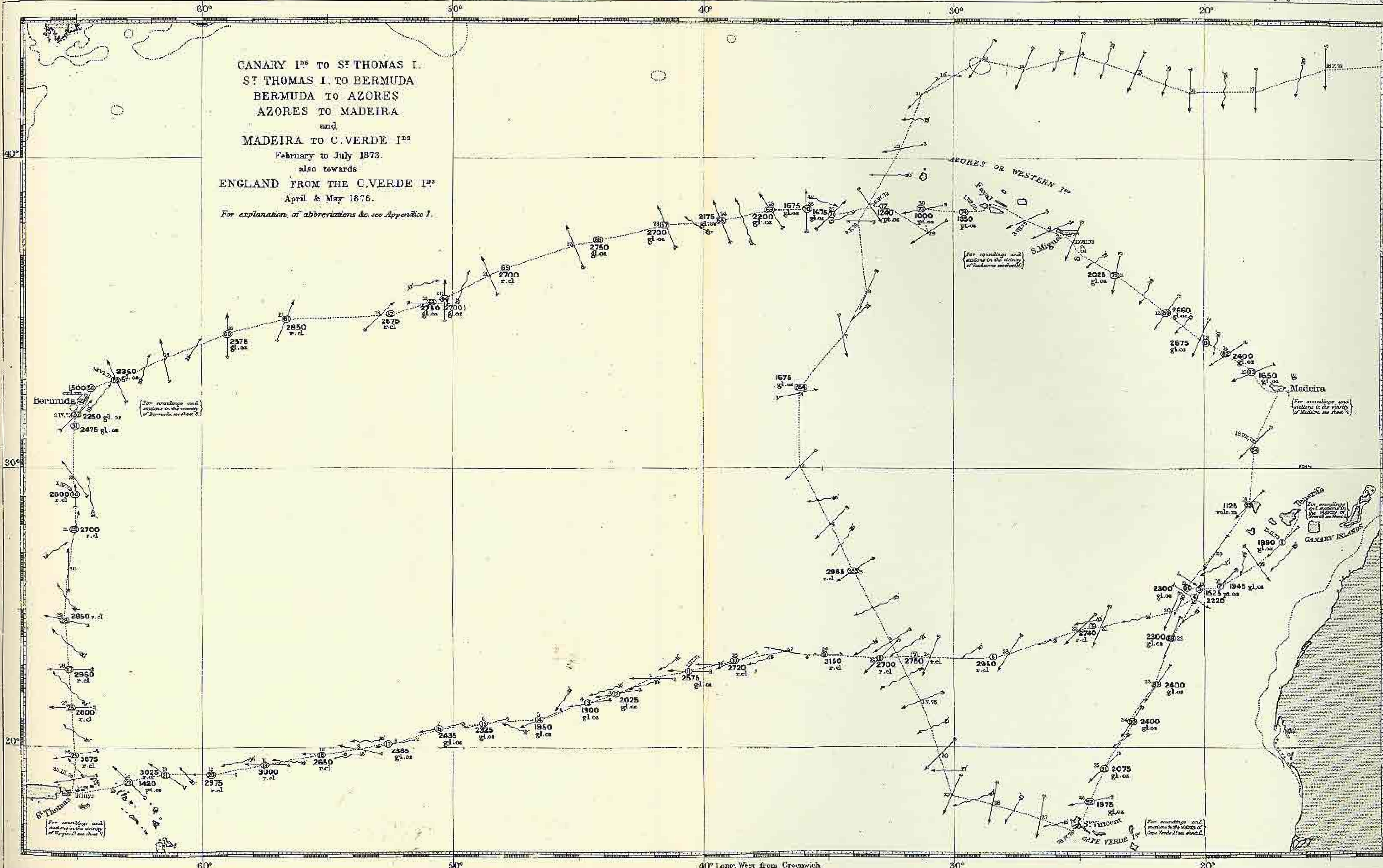

ENGLAND TO CANARY I^DS
touching at
LISBON, GIBRALTAR & MADEIRA
also towards
ENGLAND FROM THE CAPE VERDE I^DS
touching at VIGO
1873-1876
For Explanation of Abbreviations &c. See Appendix I.
20°
10°
0
50°
40°
30°
Portsmouth
C. Finisterre
Vigo
1125
blue mud
Lisbon
Gorringe bank
Josephine bank
C. St Vincent
1525
2500
600
green sand
Gibraltar
1090
Globigerina ooze
2125
Globigerina ooze
2250
Globigerina ooze
2275
Globigerina ooze
Madeira I.
1975
Globigerina ooze
Teneriffe I.
CANARY ISLANDS

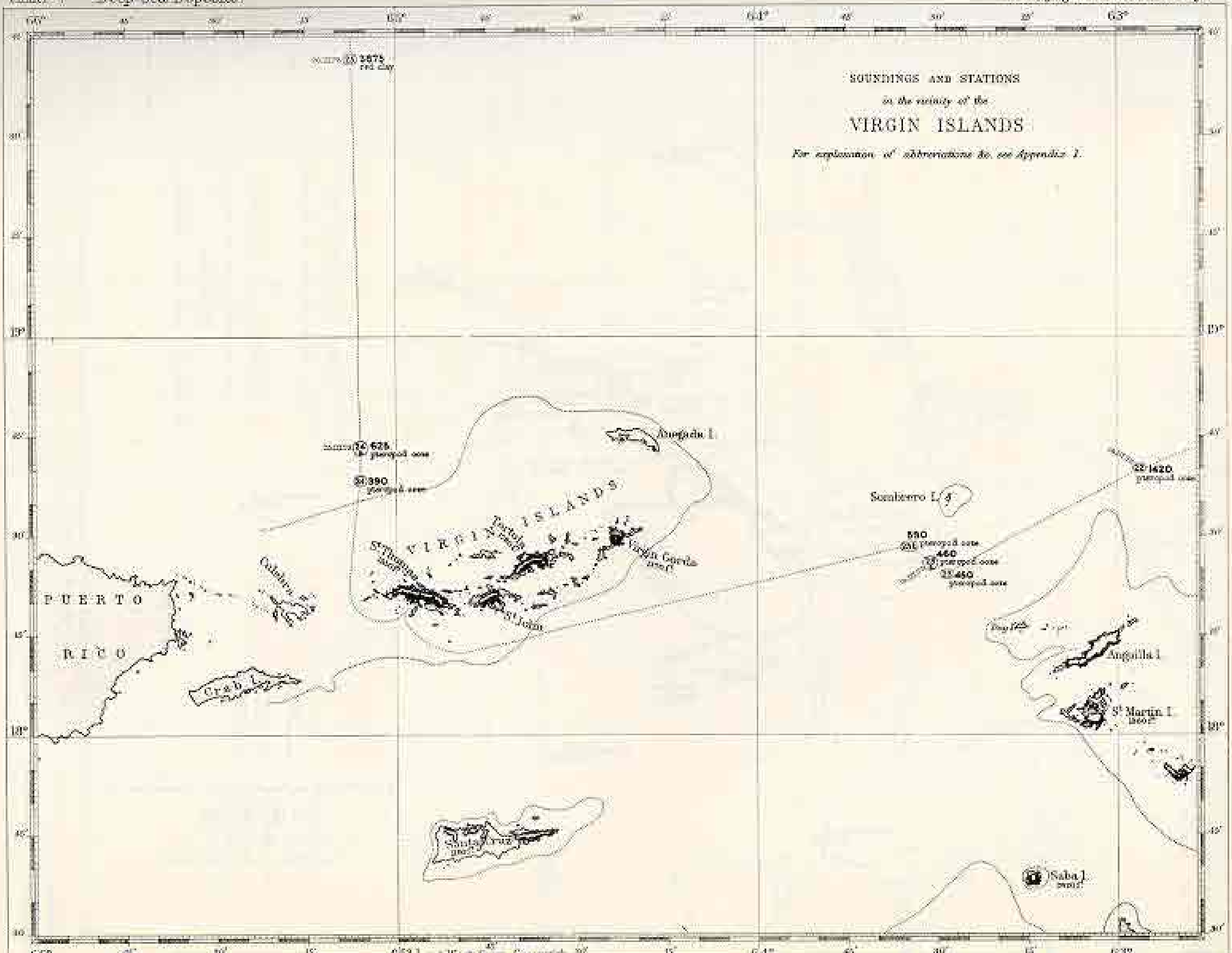


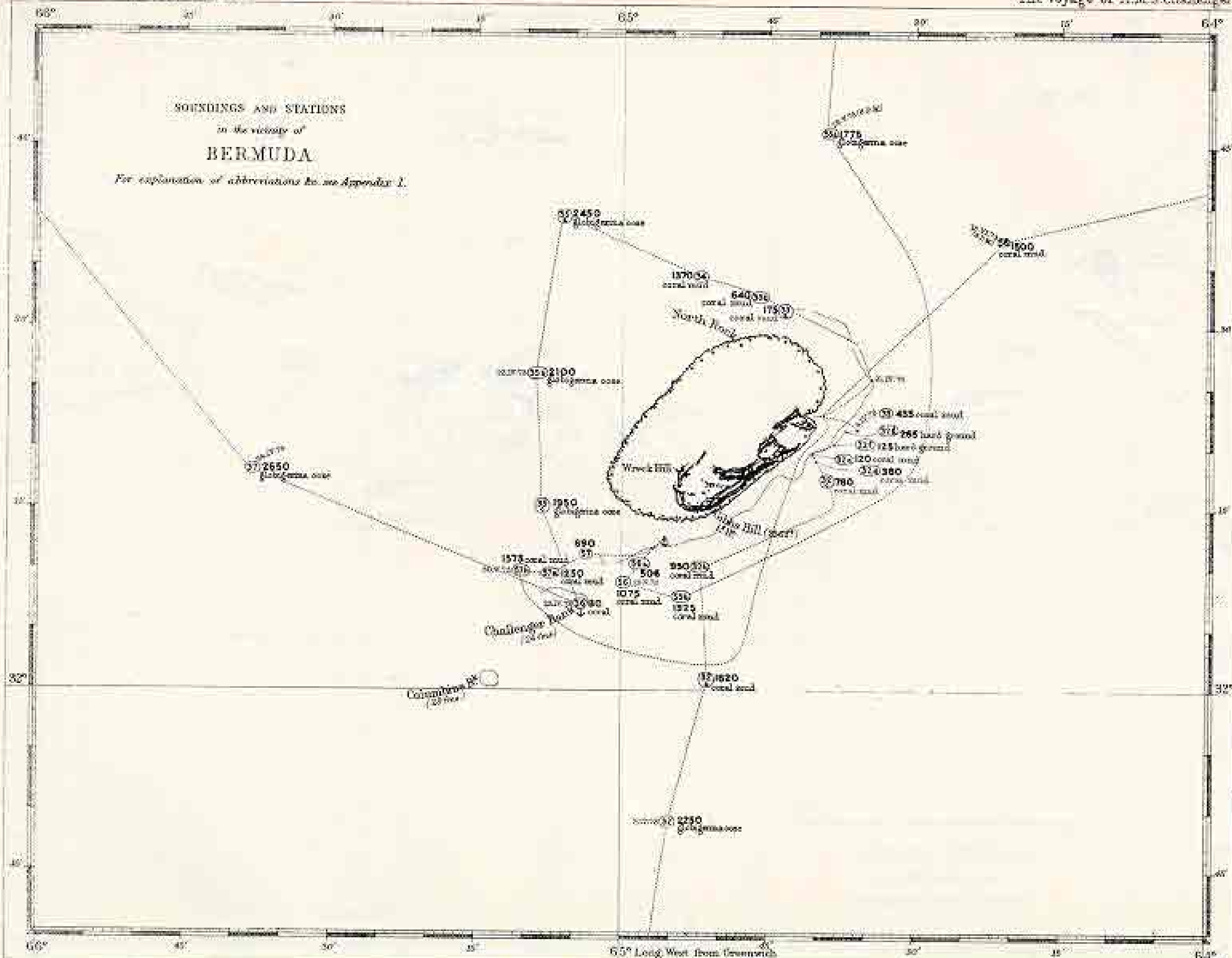
Engraved by Malby & Sons

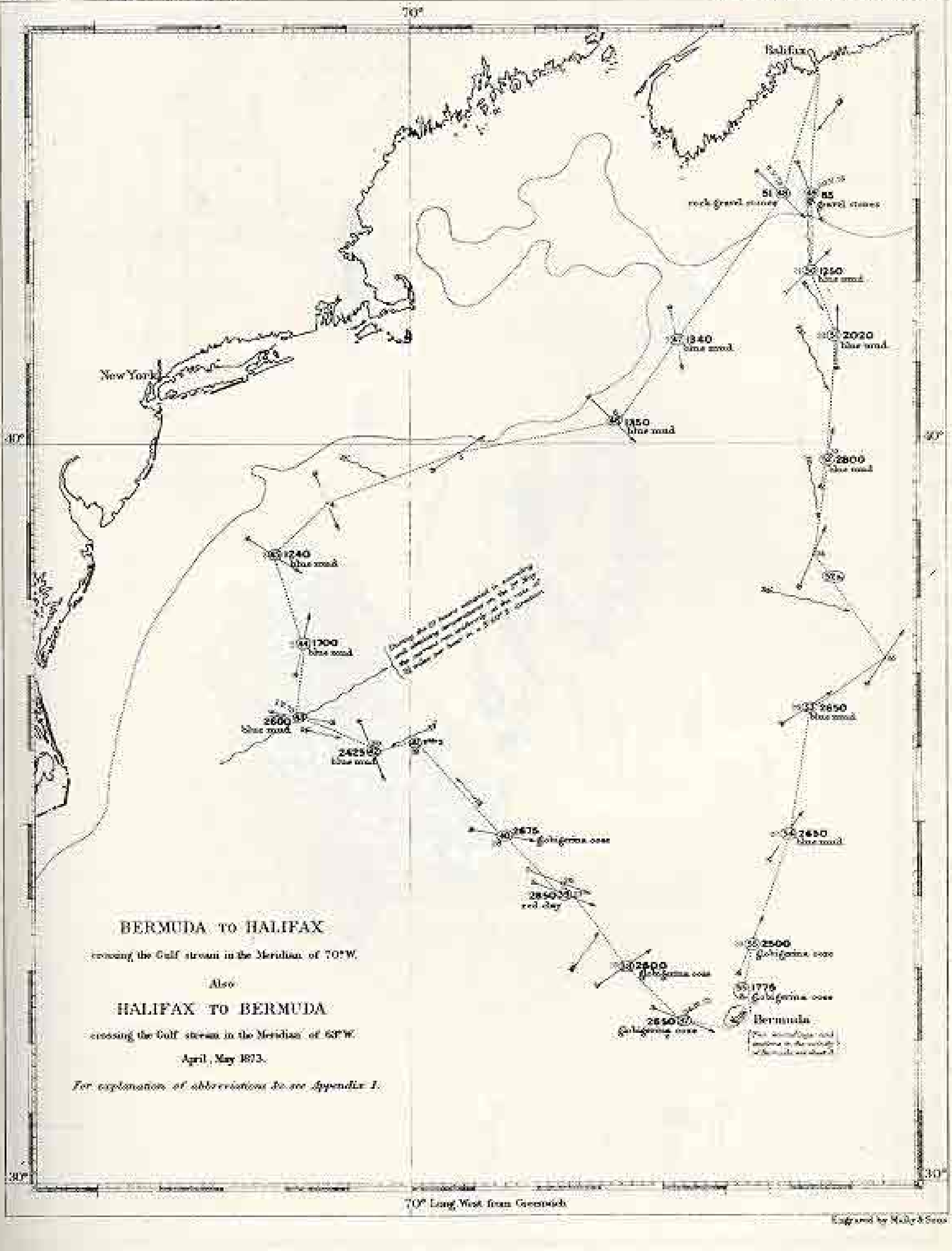

SOUNDINGS AND STATIONS
in the vicinity of
MADEIRA ISLAND
For explanation of abbreviations &c. see Appendix I.
Deserta
Grande
Bugio
490 volcanic mud
780 volcanic mud
1150 volcanic mud
1500 volcanic mud
930 volcanic mud
670 calc. sand
1150 volcanic mud
17° Long. West from Greenwich


SOUNDINGS AND STATIONS
in the vicinity of the
CANARY ISLANDS
For explanation of abbreviations &c. see Appendix I.
Palma
Tenerife
Gomera
Ferro
Gran
Canaria
1975
globigerina ooze
1890
1750 volcanic mud
640 volcanic mud
78 volcanic mud
560
volcanic mud
975
volcanic mud
630
volcanic mud
275
volcanic mud
1340
volcanic mud
620
volcanic mud
1620
volcanic mud
1125
volcanic mud
1890
globigerina ooze
19°
18°
17°
16°
15°
30°
29°
28°
27°

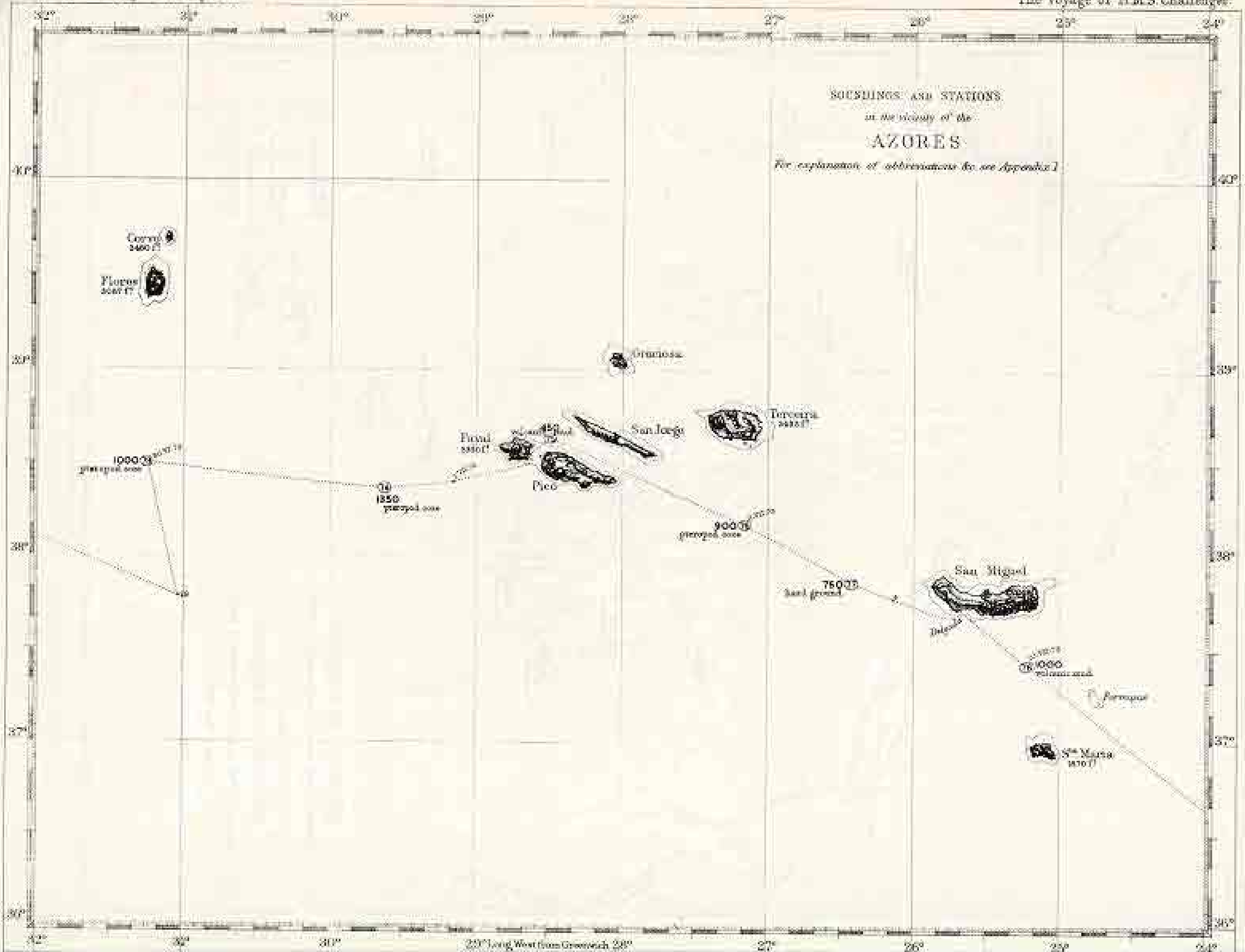

CANARY I^DS TO S^T THOMAS I.
S^T THOMAS I. TO BERMUDA
BERMUDA TO AZORES
AZORES TO MADEIRA
and
MADEIRA TO C. VERDE I^DS
February to July 1873.
also towards
ENGLAND FROM THE C. VERDE I^DS
April & May 1876.
For explanation of abbreviations &c. see Appendix I.
AZORES OR WESTERN I^DS
Fayal
S. Miguel
Madeira
Teneriffe
CANARY ISLANDS
Bermuda
S^t Thomas
S^t Vincent
CAPE VERDE I^DS
40° Long. West from Greenwich
60°
50°
40°
30°
20°

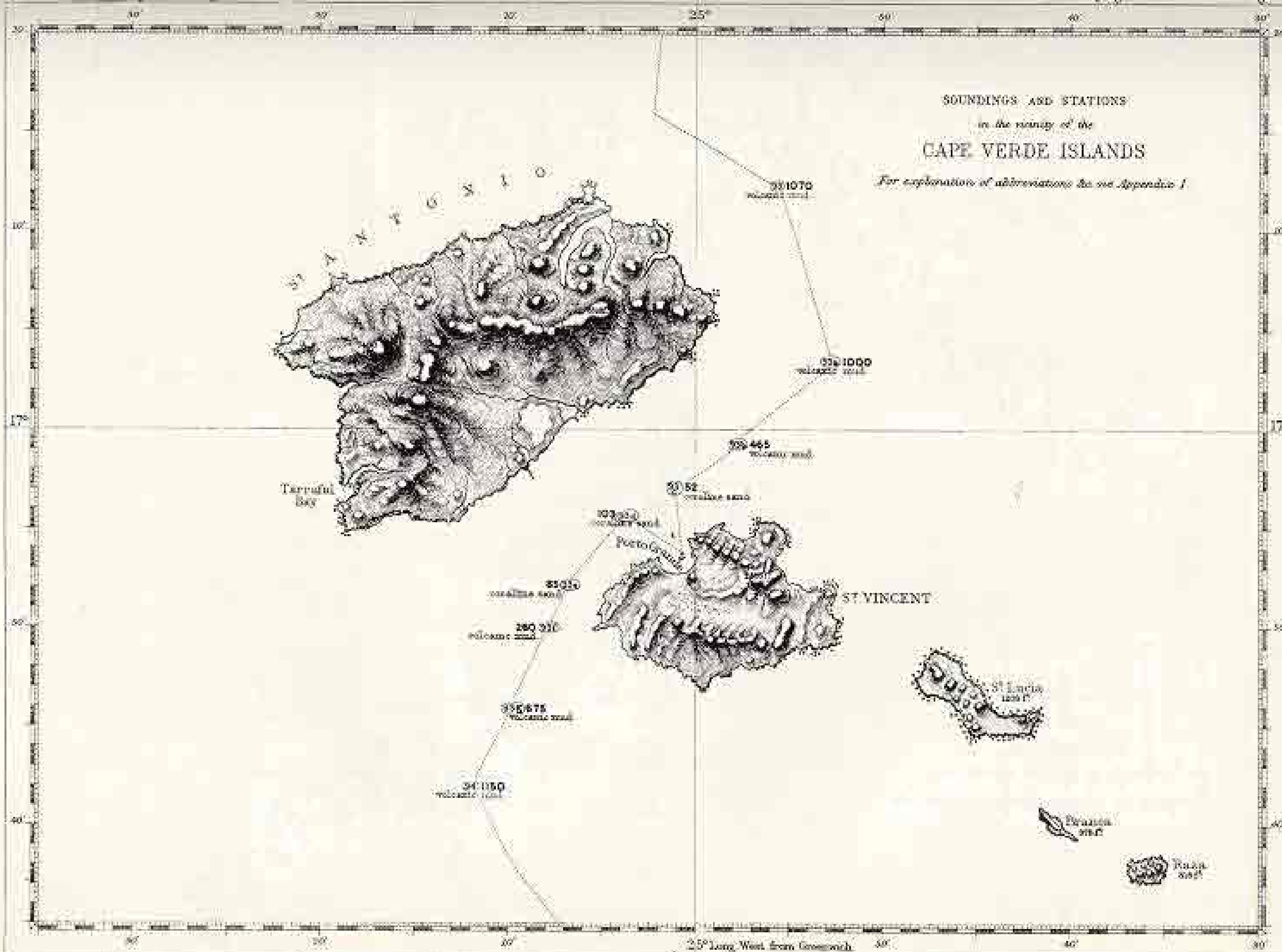

SOUNDINGS AND STATIONS
in the vicinity of the
VIRGIN ISLANDS
For explanation of abbreviations &c. see Appendix I.
PUERTO RICO
VIRGIN ISLANDS
Culebra
Crab I.
St Thomas
St John
Tortola
Virgin Gorda
Anegada I.
Santa Cruz
Sombrero I.
Anguilla I.
St Martin I.
Saba I.
3875 red clay
625 pteropod ooze
390 pteropod ooze
1420 pteropod ooze
550 pteropod ooze
460 pteropod ooze
450 pteropod ooze
19°
18°
63°
64°
65°


SOUNDINGS AND STATIONS
in the vicinity of
BERMUDA
For explanation of abbreviations &c. see Appendix I.
North Rock
Wreck Hill
Challenger Bank
Columbus Bk
65° Long. West from Greenwich
32°
2450 Globigerina ooze
2100 Globigerina ooze
1950 Globigerina ooze
2650 Globigerina ooze
1775 Globigerina ooze
1500 coral mud
1370 coral mud
640 coral mud
175 coral mud
455 coral mud
265 hard ground
125 hard ground
120 coral mud
380 coral mud
780 coral mud
690
1575 coral mud
1250 coral mud
506
950 coral mud
1075 coral mud
1525 coral mud
1820 coral mud
2250 Globigerina ooze

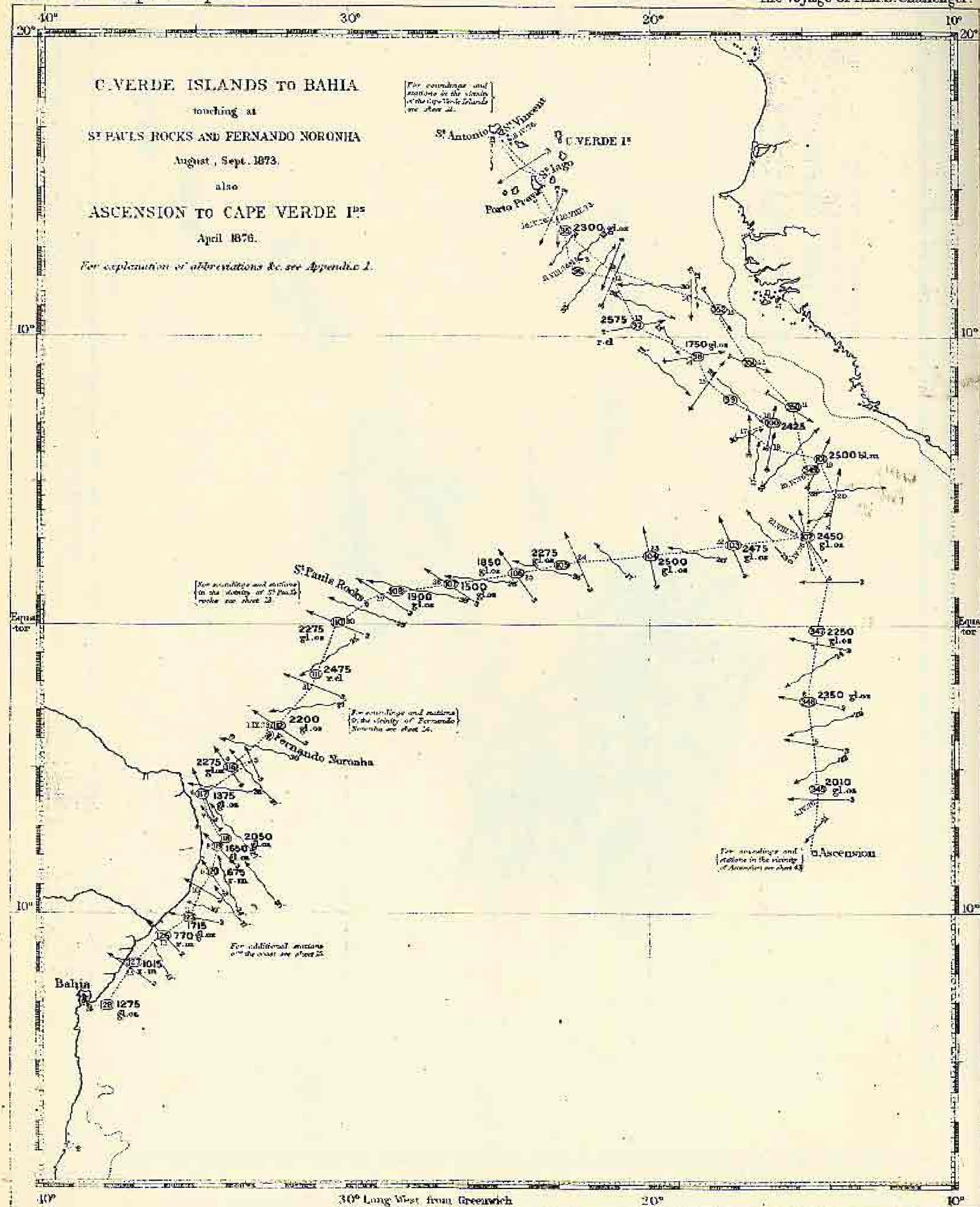


Engraved by Malby & Sons

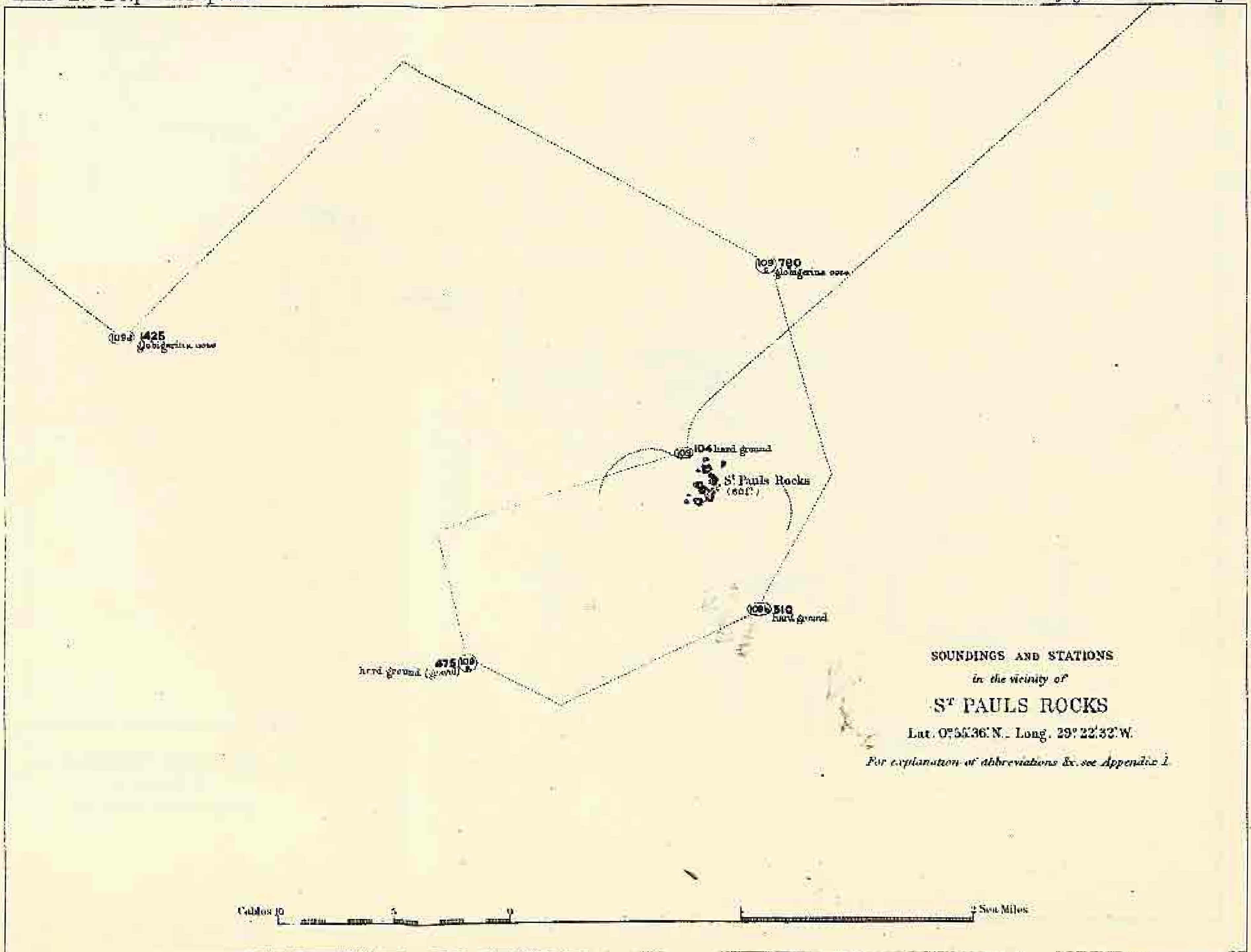

SOUNDINGS AND STATIONS
in the vicinity of the
AZORES
For explanation of abbreviations &c. see Appendix I
Corvo
Flores
Graciosa
Fayal
Pico
San Jorge
Terceira
San Miguel
Delgada
Formigas
S^ta Maria
1000
pteropod ooze
1850
pteropod ooze
900
pteropod ooze
750
hard ground
1000
volcanic mud
Long. West from Greenwich



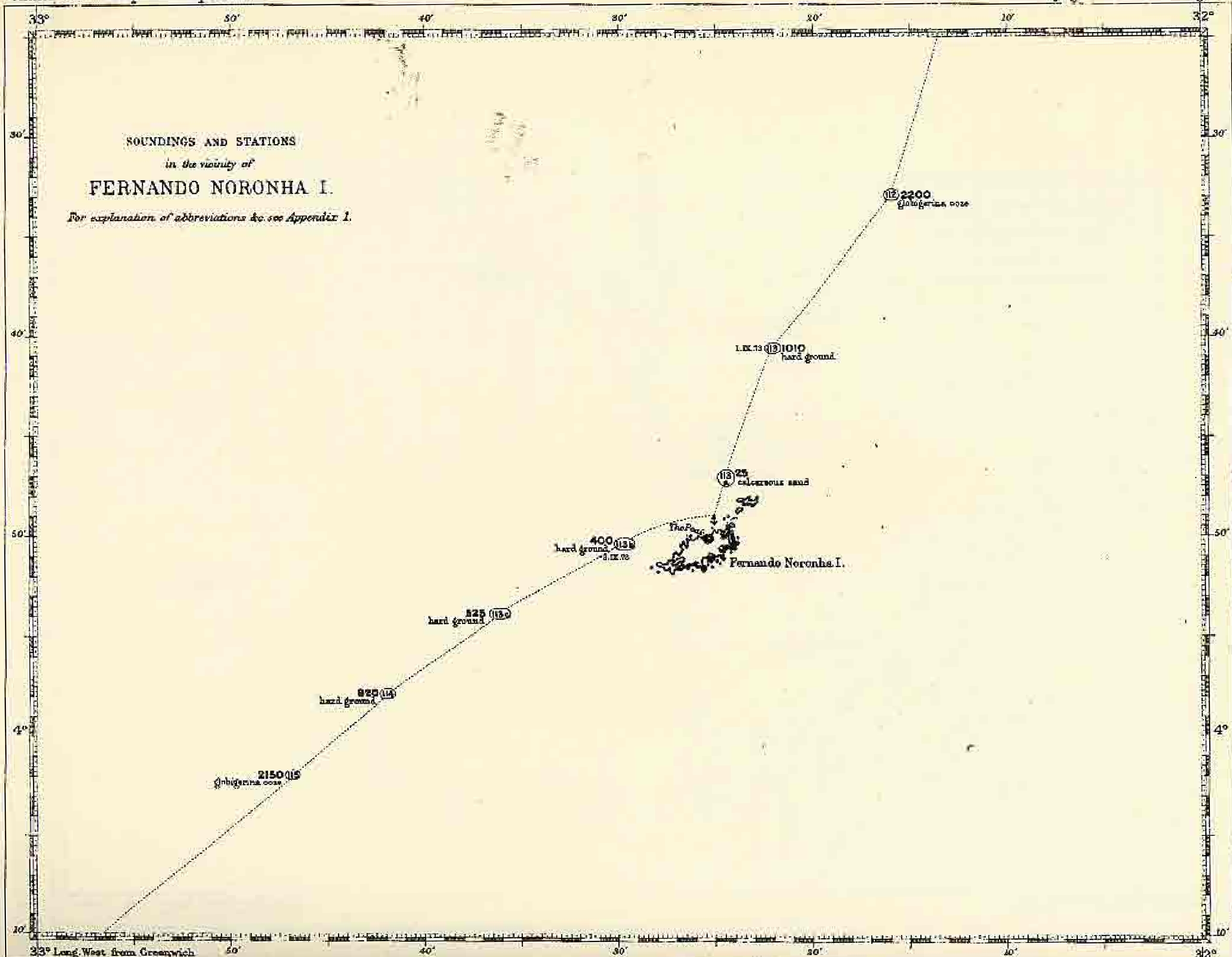
Engraved by Malby & Sons.



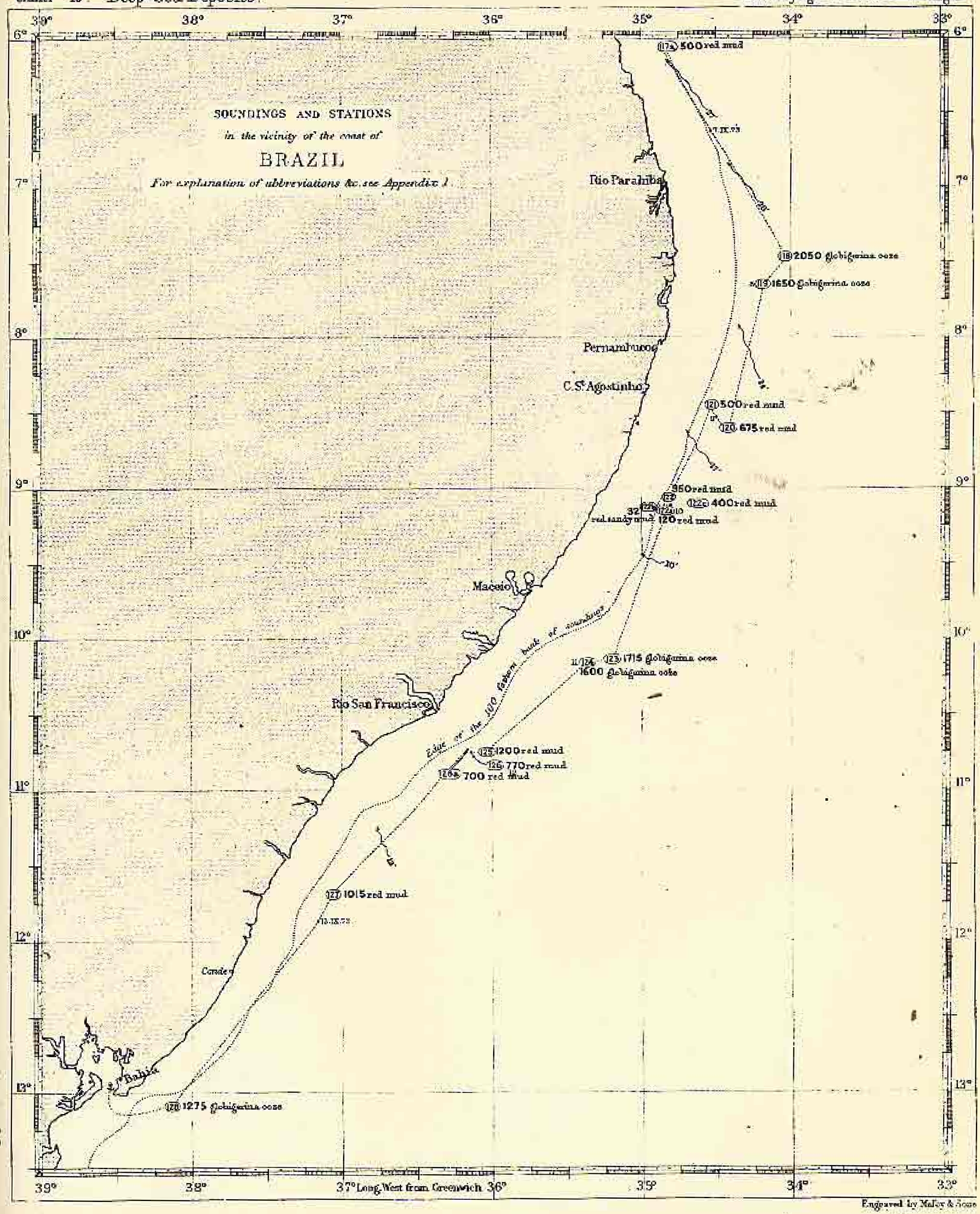
Engraved by Malby & Sons.



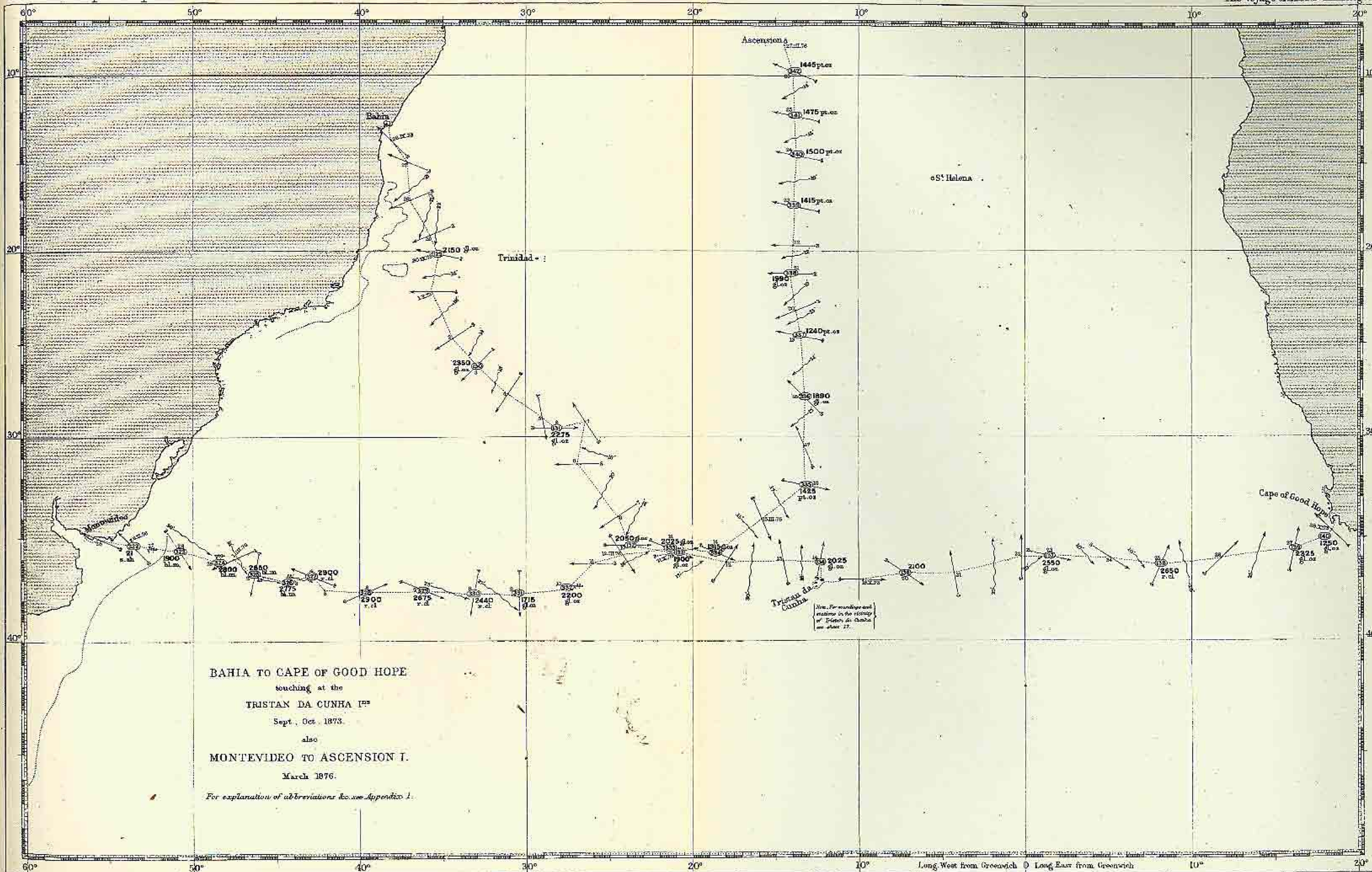
Engraved by Malby & Sons.



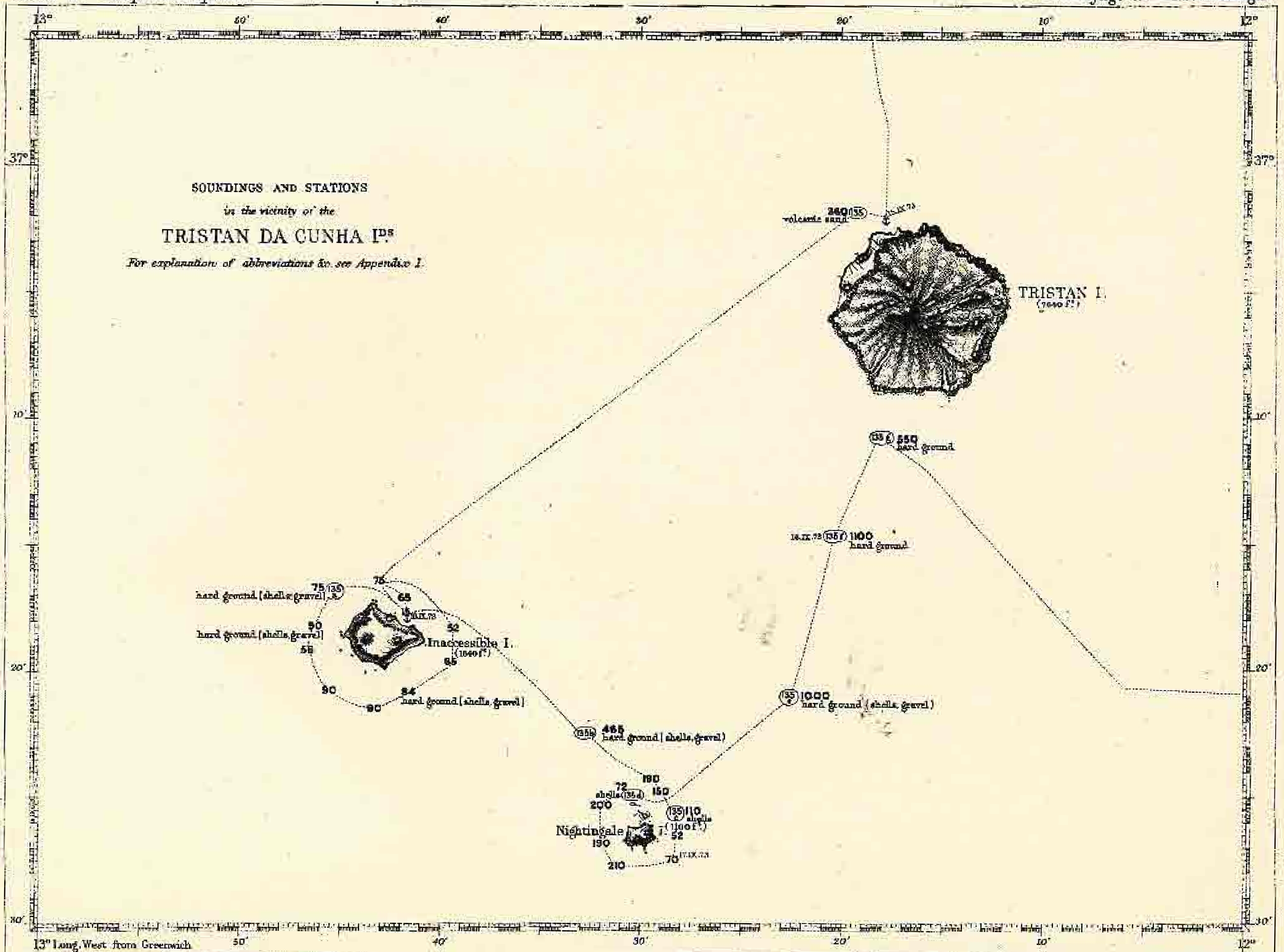
Engraved by Malby & Sons.



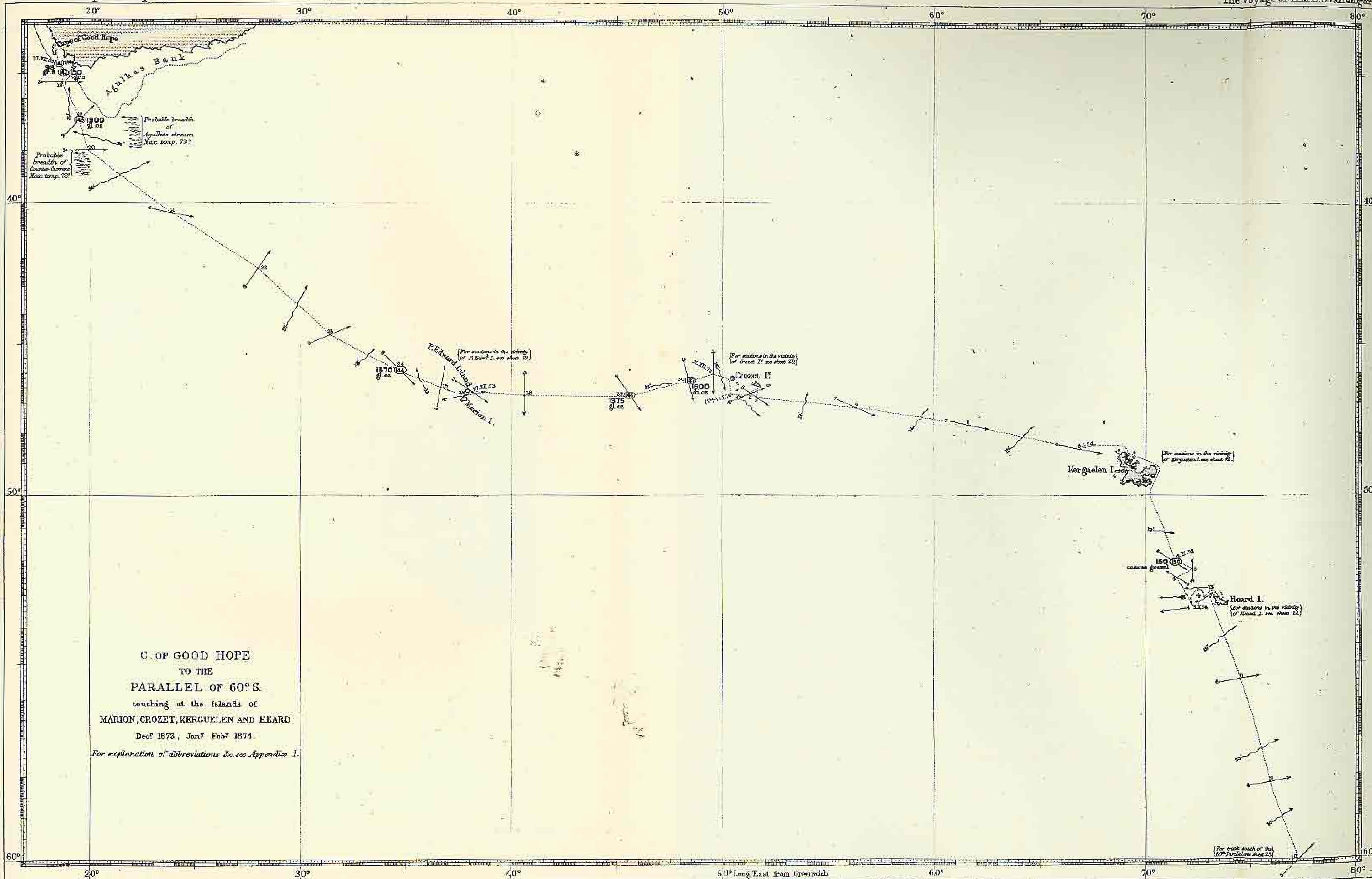
Engraved by Malby & Sons



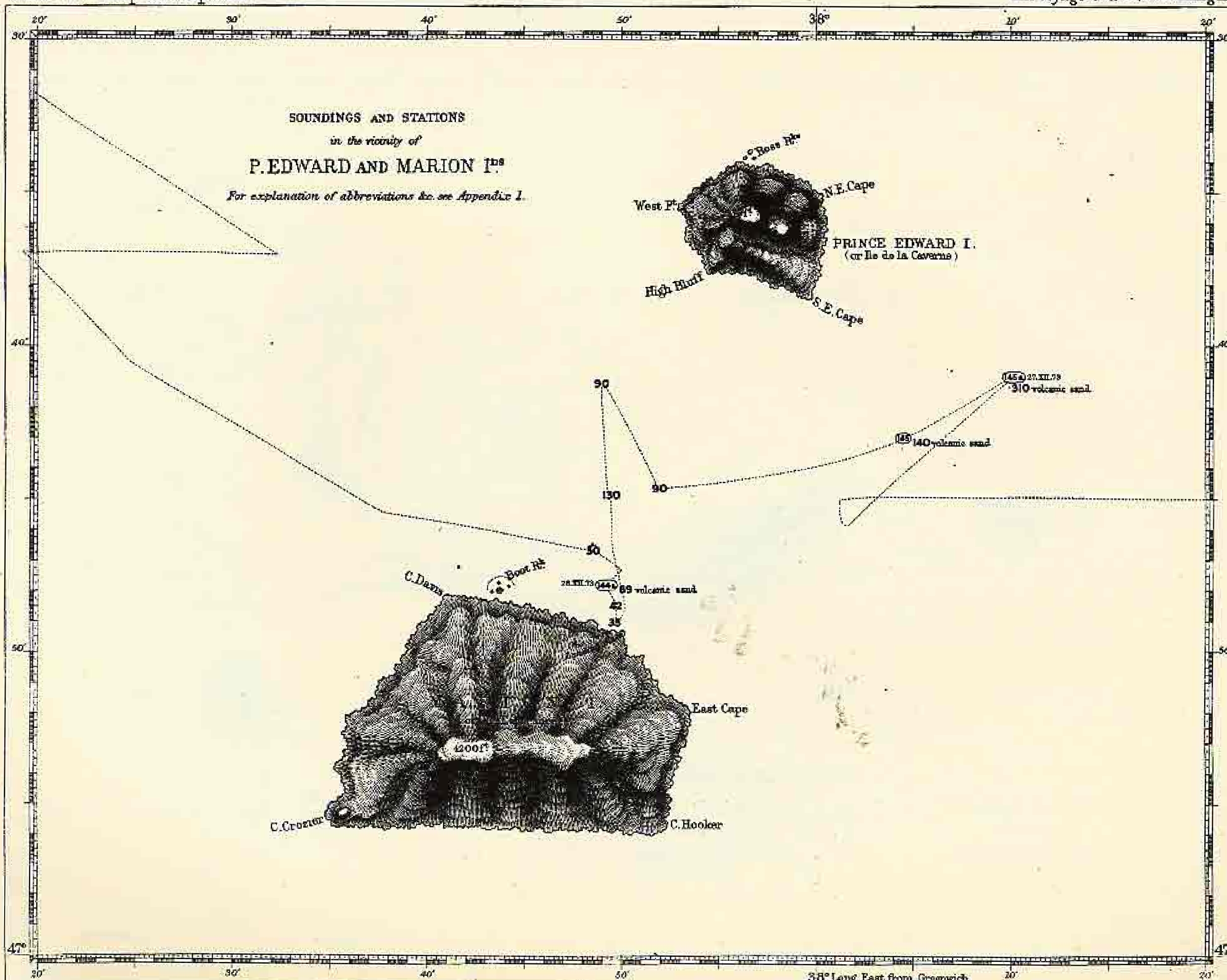
Engraved by Malby & Sons



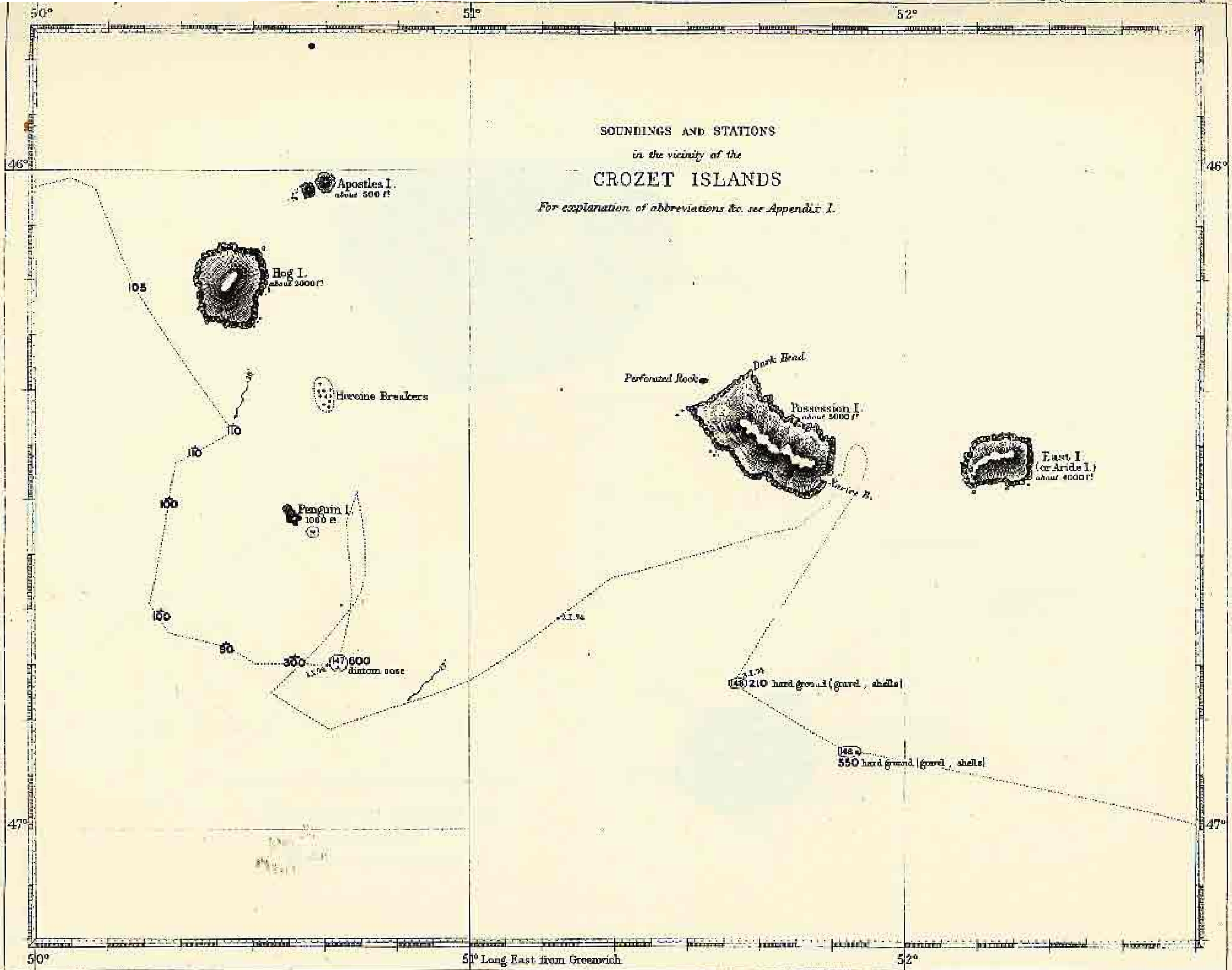
Engraved by Malby & Sons.



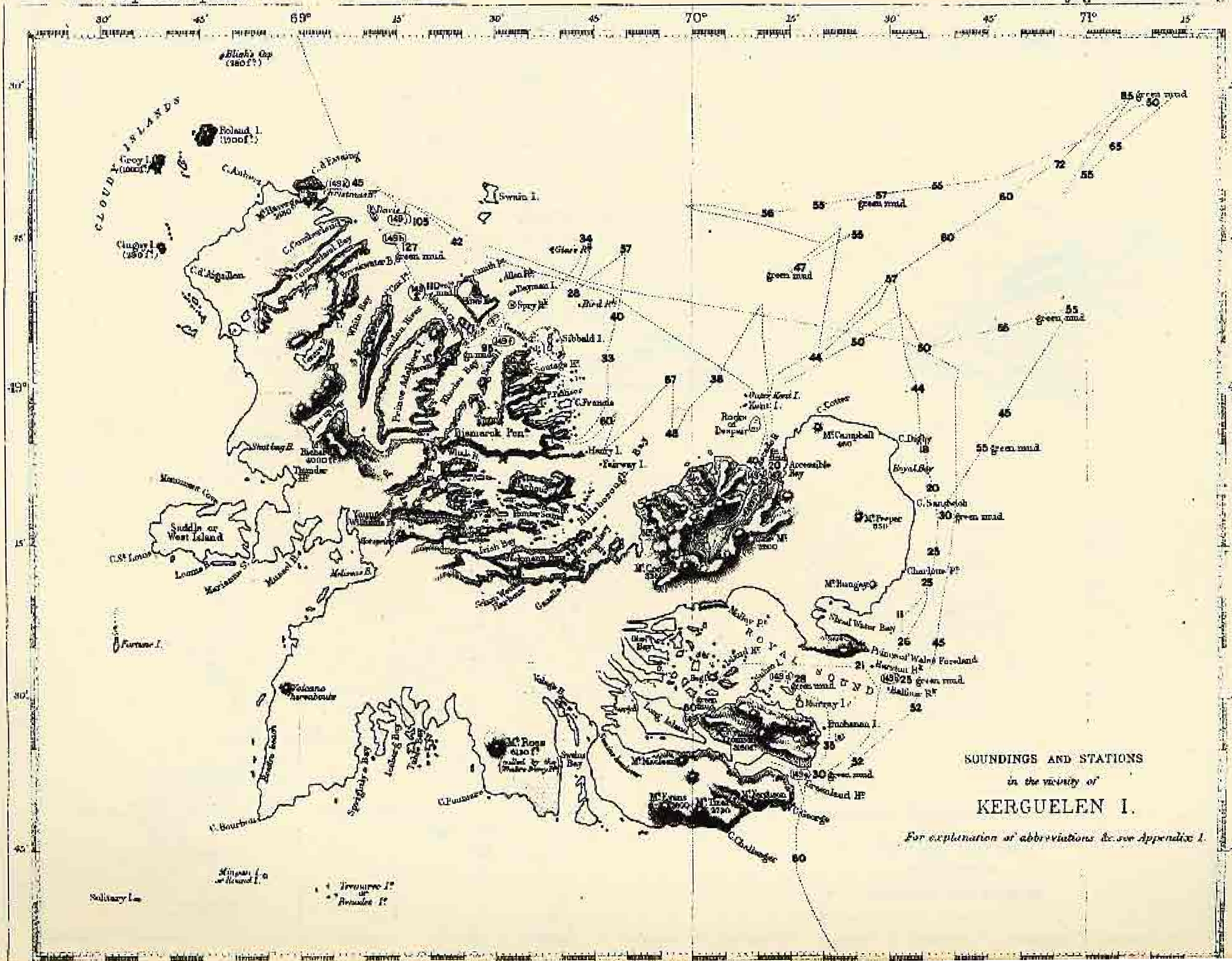
Engraved by Malby & Sons

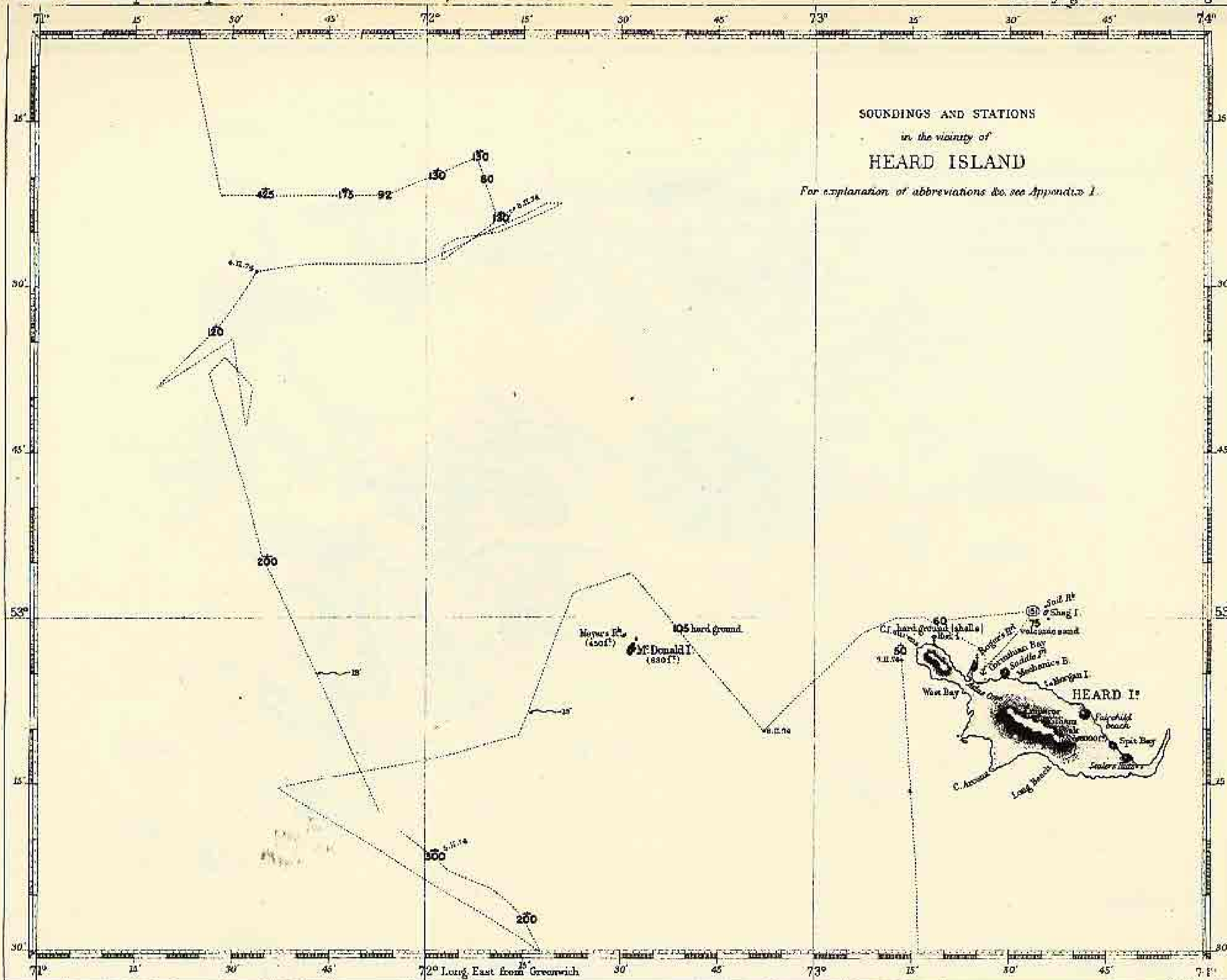


Engraved by Malby & Sons

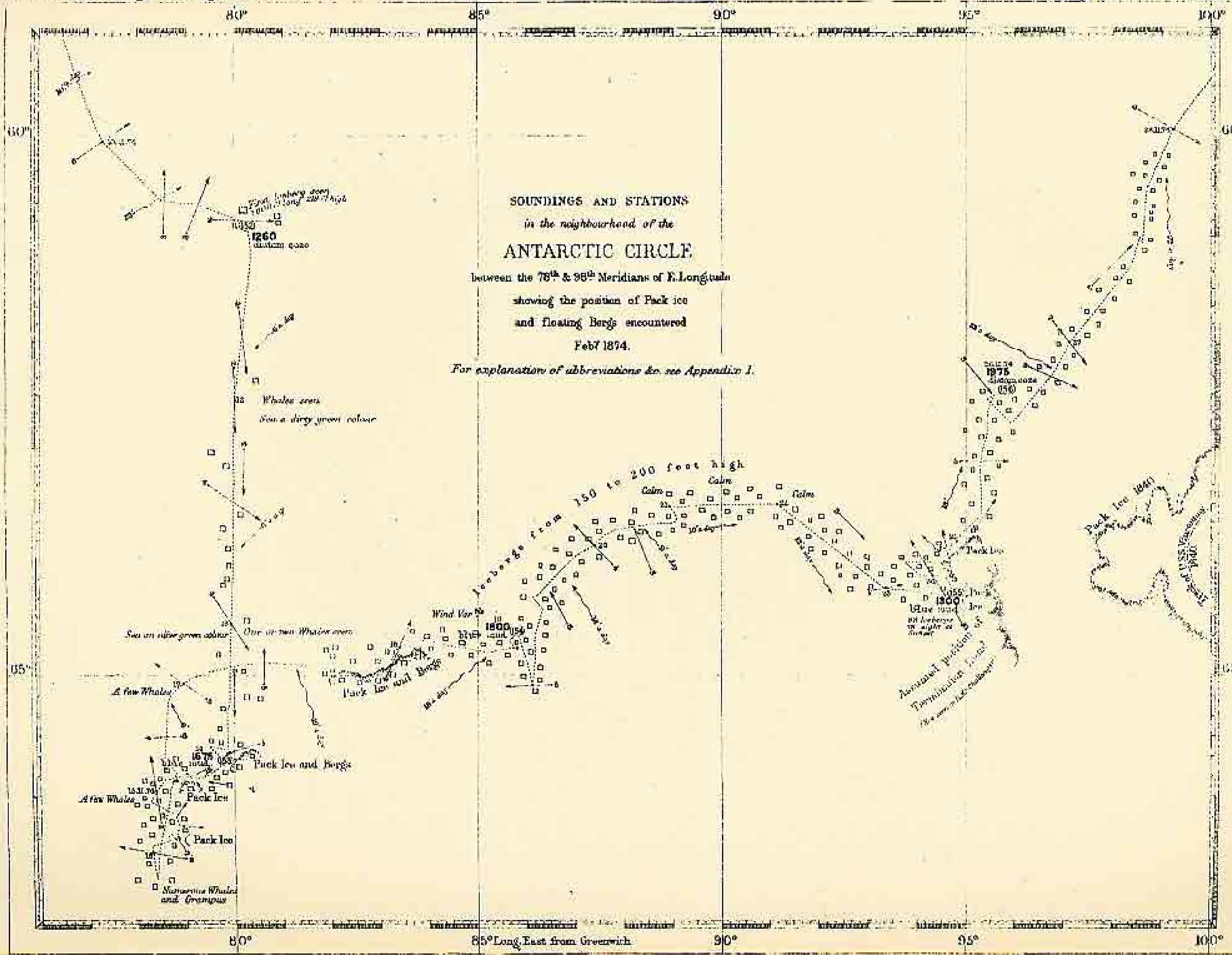


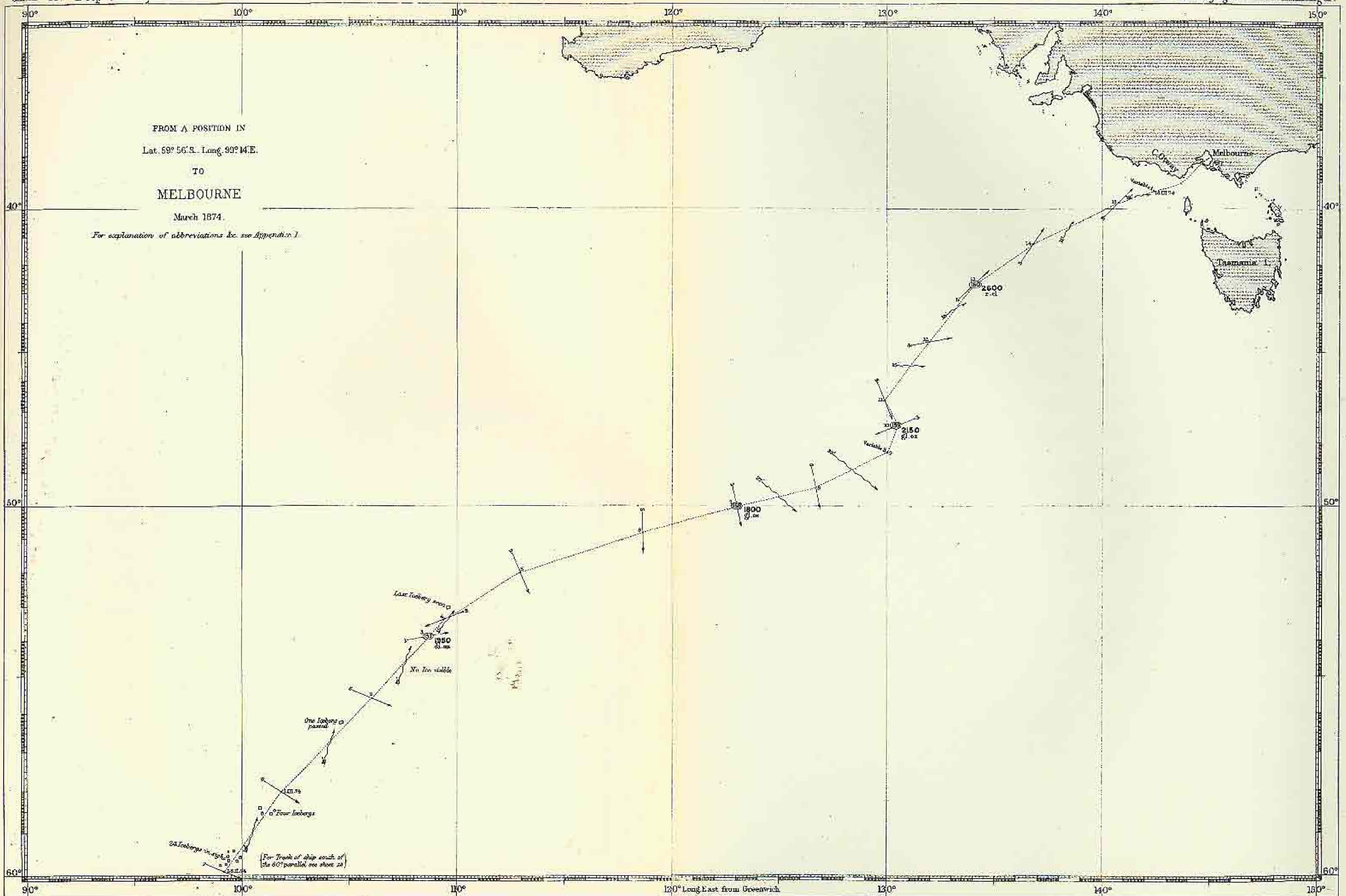
Engraved by Malby & Sons.


69°
70°
71°
49°
Bligh's Cap
CLOUDY ISLANDS
Roland I.
Swain I.
C. d'Aiguillon
White Bay
Sibbald I.
C. Francis
Bismarck Pen.
Henry I.
Fairway I.
Rocks of Despair
Mt Campbell
C. Cotter
C. Digby
Royal Bay
Accessible Bay
C. Sandwich
Mt Peeper
Charlotte Pt
Mt Bungay
Suddle or West Island
C. St Louis
Irish Bay
Fortune I.
Volcano hereabouts
Shoal Water Bay
Prince of Wales Foreland
Murray I.
Buchanan I.
Mt Ross
Swains Bay
C. Bourbon
Mt Evans
C. George
C. Challenger
Solitary I.
Treasure Pt
green mud
SOUNDINGS AND STATIONS
in the vicinity of
KERGUELEN I.
For explanation of abbreviations &c. see Appendix I.

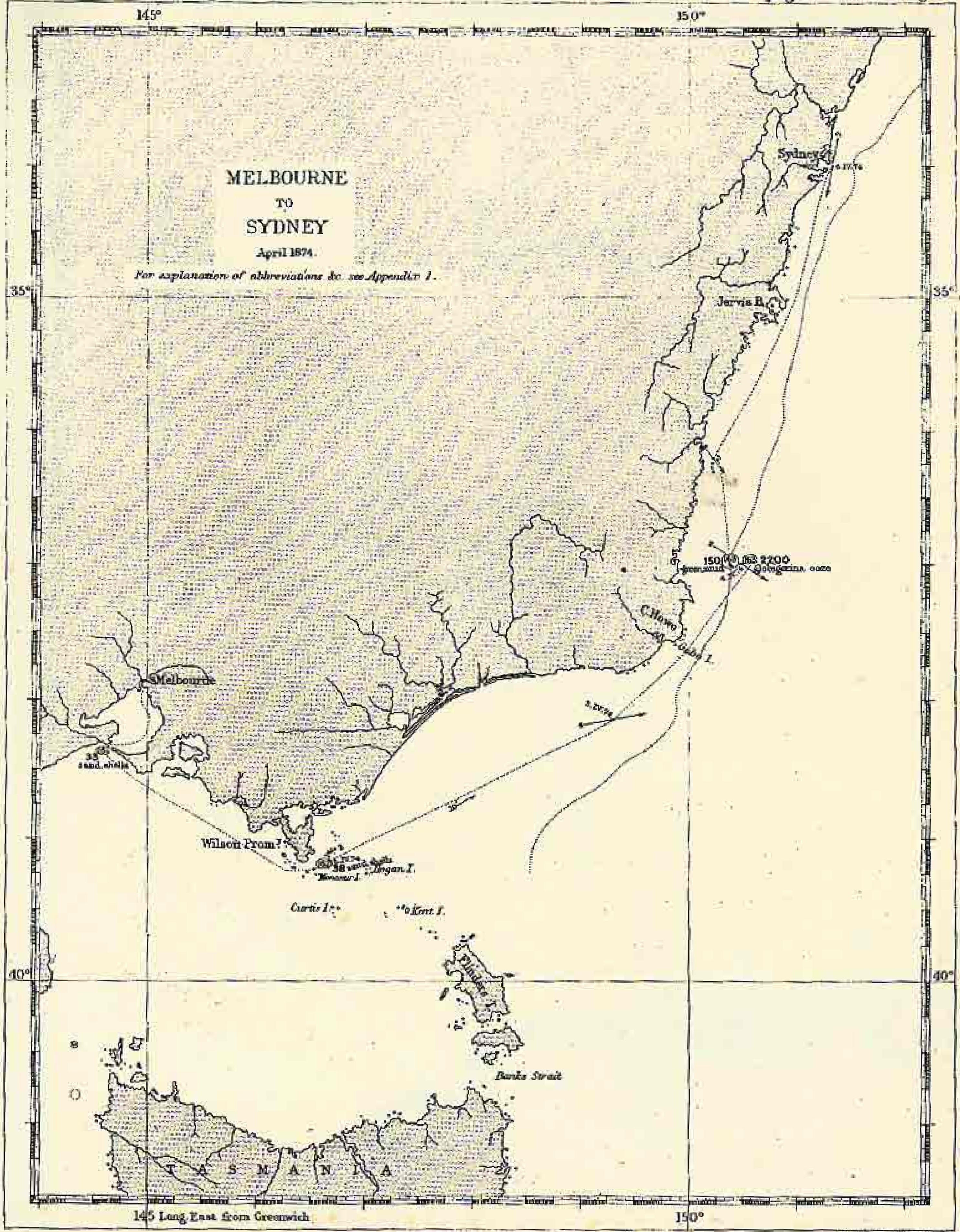


Engraved by Malby & Sons

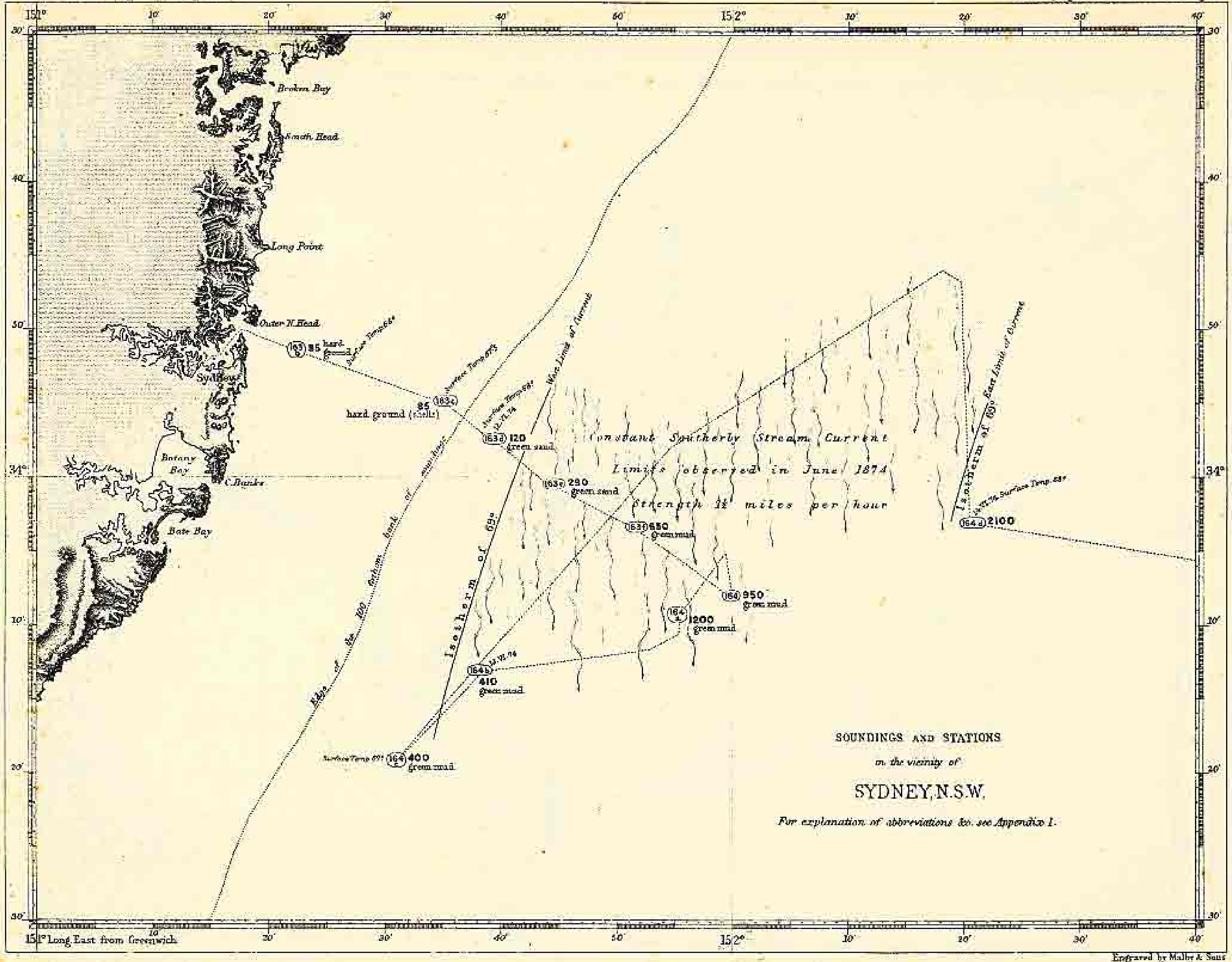

SOUNDINGS AND STATIONS
in the neighbourhood of the
ANTARCTIC CIRCLE
between the 78th & 98th Meridians of E. Longitude
showing the position of Pack ice
and floating Bergs encountered
Feb? 1874.
For explanation of abbreviations &c. see Appendix I.
1260
diatom ooze
Whales seen
Sea a dirty green colour
Sea an olive green colour
One or two Whales seen
A few Whales
Pack Ice and Bergs
Pack Ice
Numerous Whales and Grampus
Icebergs from 150 to 200 feet high
Calm
Wind Var
1800
1300
1975
diatom ooze
Pack Ice
Pack Ice 1840
Assumed position of Termination Land
80°
85°
90°
95°
100°
60°
65°
85° Long. East from Greenwich



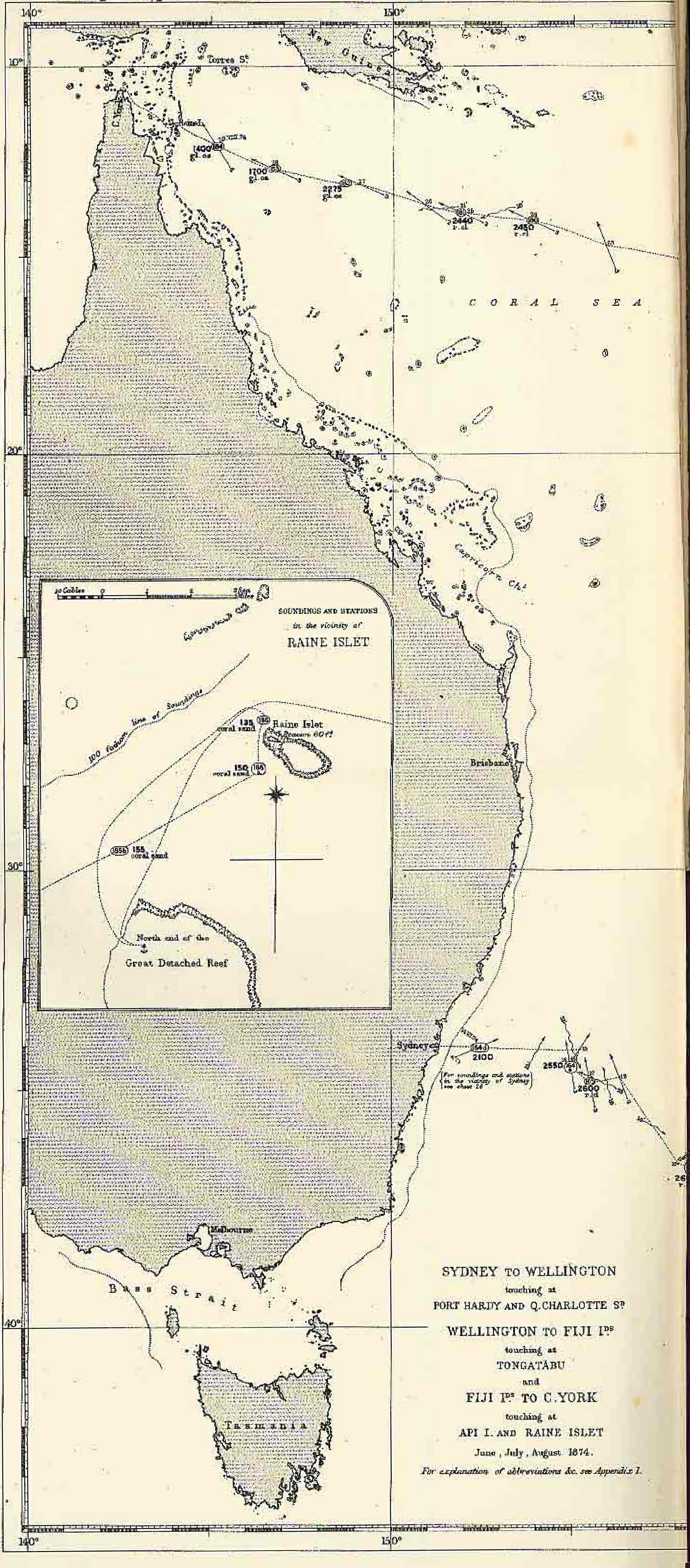
Engraved by Malby & Sons.

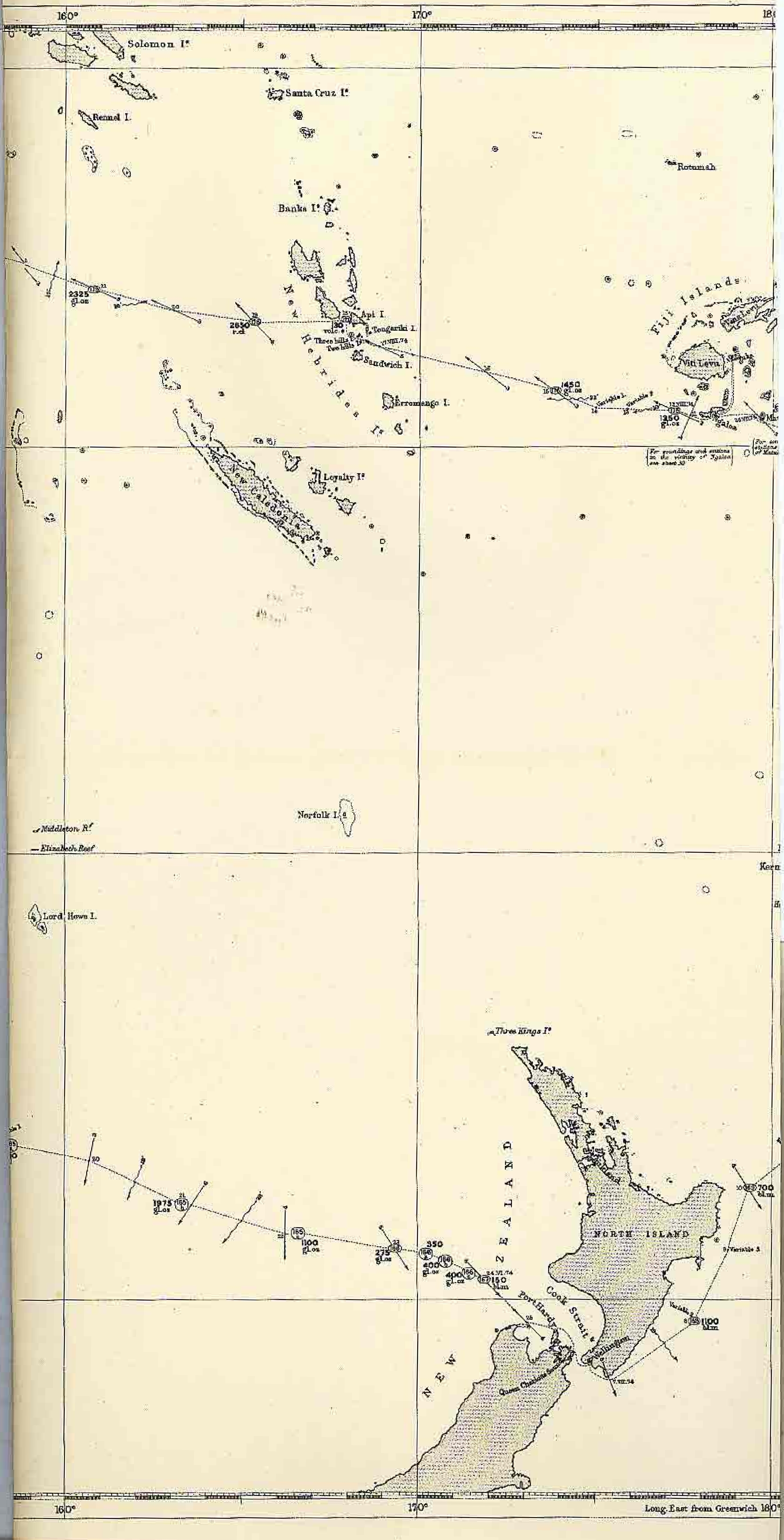


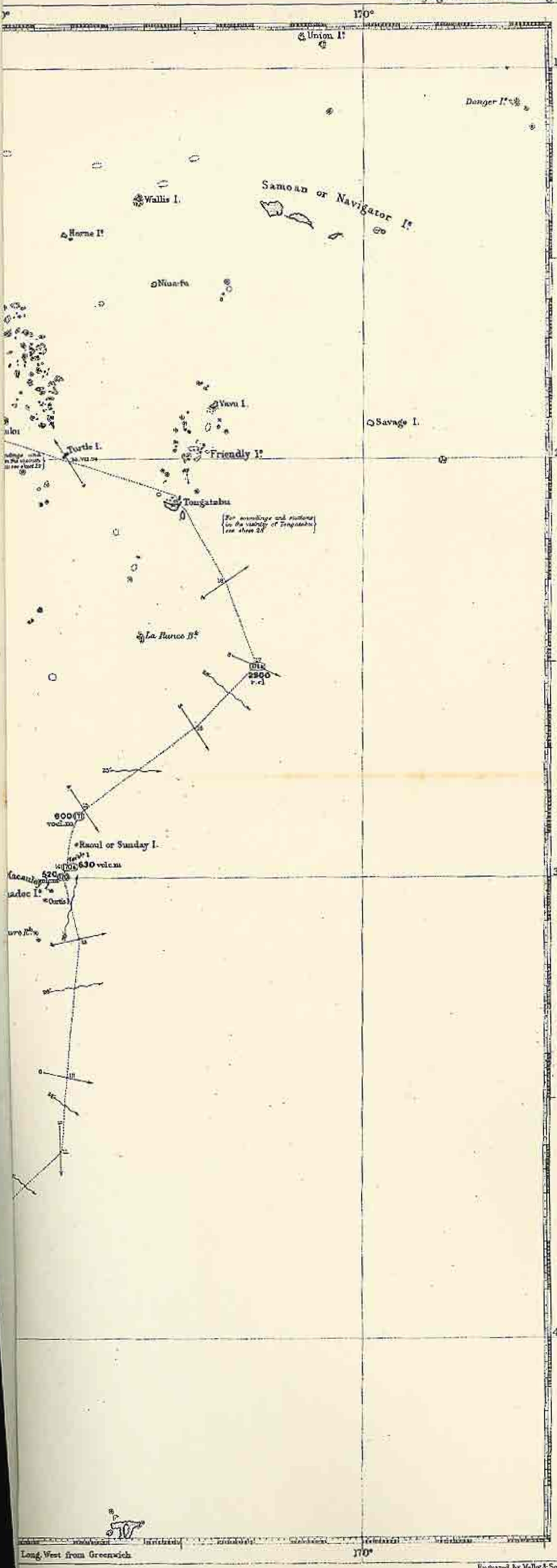
Engraved by Malby & Sons.



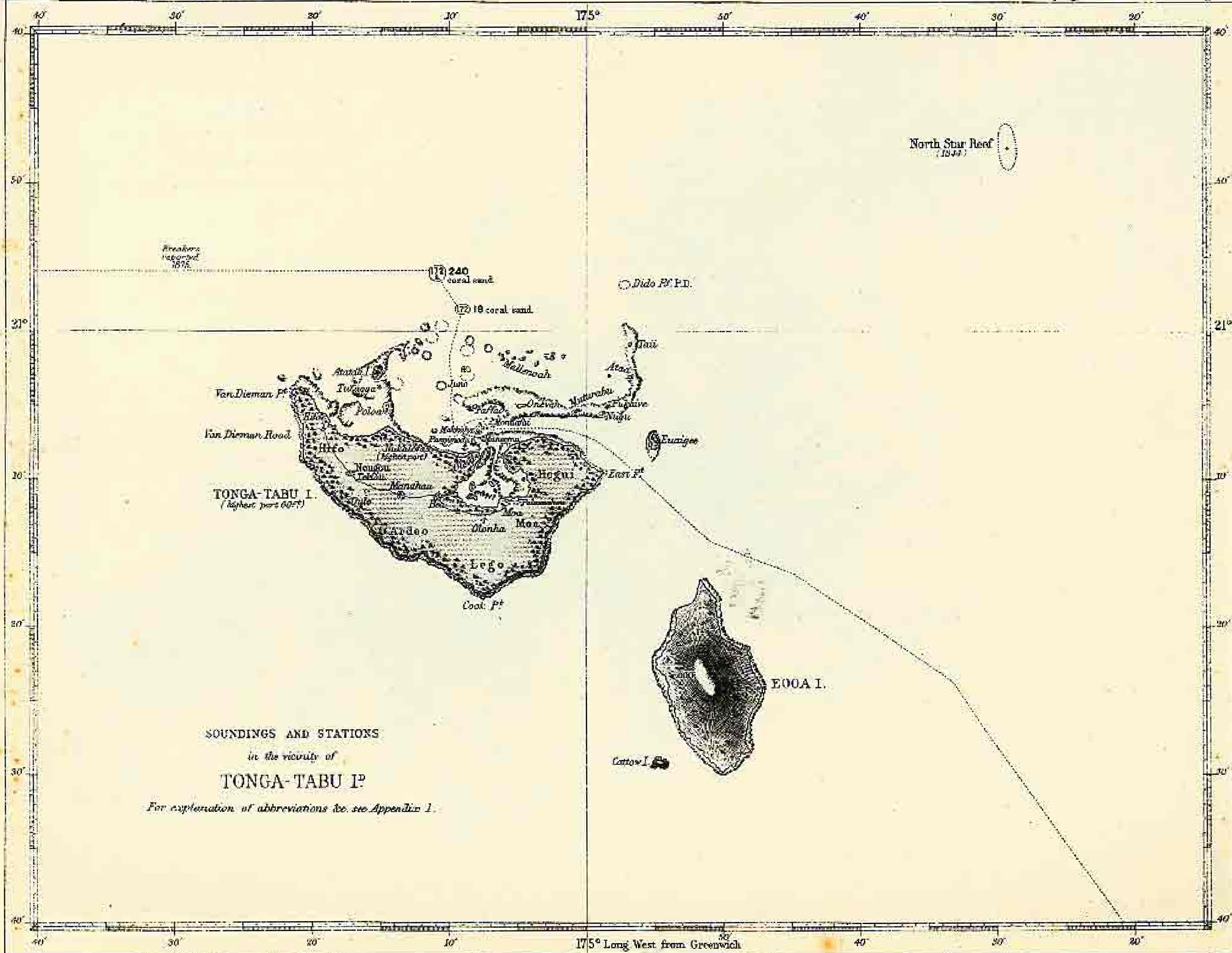
Engraved by Malby & Sons


140°
150°
10°
20°
30°
40°
Torres St
New Guinea
C. York
Raine I.
1400 gl. oz
1700 gl. oz
2275 gl. oz
2440 r. cl.
2450 r. cl.
C O R A L   S E A
Capricorn Chl
SOUNDINGS AND STATIONS in the vicinity of
RAINE ISLET
10 Cables
100 fathom line of Soundings
135 coral sand
Raine Islet
Beacon 60 ft
150 coral sand
155 coral sand
North end of the
Great Detached Reef
Brisbane
Sydney
2100
2550
2600 r. cl.
For soundings and stations in the vicinity of Sydney see sheet 26
Melbourne
Bass Strait
Tasmania
SYDNEY TO WELLINGTON
touching at
PORT HARDY AND Q. CHARLOTTE SD
WELLINGTON TO FIJI IDS
touching at
TONGATABU
and
FIJI IDS TO C. YORK
touching at
API I. AND RAINE ISLET
June, July, August 1874.
For explanation of abbreviations &c. see Appendix I.


160°
170°
Solomon Is
Santa Cruz Is
Rennel I.
Rotumah
Banks Is
New Hebrides Is
Api I.
Tongariki I.
Three hills
Two hills
Sandwich I.
Erromango I.
Fiji Islands
Viti Levu
2325 gl.oz
2650 r.cl
1450 gl.oz
1250 gl.oz
New Caledonia
Loyalty Is
Norfolk I.
Middleton Rf
Elizabeth Reef
Lord Howe I.
Three Kings Is
NEW ZEALAND
NORTH ISLAND
Cook Strait
Port Hardy
Wellington
Queen Charlotte Sound
1975 gl.oz
1100 gl.oz
275 gl.oz
350
400 gl.oz
150 bl.m
700 bl.m
1100 bl.m
Variable
Long. East from Greenwich 180°



Engraved by Malby & Sons.


North Star Reef (1844)
Breakers reported 1875.
(172) 240 coral sand.
(172) 18 coral sand.
Dido Pt. P.D.
Van Dieman Pt.
Van Dieman Road
TONGA-TABU I. (highest part 60 ft.)
Hifo
Ardeo
Lego
Hogui
Cook Pt.
East Pt.
Euaigee
EOOA I.
Cattow I.
Eaii
Atata I.
Mallenoah
Juno
Nukualofa
Monahau
Olonha
Moa
Mua
Fugitive
Night
Atai
Mutaraba
SOUNDINGS AND STATIONS
in the vicinity of
TONGA-TABU Is.
For explanation of abbreviations &c. see Appendix I.
175°
21°
175° Long. West from Greenwich
Engraved by Malby & Sons.

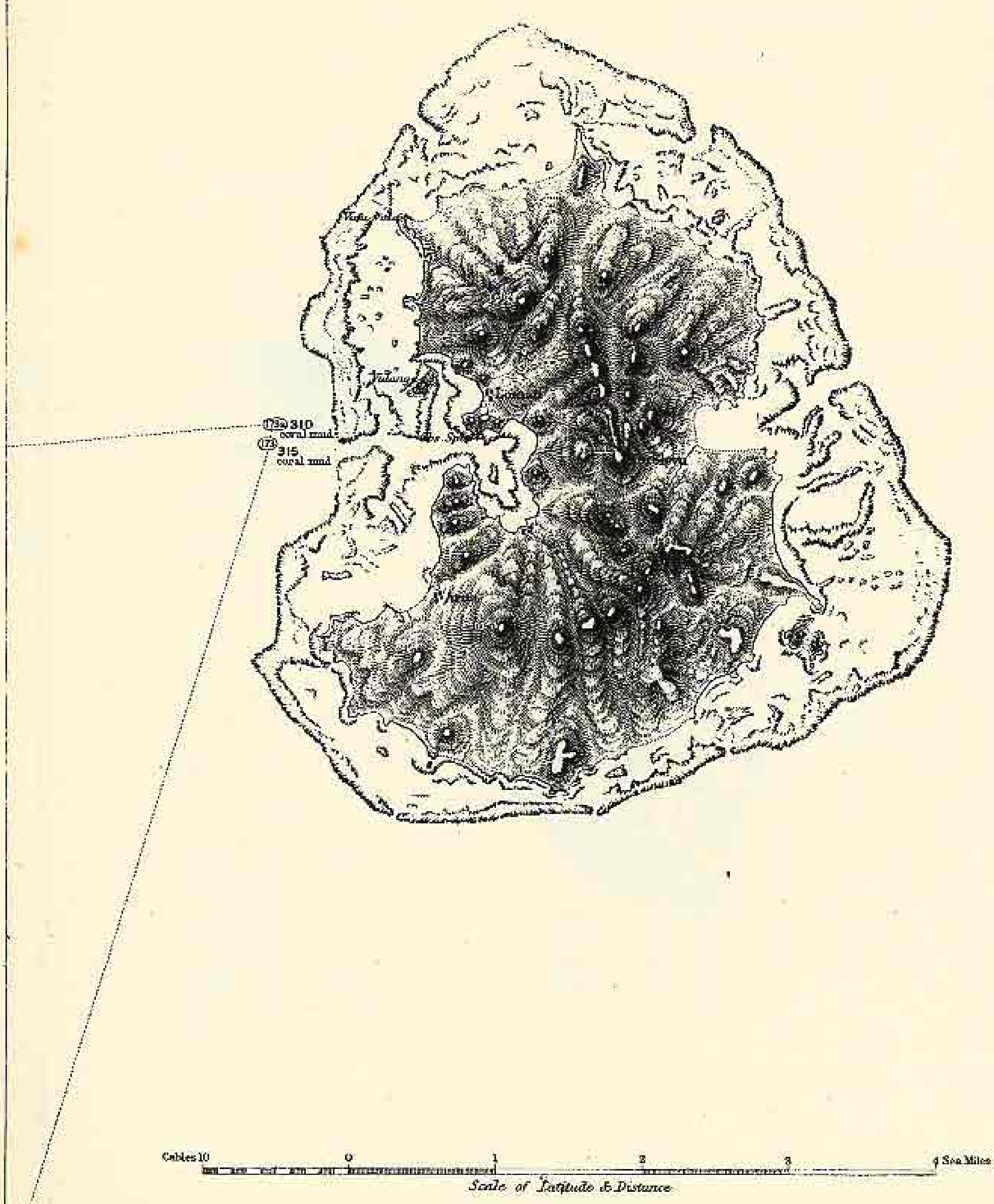
SOUNDINGS AND STATIONS

in the vicinity of

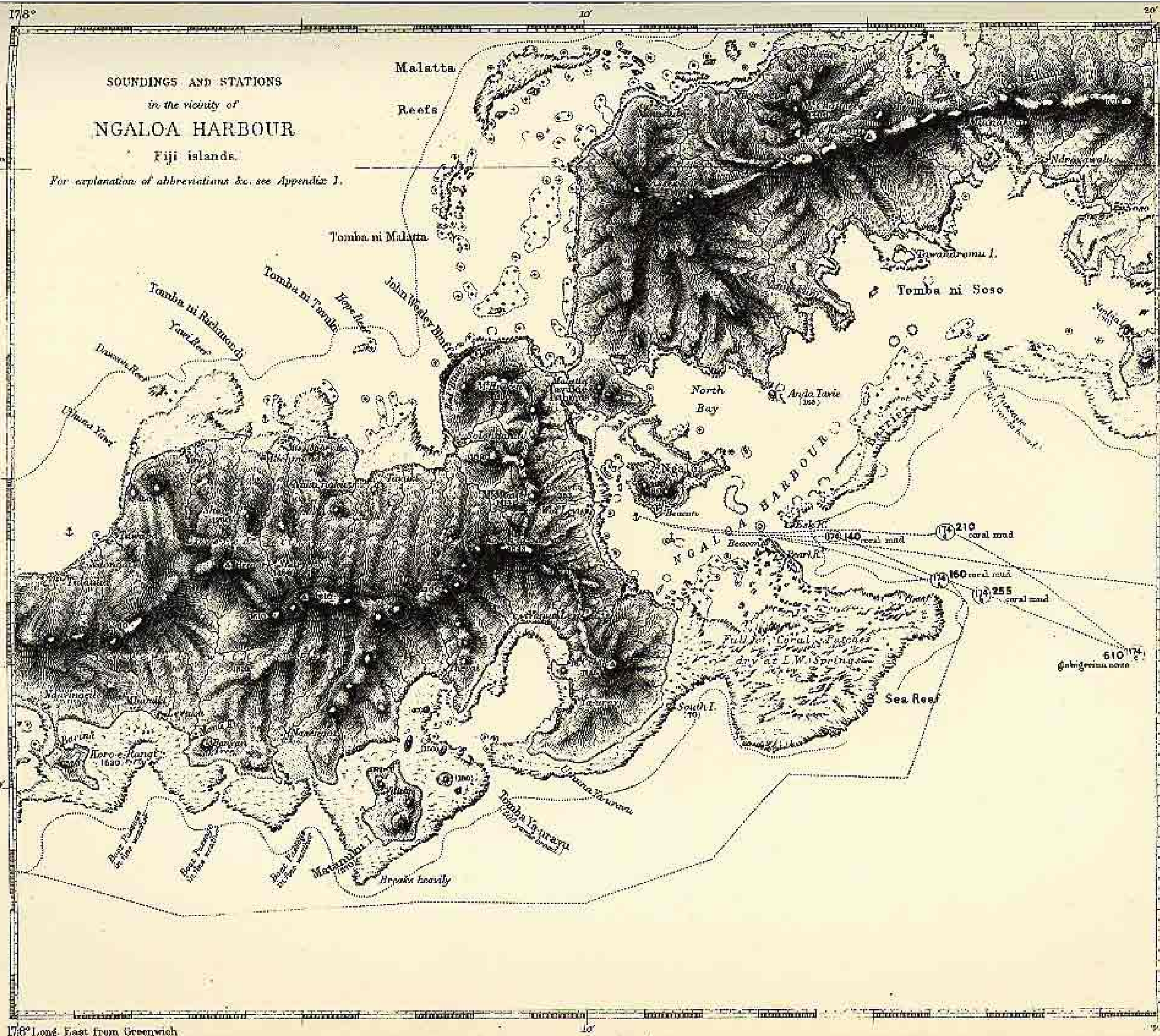
MATUKU ISLAND

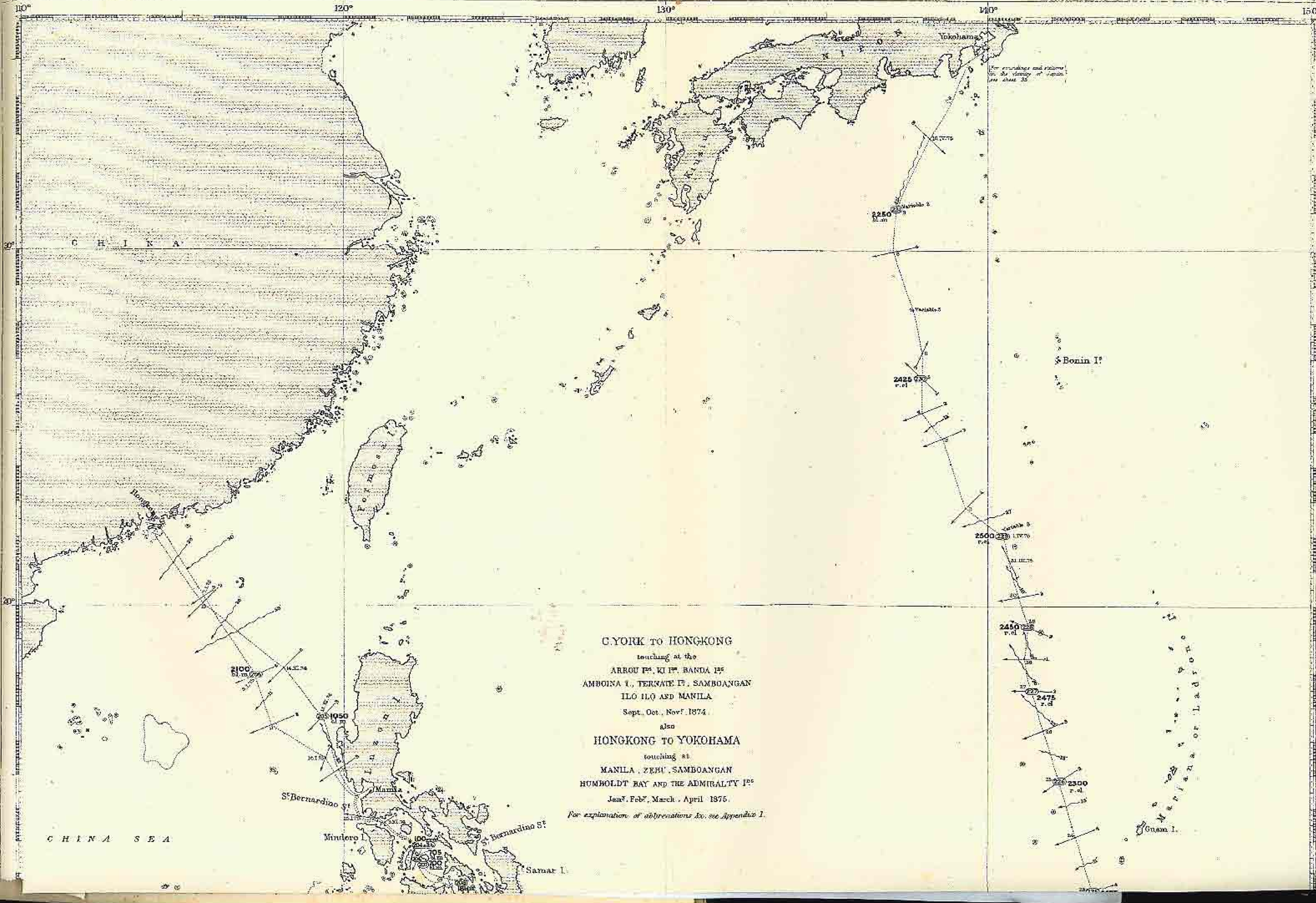
Obs. Spot + Lat. 19°9'36"S. Long. 179°43'23"E.

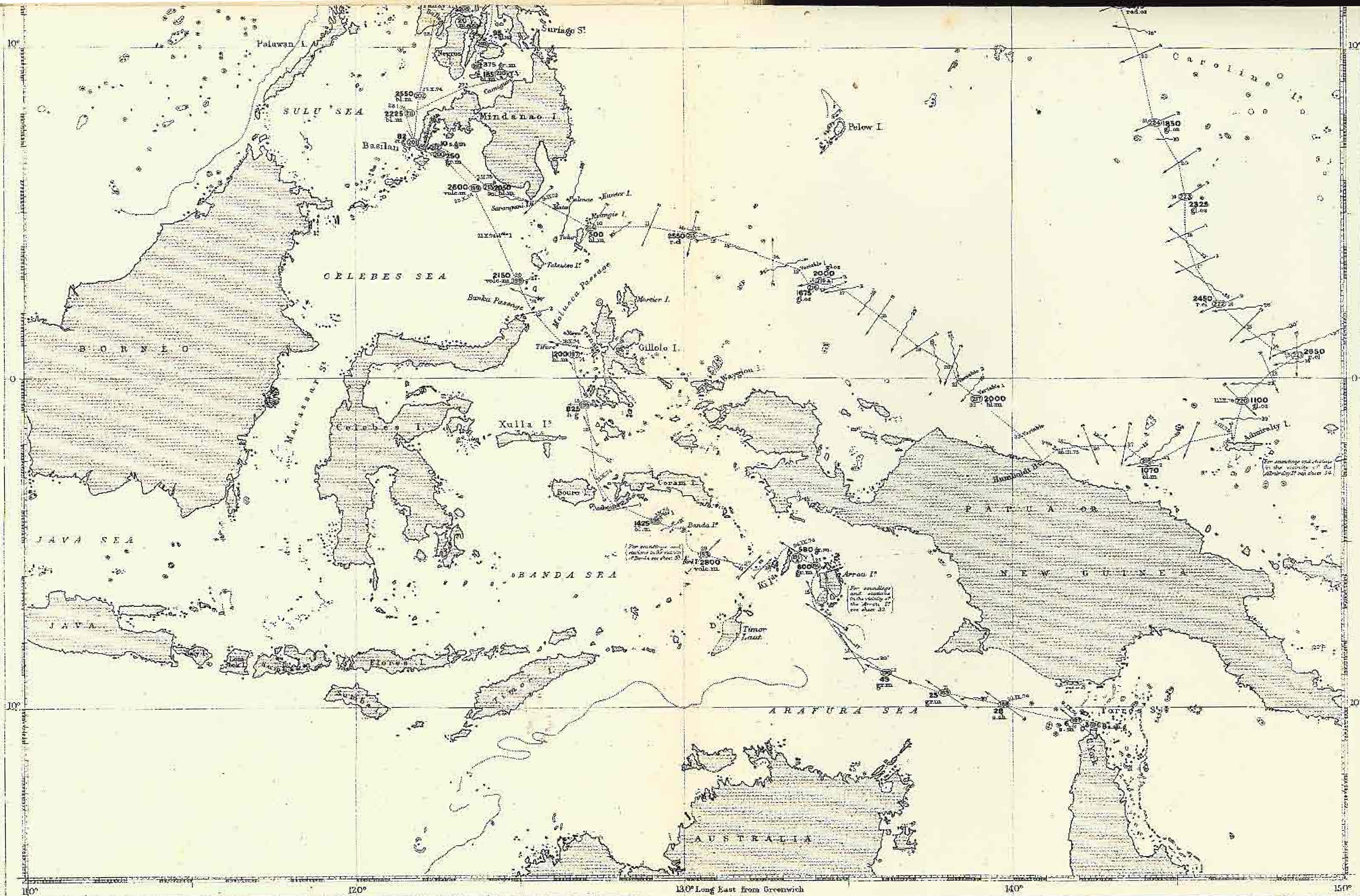
For explanation of abbreviations see Appendix I.



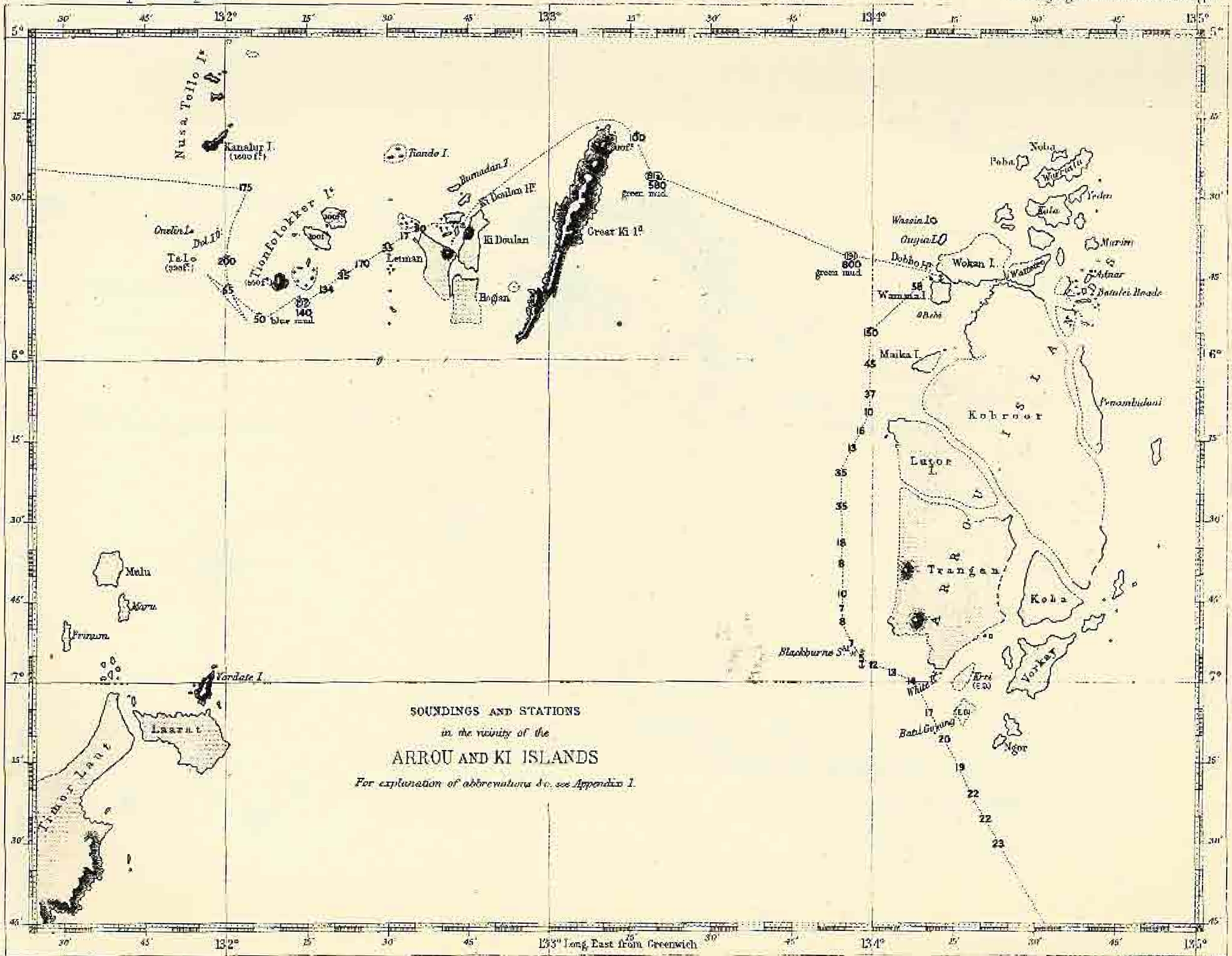
Engraved by Malby & Sons


SOUNDINGS AND STATIONS
in the vicinity of
NGALOA HARBOUR
Fiji islands.
For explanation of abbreviations &c. see Appendix I.
178°
10'
20'
19°
Malatta
Reefs
Tomba ni Malatta
Tomba ni Tavula
Hope Reef
John Wesley Bluff
Tomba ni Richmond
Yawi Reef
Dawson Reef
Ulunna Yawi
Tawandromu I.
Tomba ni Soso
North
Bay
Anda Tavie
NGALOA HARBOUR
Barrier Reef
Beacon
Pearl R.
210 coral mud
140 coral mud
160 coral mud
255 coral mud
610 Globigerina ooze
Full of Coral Patches
dry at L.W. Springs
Sea Reef
South I.
Koro-e-Rangi
Matanuku I.
Breaks heavily
Tomba Yauravu
Ulunna Yauravu
178° Long. East from Greenwich

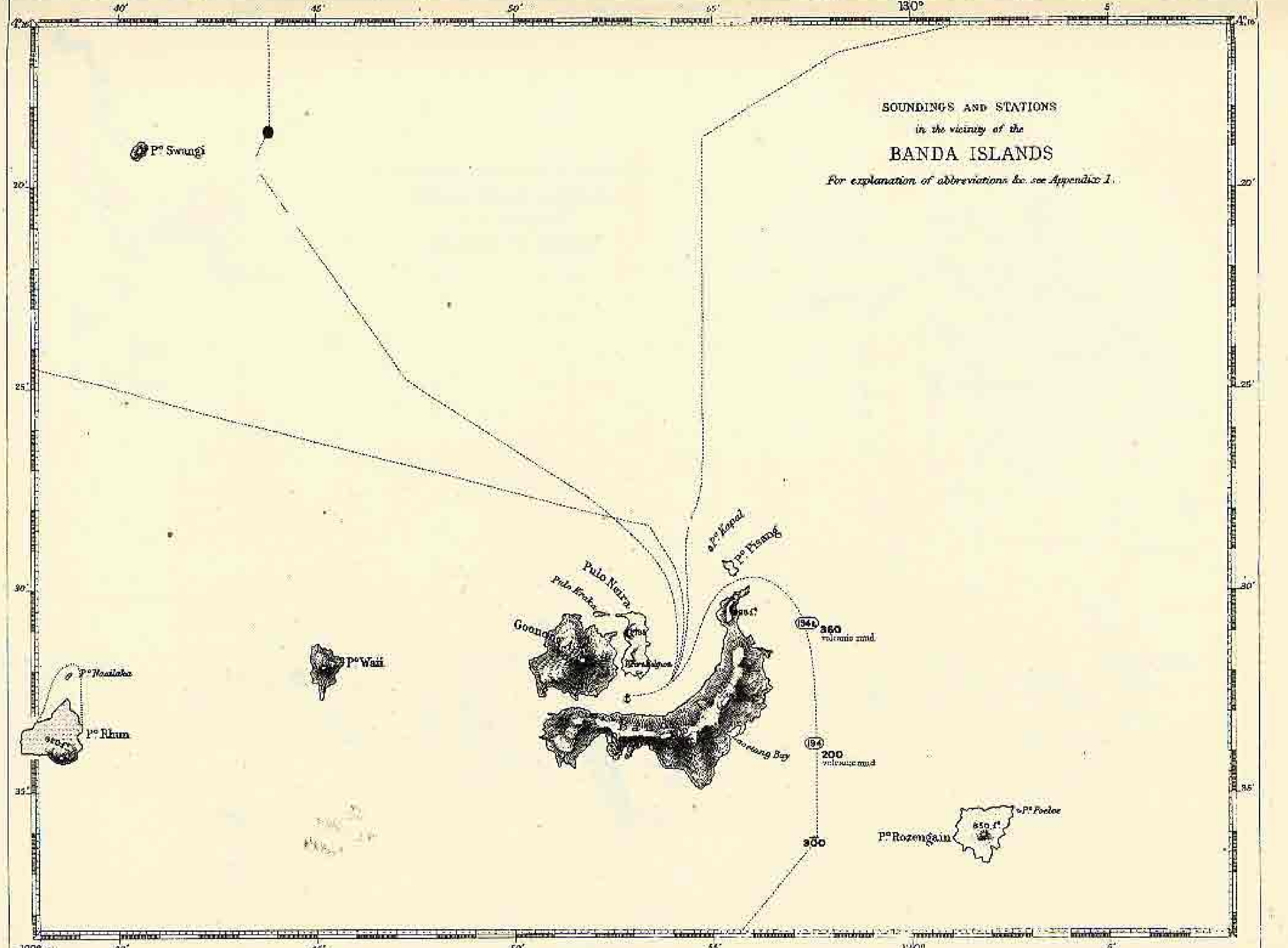

C. YORK TO HONGKONG
touching at the
ARROU Is., KI Is., BANDA Is.
AMBOINA I., TERNATE I., SAMBOANGAN
ILO ILO AND MANILA
Sept., Oct., Novr. 1874.
also
HONGKONG TO YOKOHAMA
touching at
MANILA, ZEBU, SAMBOANGAN
HUMBOLDT BAY AND THE ADMIRALTY Is.
Janr., Febr., March, April 1875.
For explanation of abbreviations &c. see Appendix I.
110°
120°
130°
140°
150°
30°
20°
CHINA
CHINA SEA
NIPON
Yokohama
Kiusiu
Formosa
Hongkong
Luzon
Manila
Mindoro I.
St. Bernardino St.
Samar I.
Bonin Is.
Mariana or Ladrone Is.
Guam I.
2250
2425
2500
2450
2475
2300
2100
1050



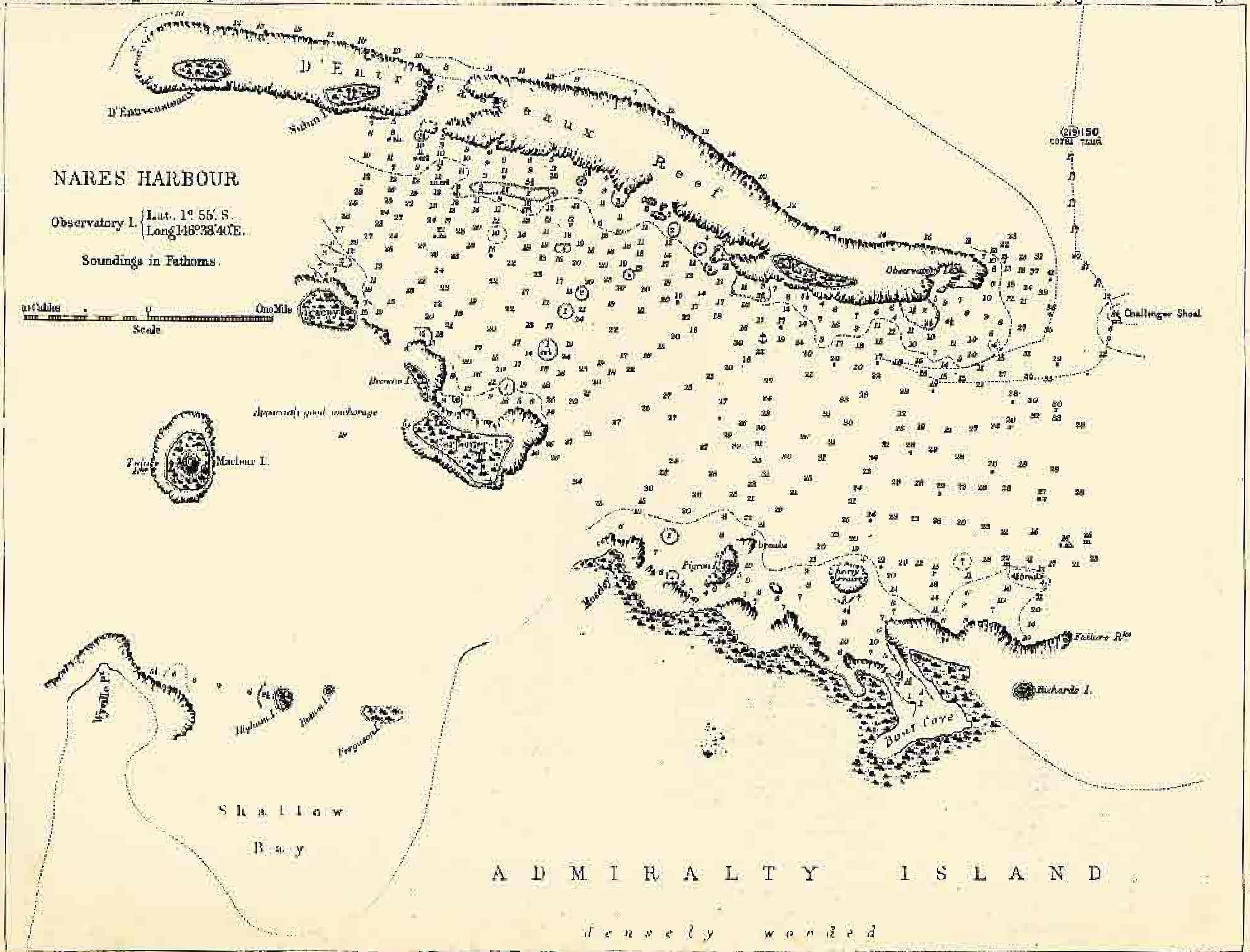
Engraved by Malby & Sons

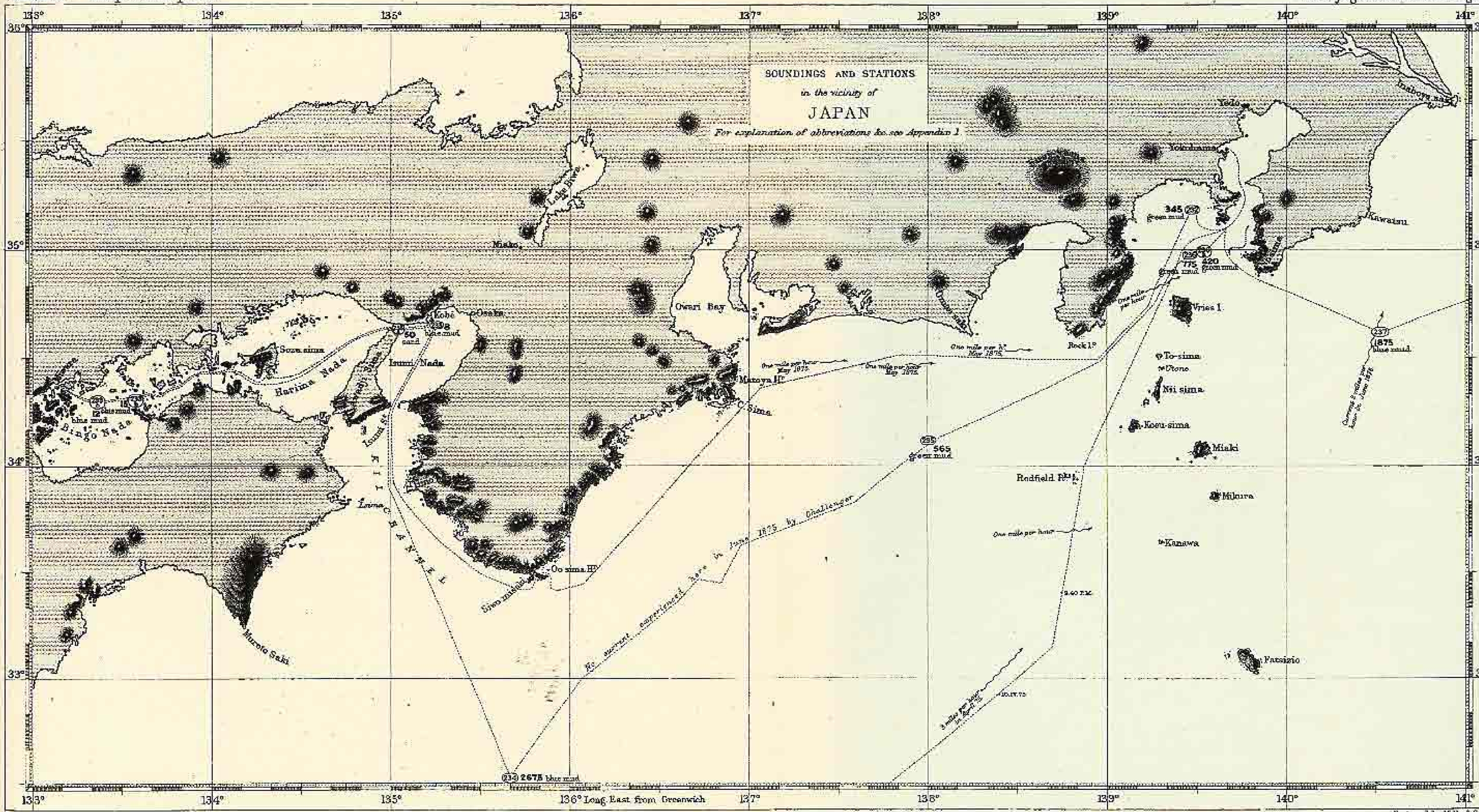


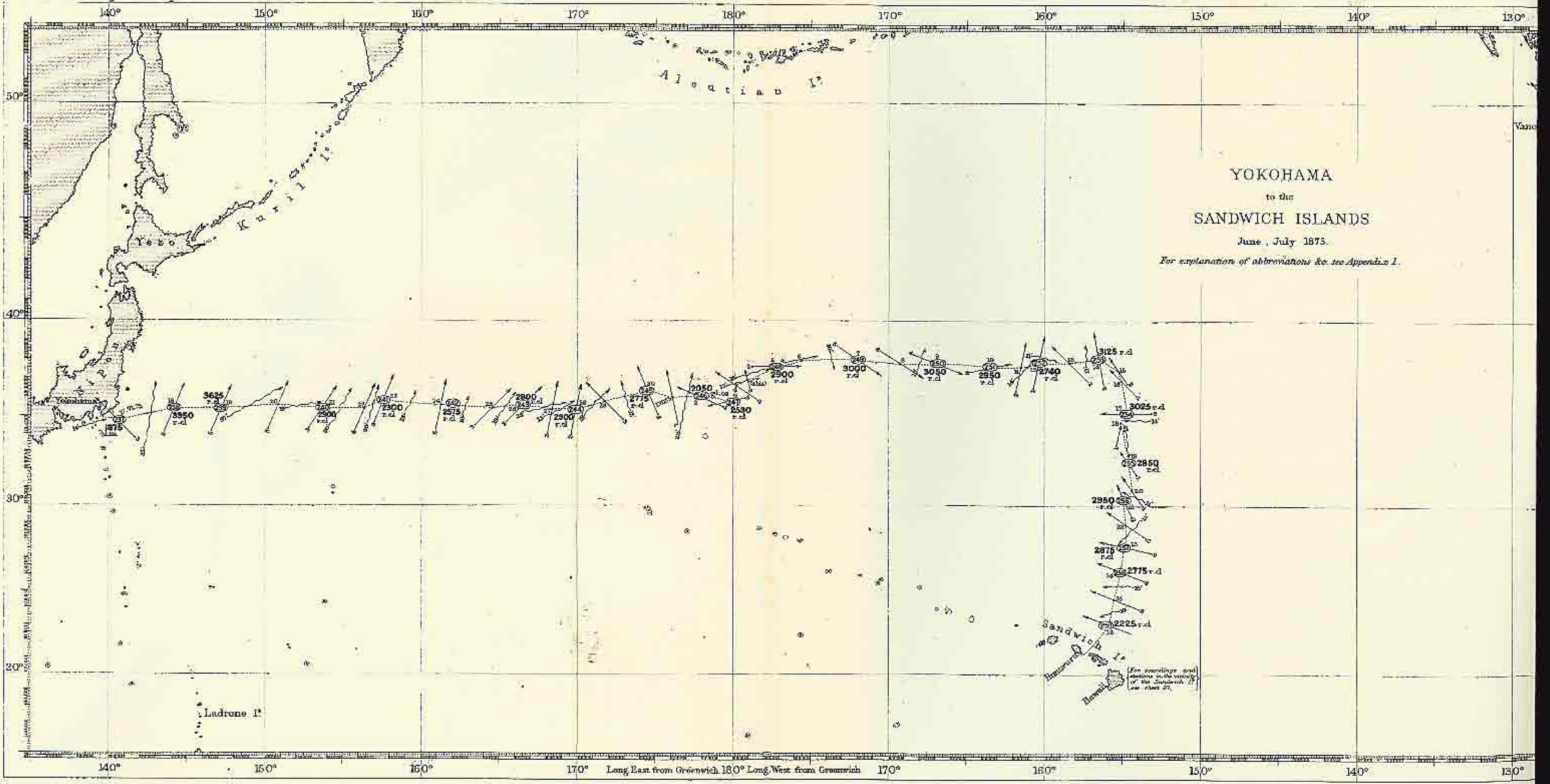
Engraved by Malby & Sons



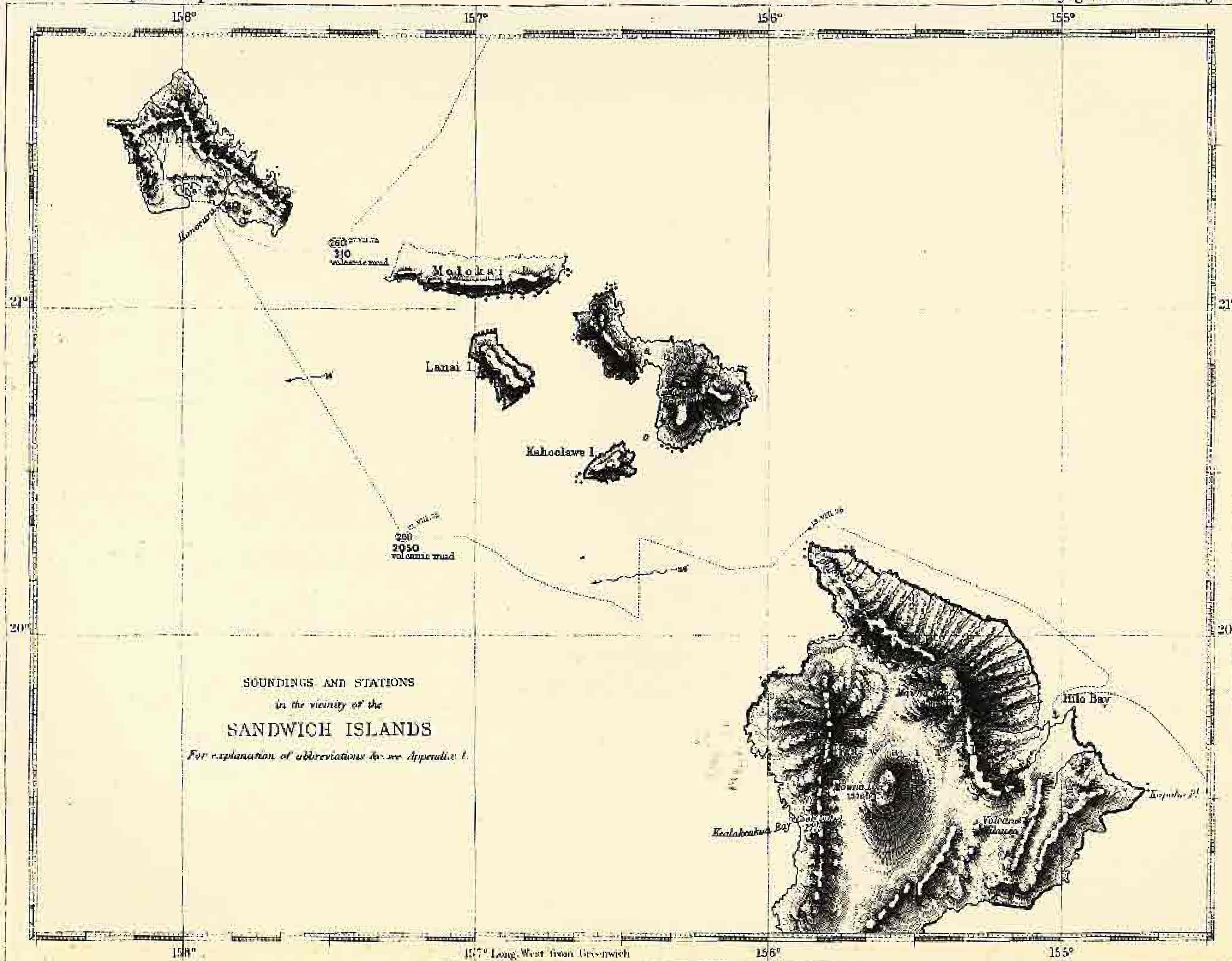
Engraved by Malby & Sons.


NARES HARBOUR
Observatory I. {Lat. 1° 55' S. Long. 146° 38' 40" E.
Soundings in Fathoms.
One Mile
Scale
D'Entrecasteaux Reef
Observatory I.
Challenger Shoal
Brown I.
Apparently good anchorage
Maclure I.
Wyville Pt.
Ferguson I.
Pigeon I.
Failure Rks.
Richards I.
Boat Cove
Shallow Bay
ADMIRALTY ISLAND
densely wooded

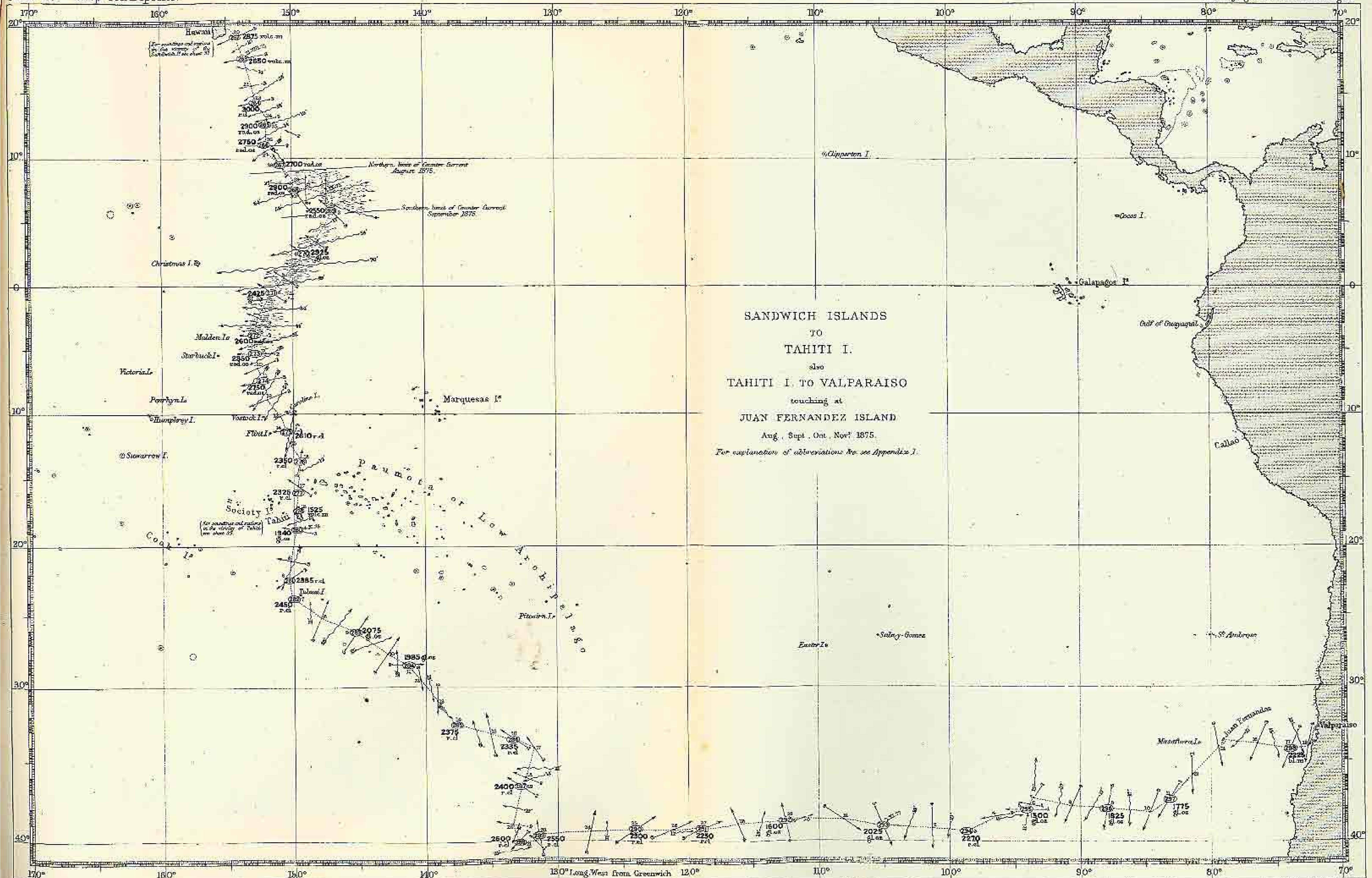

SOUNDINGS AND STATIONS
in the vicinity of
JAPAN
For explanation of abbreviations &c. see Appendix I.
Yedo
Yokohama
Kawatsu
Vries I.
To-sima
Utone
Nii sima
Kozu-sima
Miaki
Mikura
Kanawa
Fatsizio
Redfield Rks.
Rock I.
Owari Bay
Matoya Hd.
C. Sima
Oo sima Hd.
Osaka
Kobé
Harima Nada
Isumi Nada
Isumi St.
KII CHANNEL
Bingo Nada
Muroto Saki
Miako
Lake Biwa
Sozu sima
345 green mud
775 green mud
420 green mud
1875 blue mud
565 green mud
2675 blue mud
50 sand
8 blue mud
12 blue mud
No current experienced here in June 1875 by Challenger
One mile per hour
One mile per hour May 1875
136° Long. East from Greenwich
Engraved by Malby & Sons.


YOKOHAMA
to the
SANDWICH ISLANDS
June, July 1875.
For explanation of abbreviations &c. see Appendix I.
Aleutian Is.
Kuril Is.
Yezo
Nipon
Yokohama
Sandwich Is.
Hawaii
Ladrone Is.
Long. East from Greenwich 180° Long. West from Greenwich
140°
150°
160°
170°
180°
130°
50°
40°
30°
20°

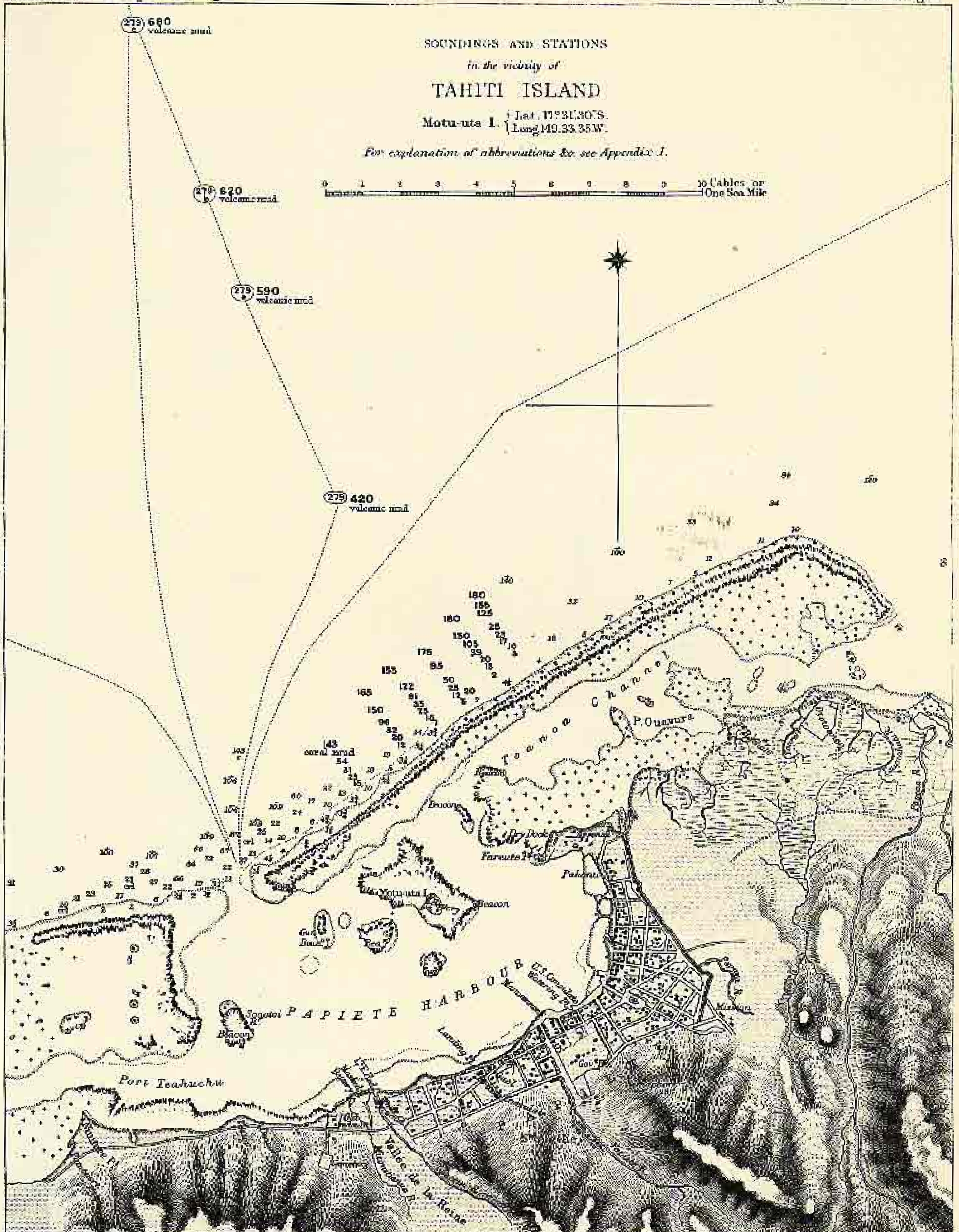

120°
110°
50°
40°
30°
20°
ouver I.
San Francisco
120°
110°
Engraved by Malby & Sons.



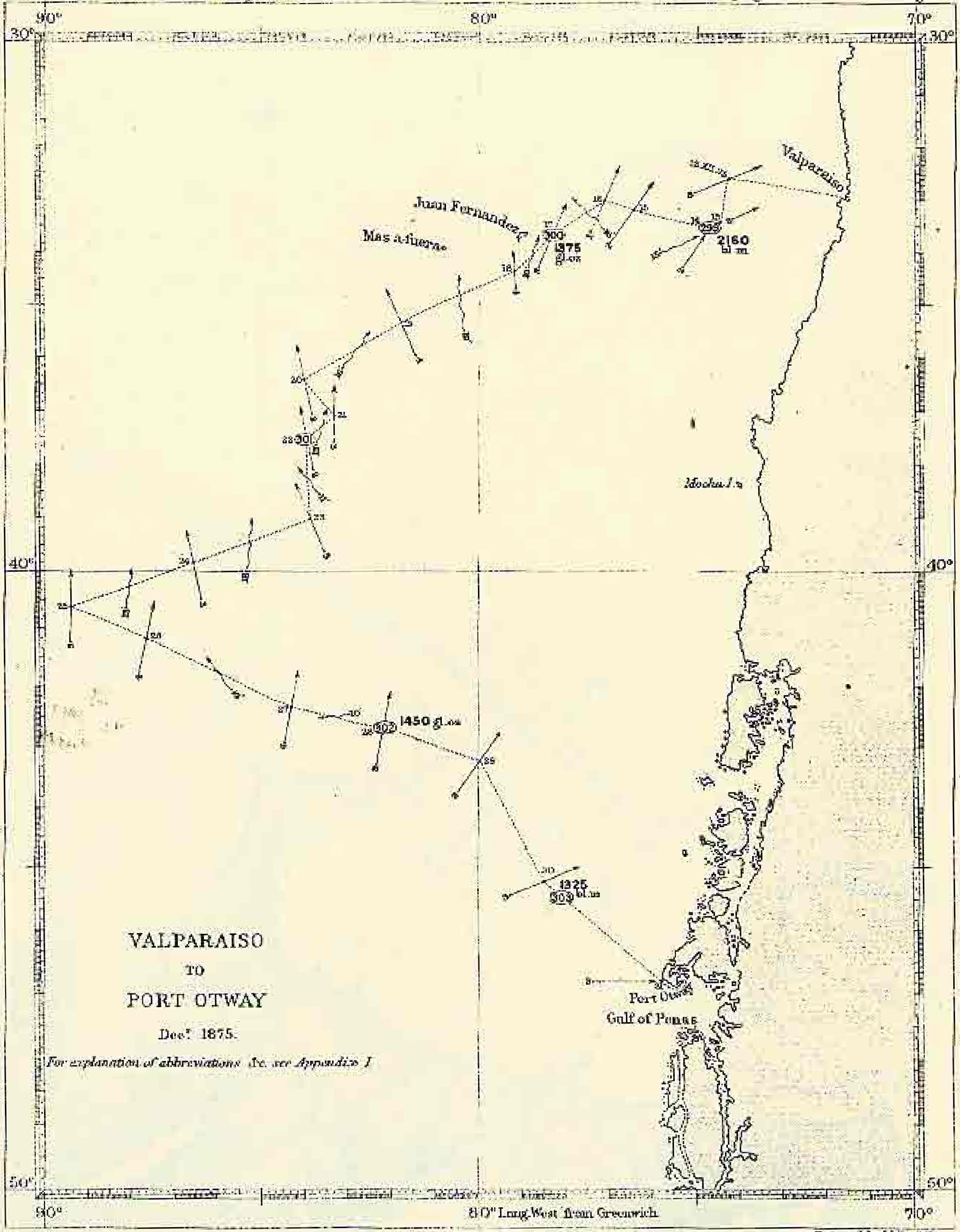
Engraved by Malby & Sons

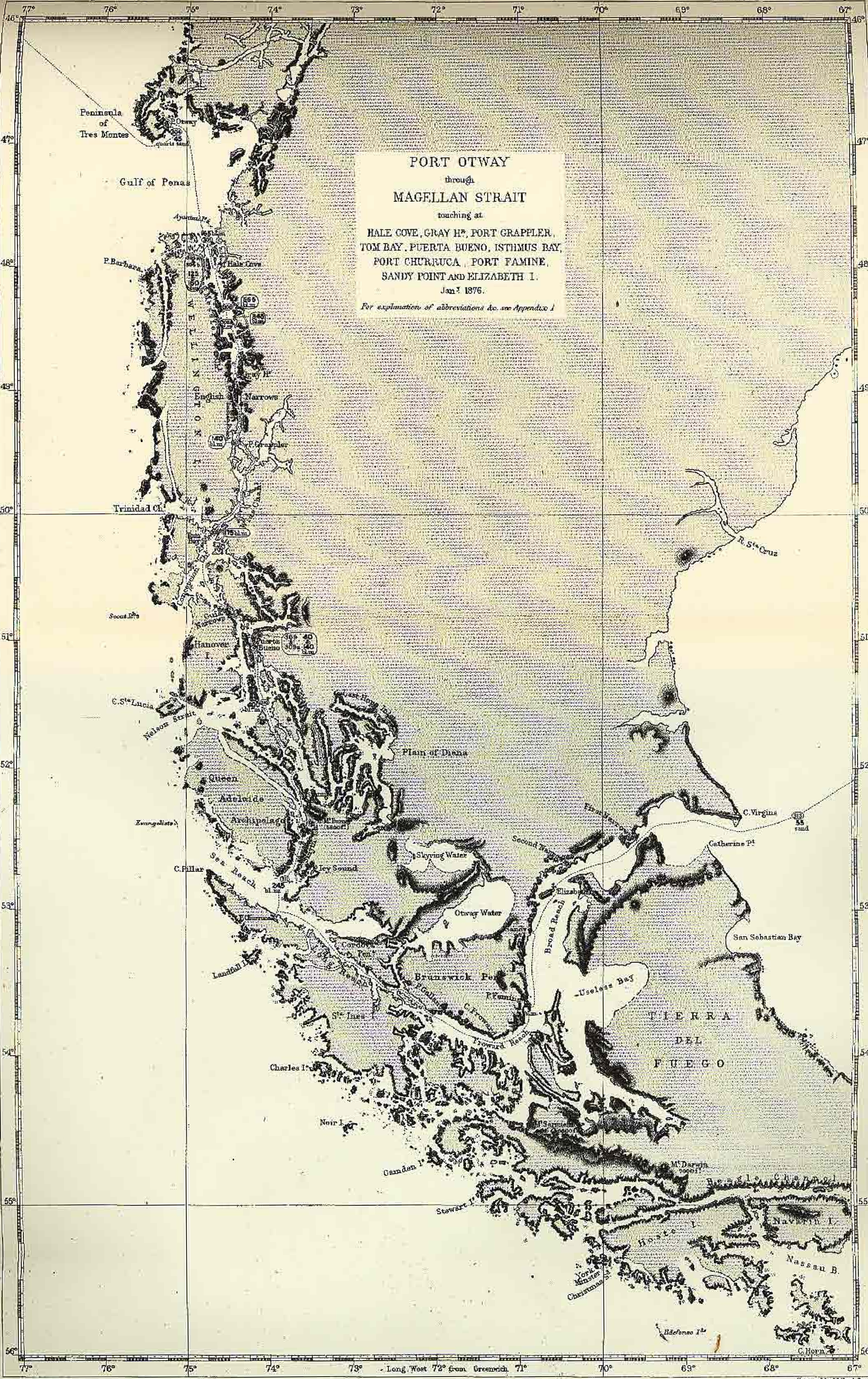


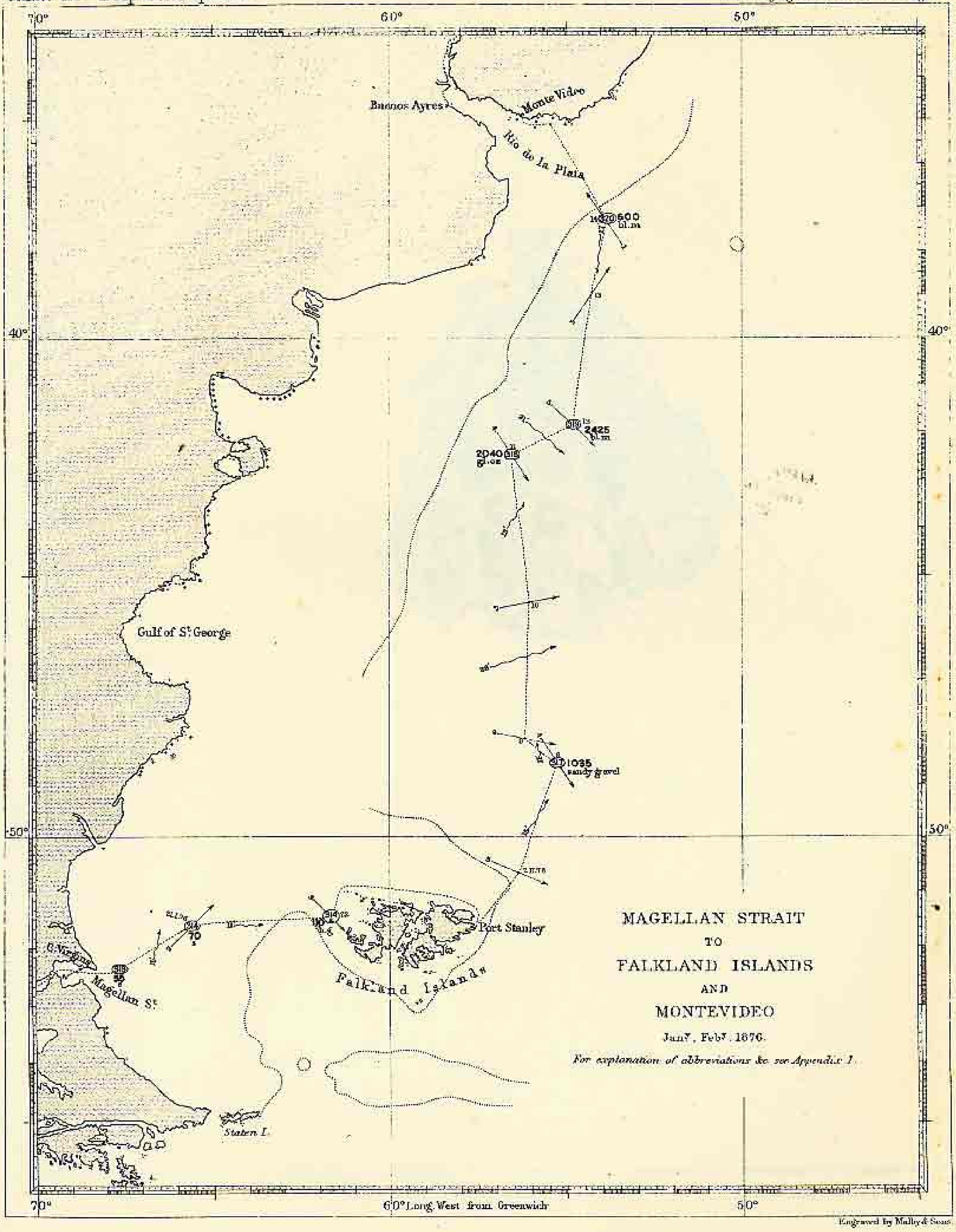
Engraved by Malby & Sons.



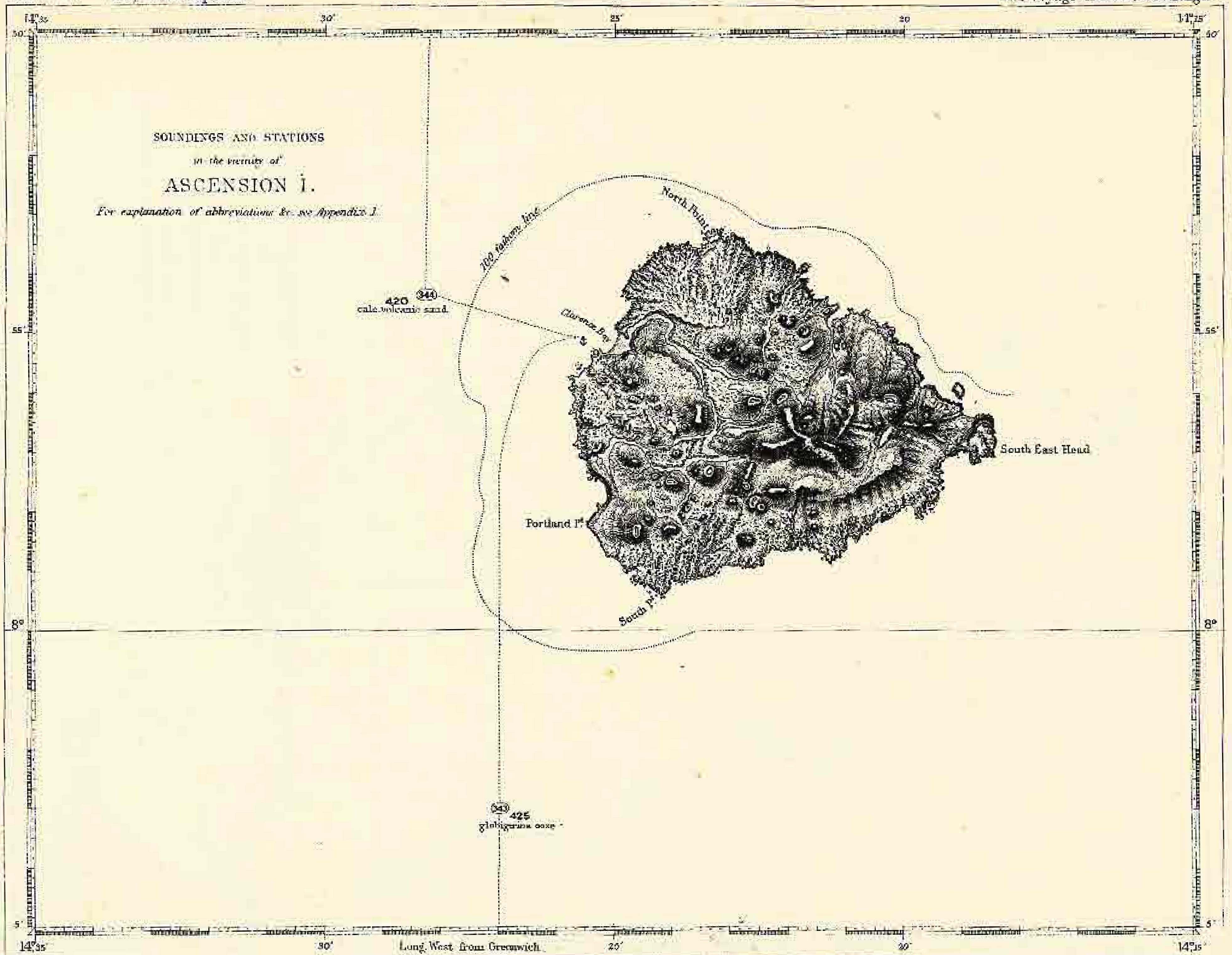
Engraved by Malby & Sons.


Valparaiso
Juan Fernandez
Mas a fuera
2160 bl.m
1375 gl.oz
Mocha I.
1450 gl.oz
1325 bl.m
Port Otway
Gulf of Penas
VALPARAISO
TO
PORT OTWAY
Decr. 1875.
For explanation of abbreviations &c. see Appendix I.
80° Long. West from Greenwich
30°
40°
50°
90°
80°
70°


PORT OTWAY
through
MAGELLAN STRAIT
touching at
HALE COVE, GRAY H^r, PORT GRAPPLER,
TOM BAY, PUERTA BUENO, ISTHMUS BAY,
PORT CHURRUCA, PORT FAMINE,
SANDY POINT AND ELIZABETH I.
Jan^y 1876.
For explanation of abbreviations &c. see Appendix I
Peninsula of Tres Montes
Gulf of Penas
P. Barbara
Hale Cove
English Narrows
P. Grappler
Trinidad Ch.
R. S^ta Cruz
Hanover I.
C. S^ta Lucia
Nelson Strait
Plain of Diana
Queen Adelaide Archipelago
C. Virgins
Catherine P^t
Skyring Water
Icy Sound
C. Pillar
Sea Reach
Otway Water
San Sebastian Bay
Broad Reach
Brunswick Pen^a
P. Famine
Useless Bay
TIERRA DEL FUEGO
Froward Reach
Landfall I.
S^ta Inez
Charles I^s
Noir I.
Camden I^s
Stewart I^s
Navarin I.
Hoste I.
Nassau B.
York Minster
Christmas S^d
C. Horn
Long. West 72° from Greenwich
Engraved by Malby & Sons



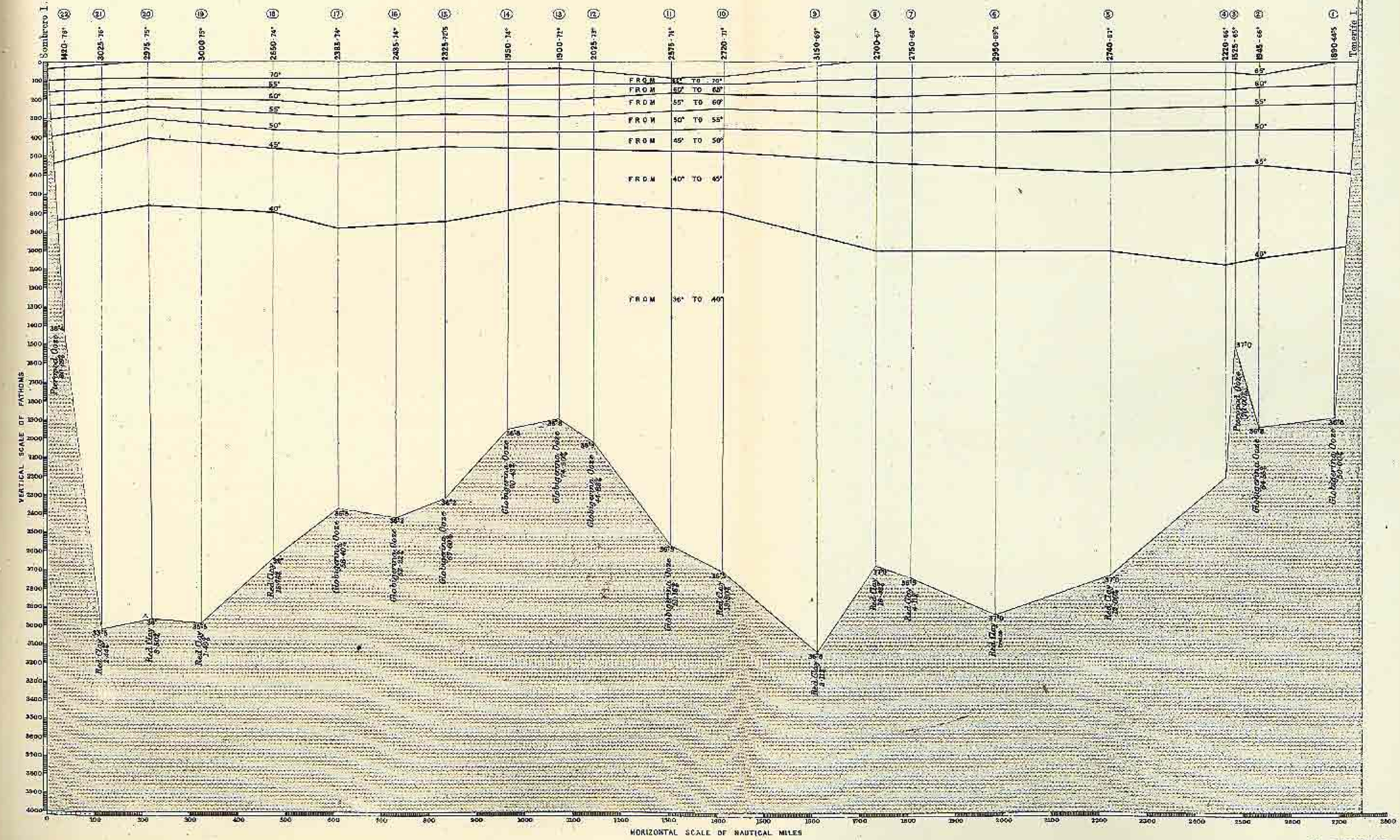
Engraved by Malby & Sons.



Engraved by Malby & Sons

ATLANTIC OCEAN Longitudinal Temperature Section Tenerife I. to Sombrero I.

For Explanation of Symbols see Appendix I.

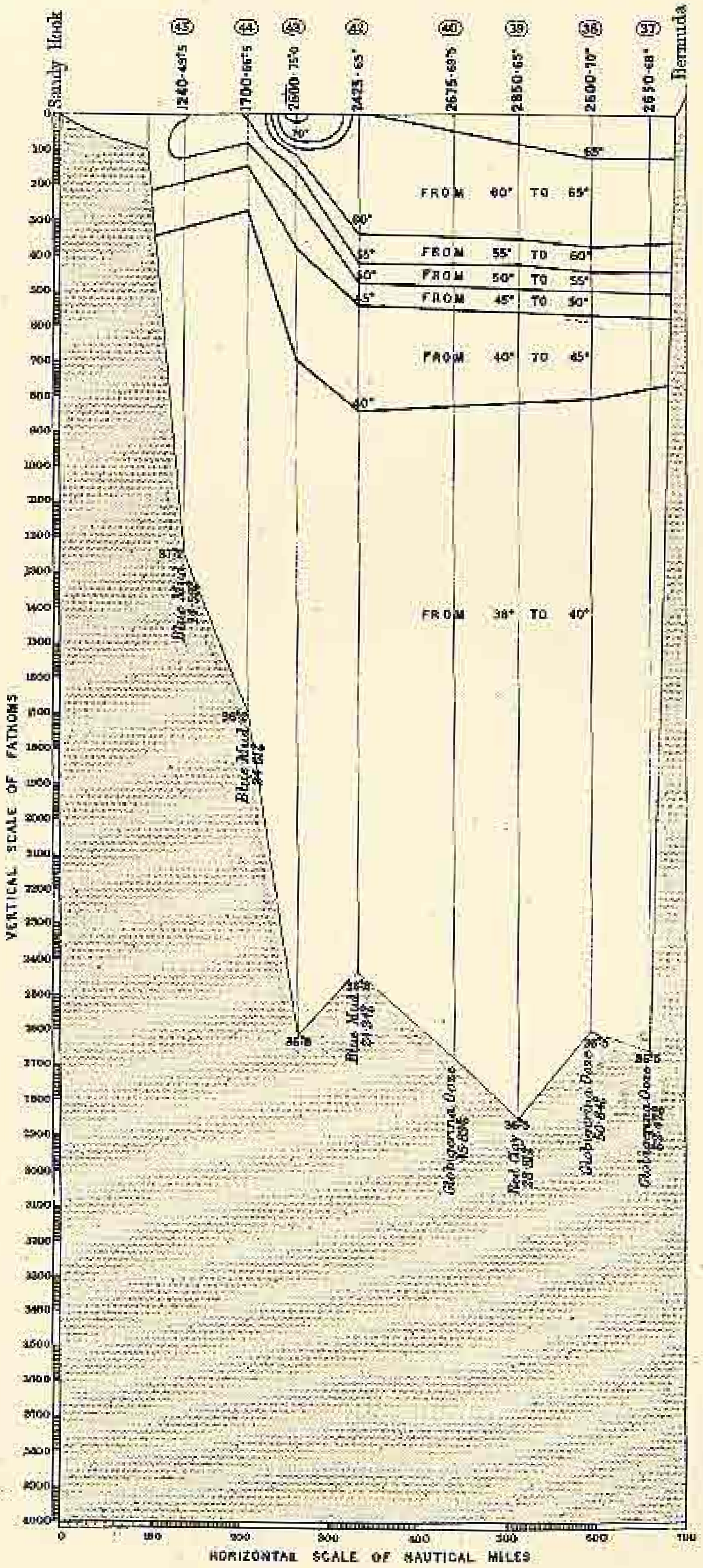


Engraved by Malby & Sons

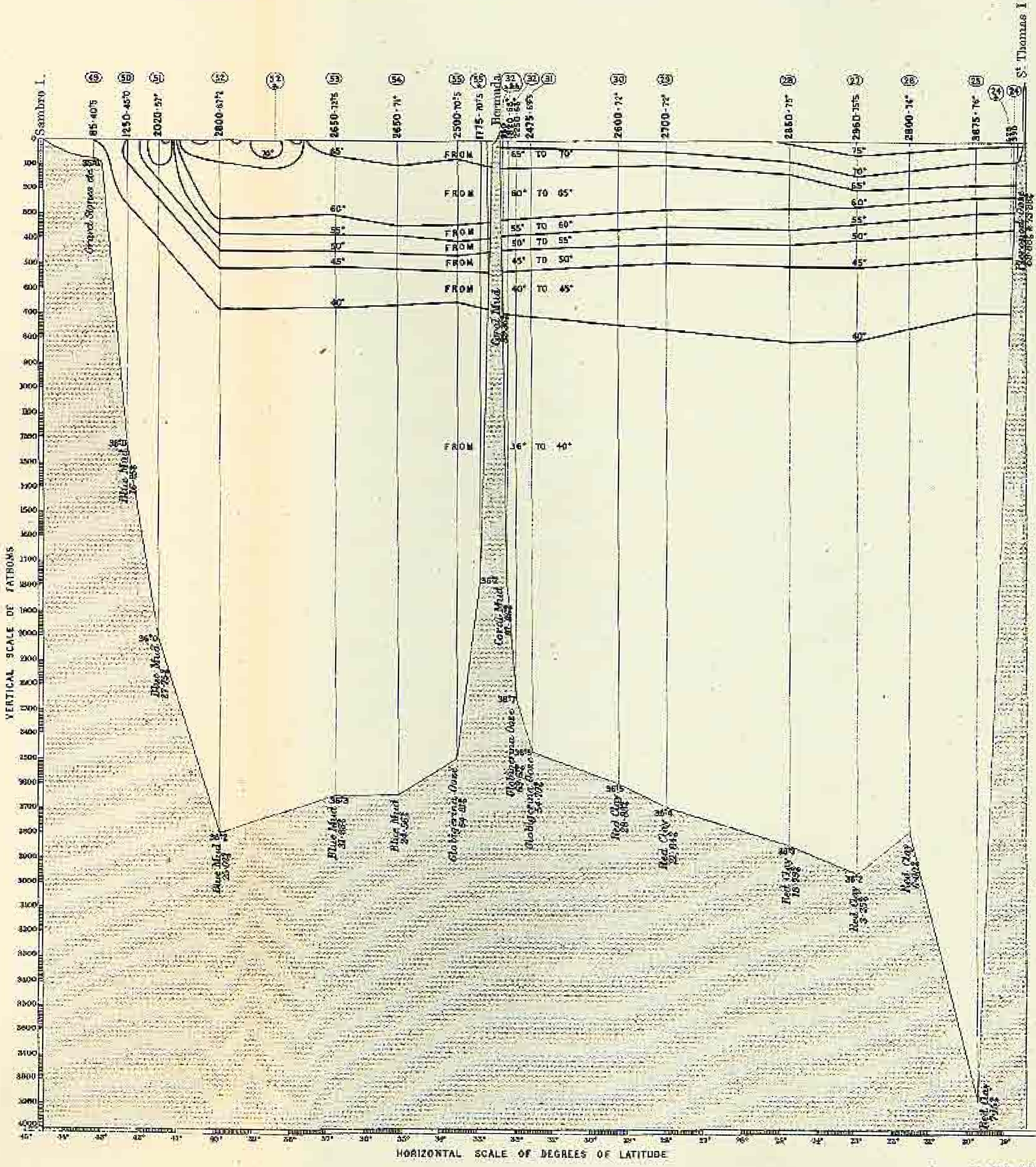
ATLANTIC OCEAN

For explanation of Symbols see Appendix 1.

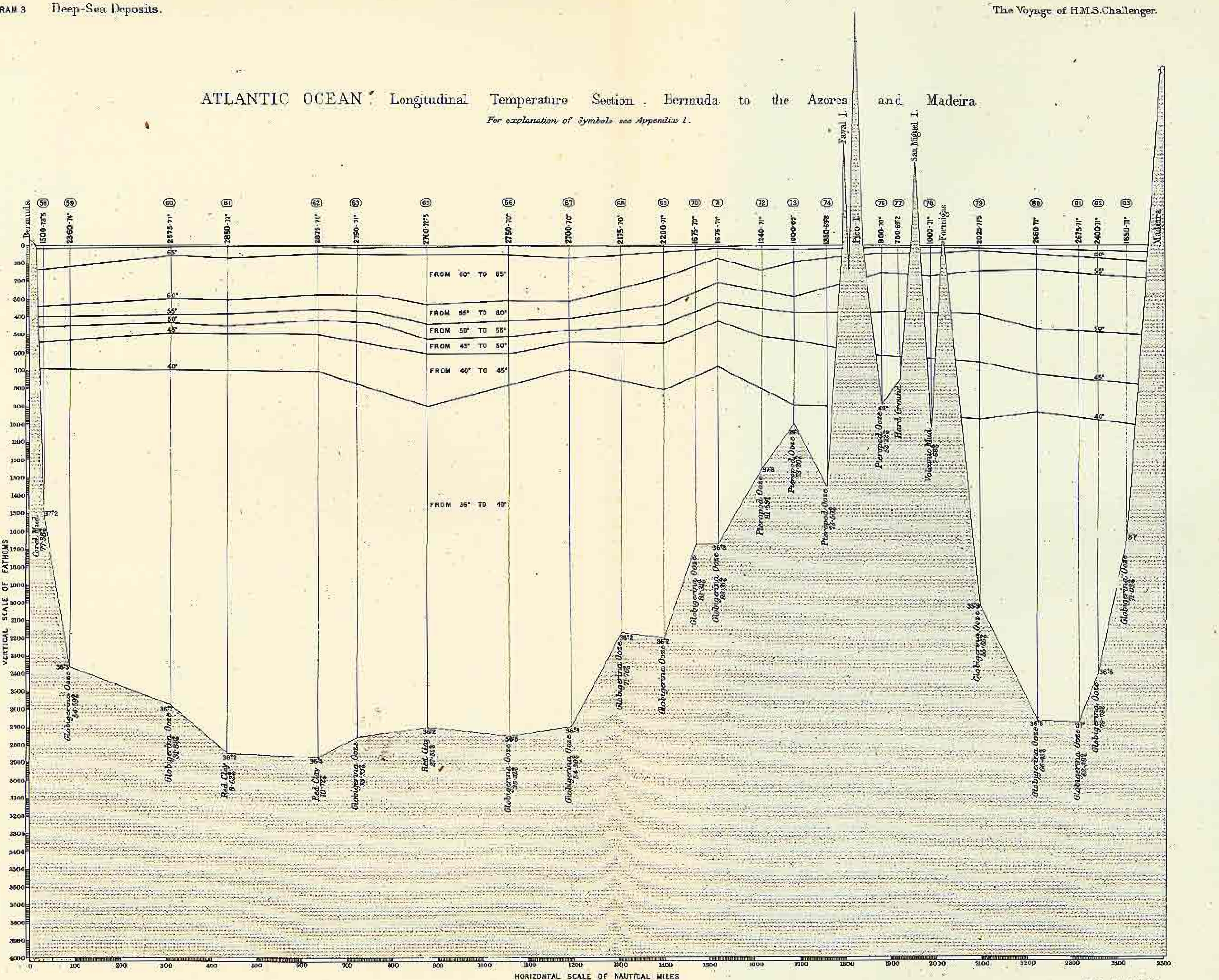
Diagonal Temperature Section. Bermuda towards New York.



Meridional Temperature Section Halifax to St. Thomas Id.



Engraved by Malby & Sons.

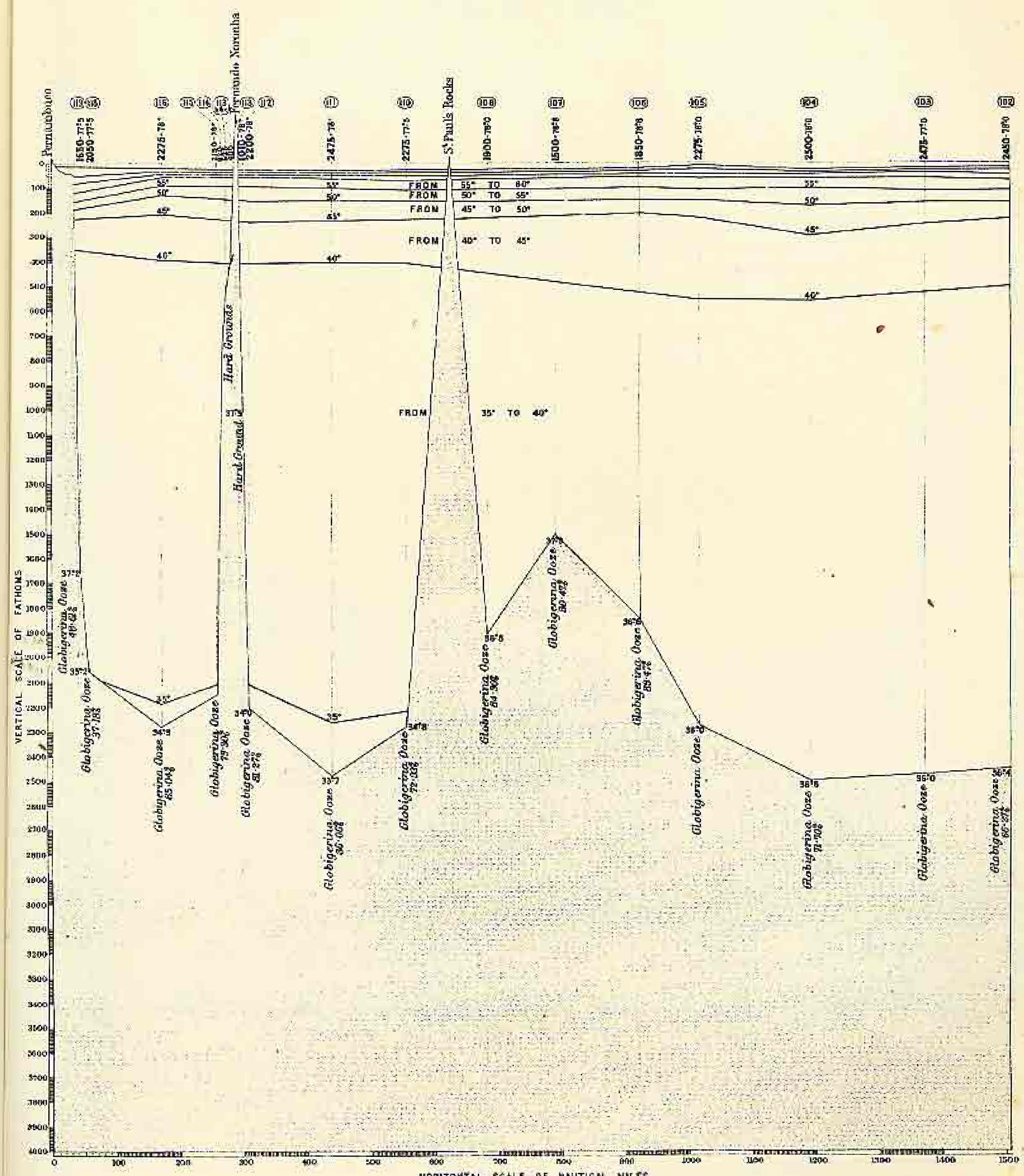


Engraved by Malby & Sons

ATLANTIC OCEAN

Longitudinal Temperature Section From a position in Lat. 3°8′ N., Long. 14°39′ W. to Pernambuco.

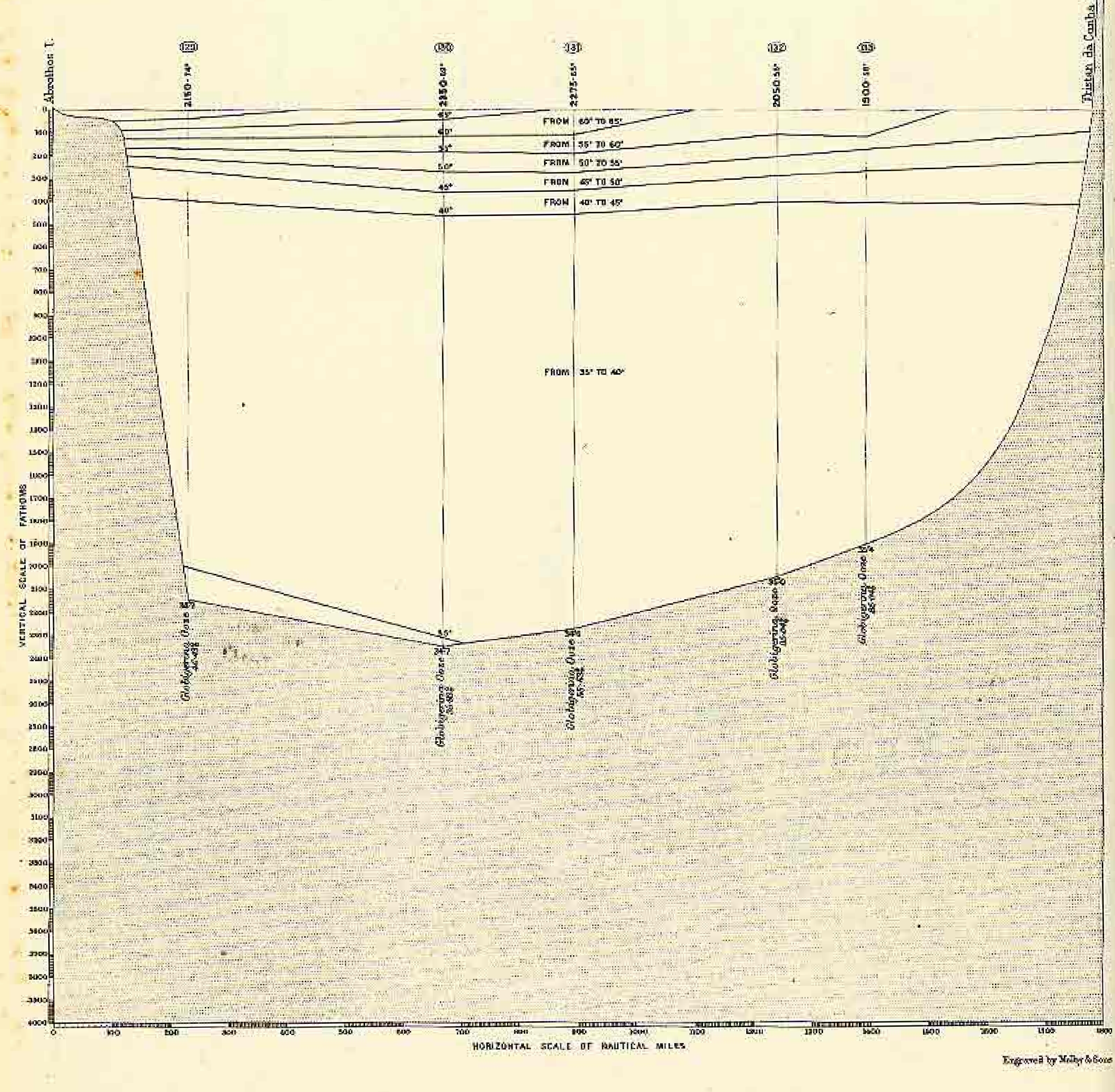
For explanation of Symbols see Appendix I.



Engraved by Malby & Sons

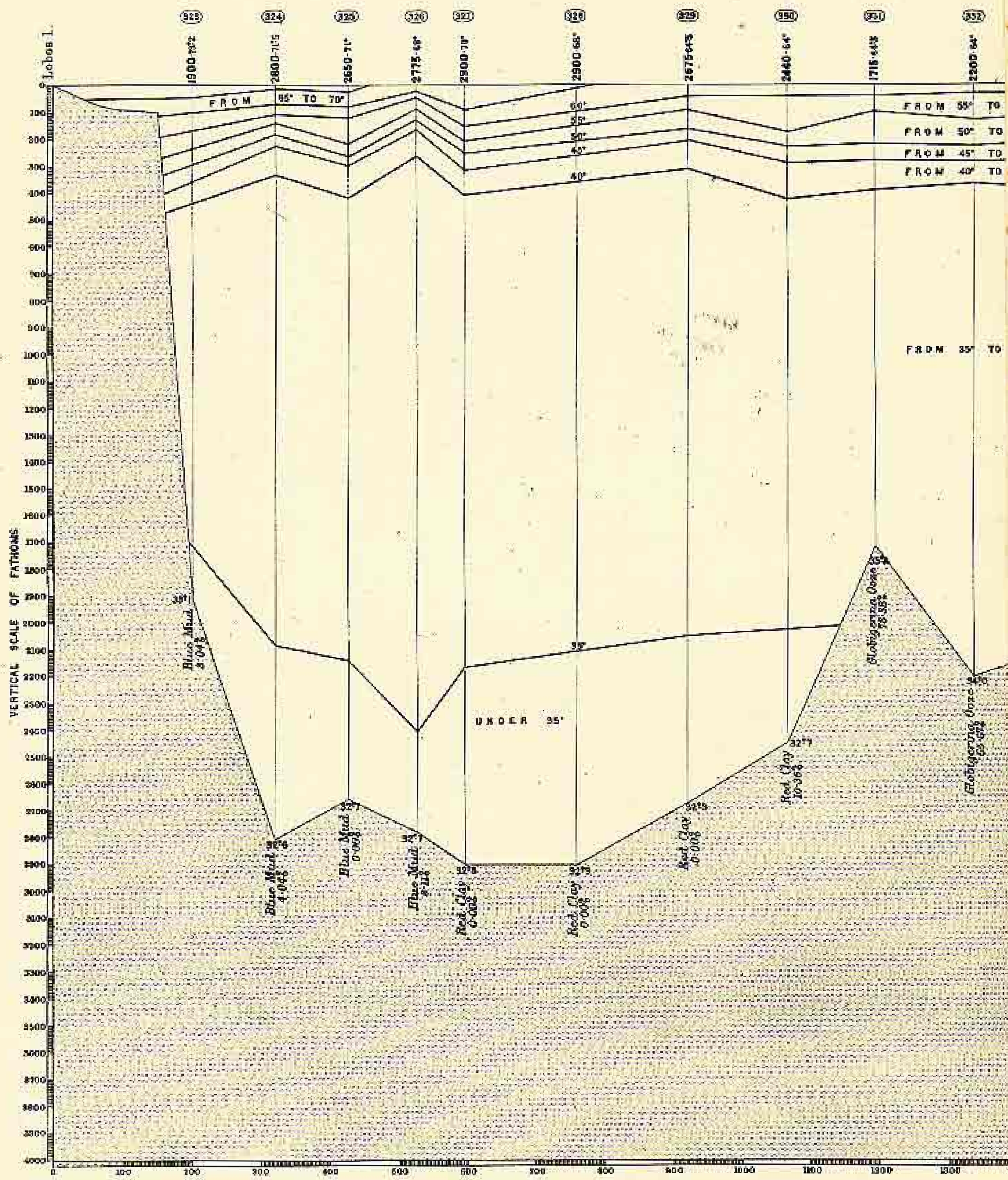
ATLANTIC OCEAN. Diagonal Temperature Section. Abrolhos I^d. to Tristan da Cunha I^ds.

For explanation of Symbols see Appendix I.



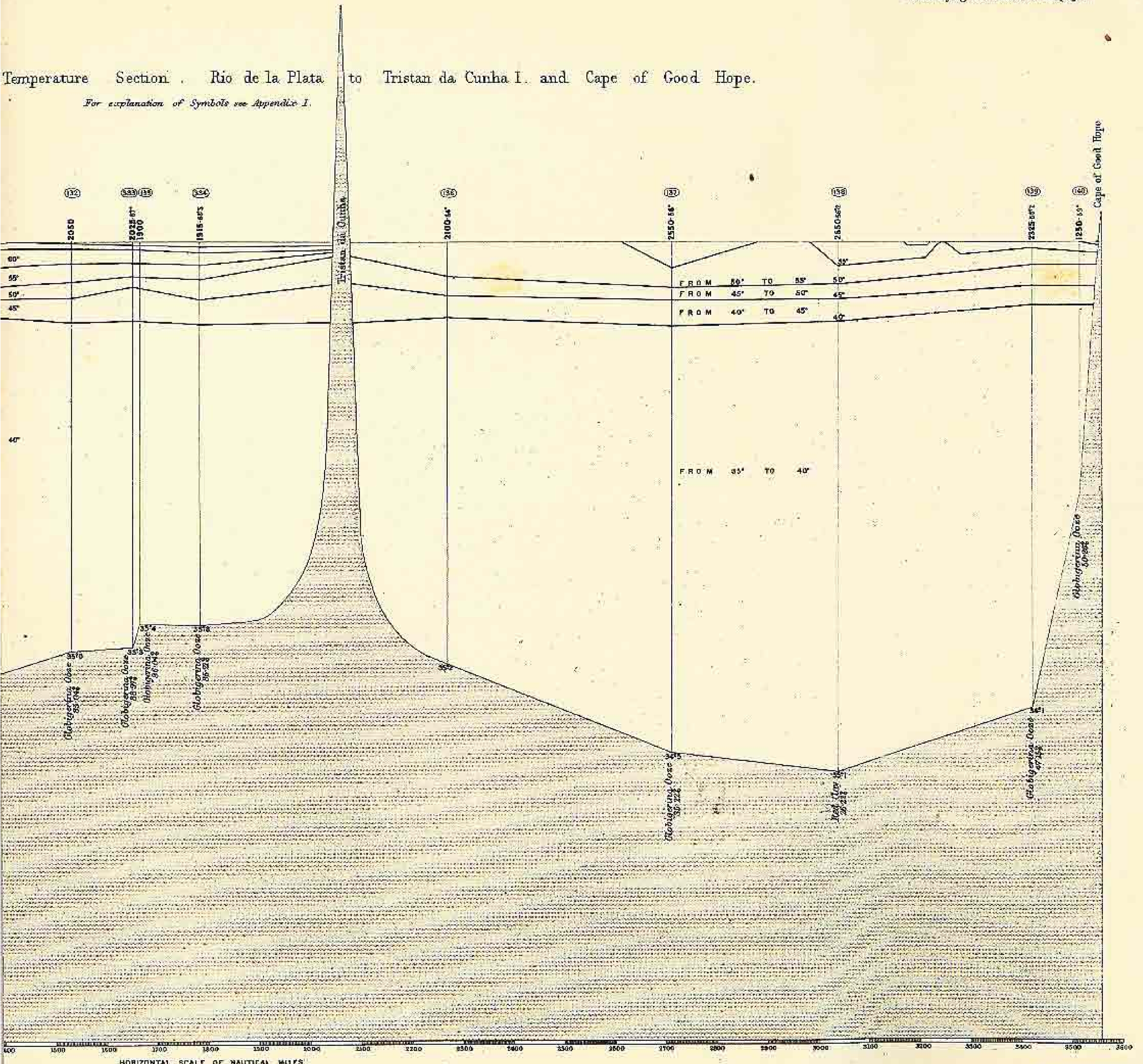
Engraved by Malby & Sons

ATLANTIC OCEAN Longitudinal

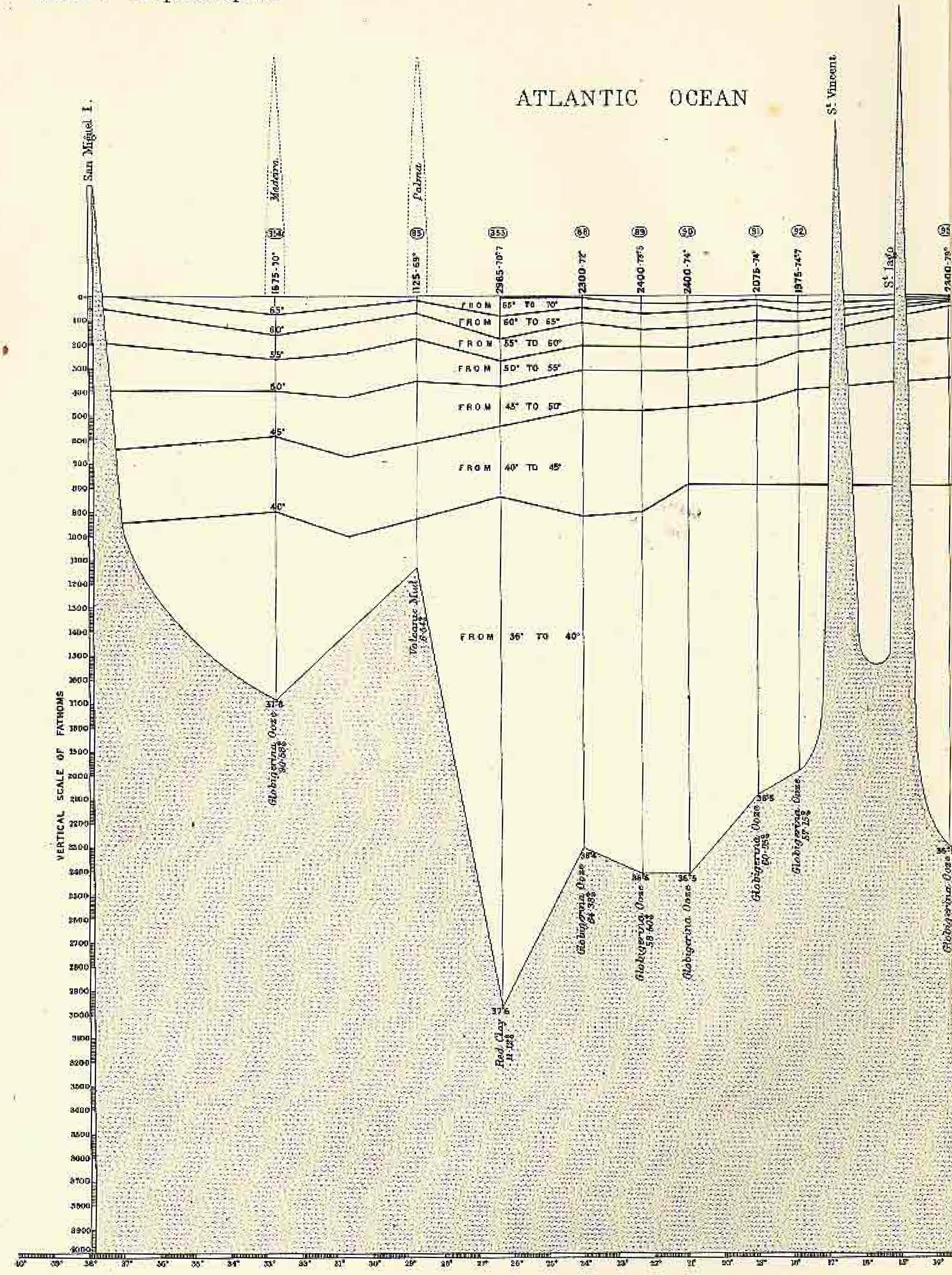


Temperature Section. Rio de la Plata to Tristan da Cunha I. and Cape of Good Hope.

For explanation of Symbols see Appendix I.

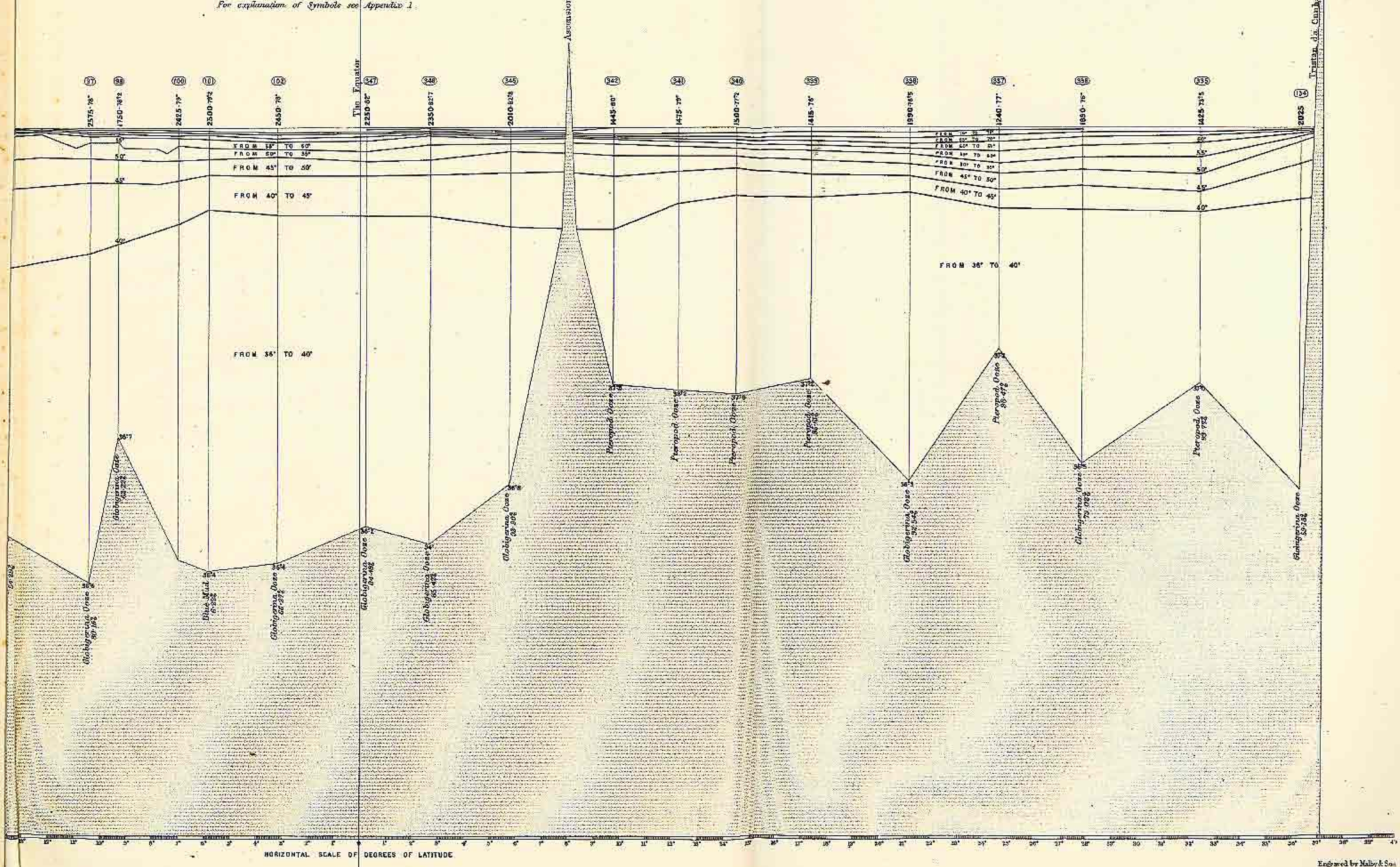


Engraved by Malby & Sons


ATLANTIC OCEAN
San Miguel I.
Madeira
Palma
St. Vincent
St. Iago
VERTICAL SCALE OF FATHOMS
FROM 65° TO 70°
FROM 60° TO 65°
FROM 55° TO 60°
FROM 50° TO 55°
FROM 45° TO 50°
FROM 40° TO 45°
FROM 36° TO 40°
Globigerina Ooze 90.58%
Volcanic Mud
Red Clay
Globigerina Ooze
Globigerina Ooze
Globigerina Ooze
Globigerina Ooze
Globigerina Ooze
Globigerina Ooze

Meridional Temperature Section The Azores to the Tristan da Cunha Islands

For explanation of Symbols see Appendix 1.



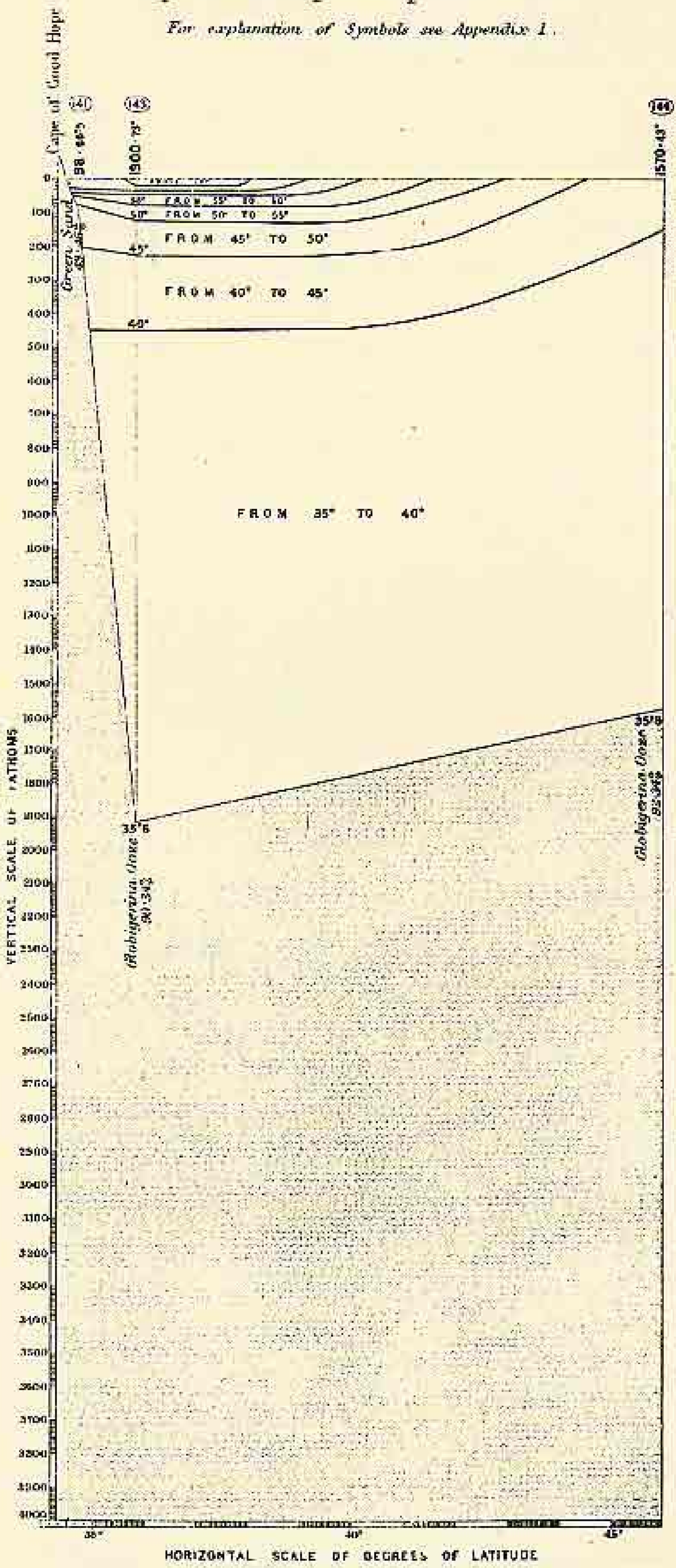
Engraved by Malby & Sons

INDIAN OCEAN

Meridional Temperature Section

Cape of Good Hope to the parallel of 46° S.

For explanation of Symbols see Appendix 1.



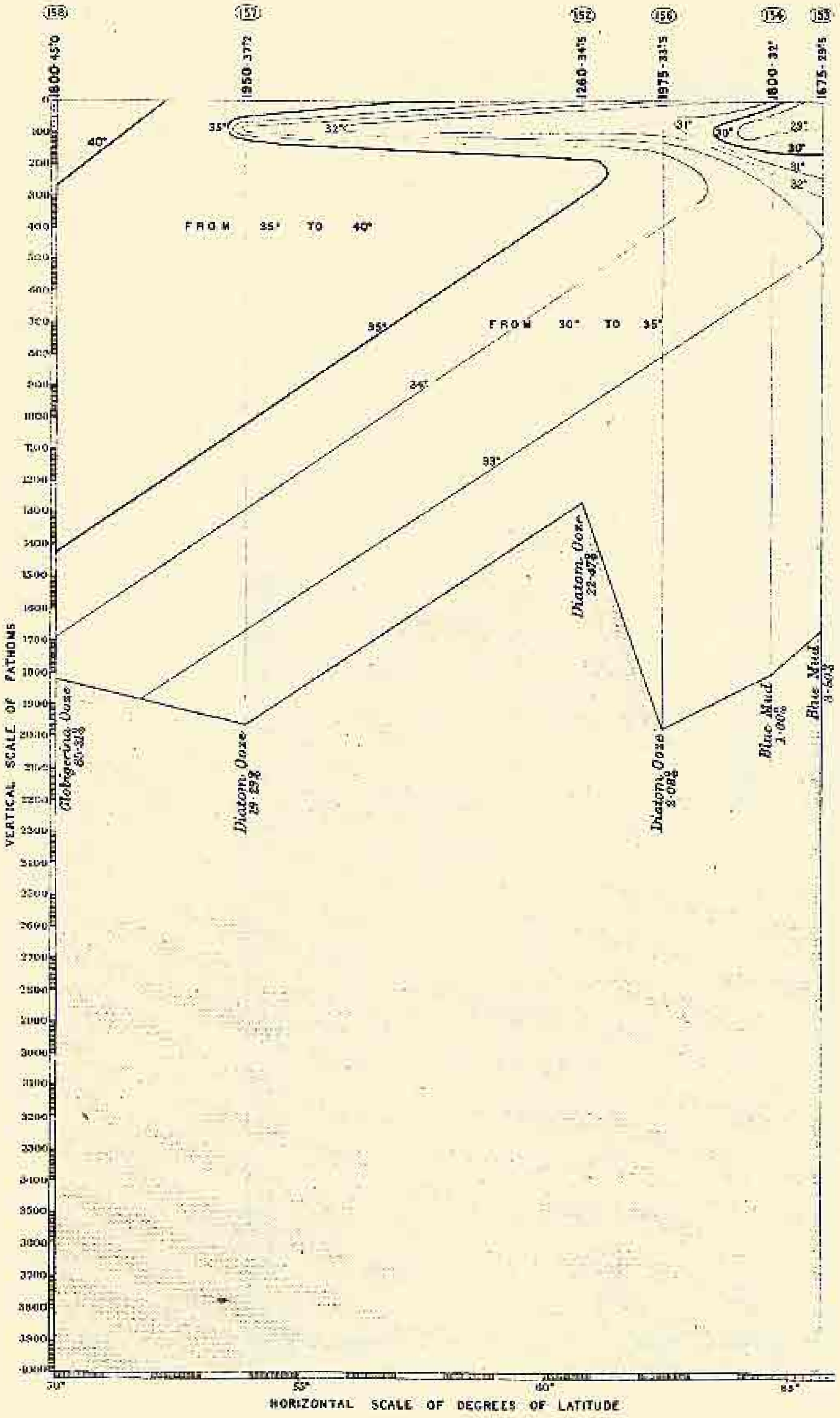
Engraved by Malby & Sons

SOUTHERN INDIAN OCEAN

Meridional Temperature Section

Between the Parallels of 50° and 65° South Lat.

For explanation of Symbols see Appendix I.

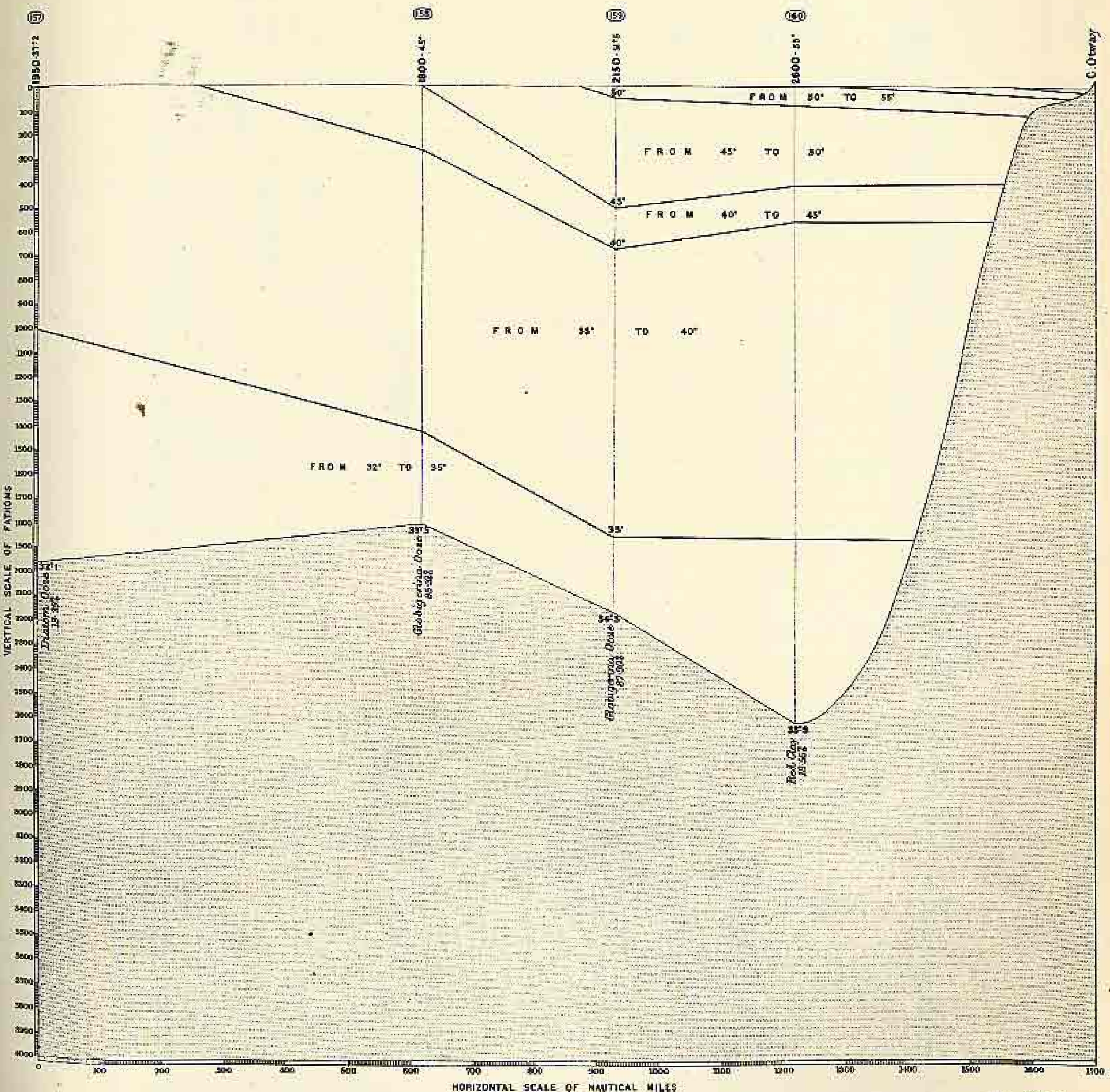


Engraved by Malby & Sons.

SOUTHERN INDIAN OCEAN

Diagonal Temperature Section. From a Position in Lat. 53°55′S. Long. 108°35′E. to C. Otway.

… of Symbols see Appendix I.



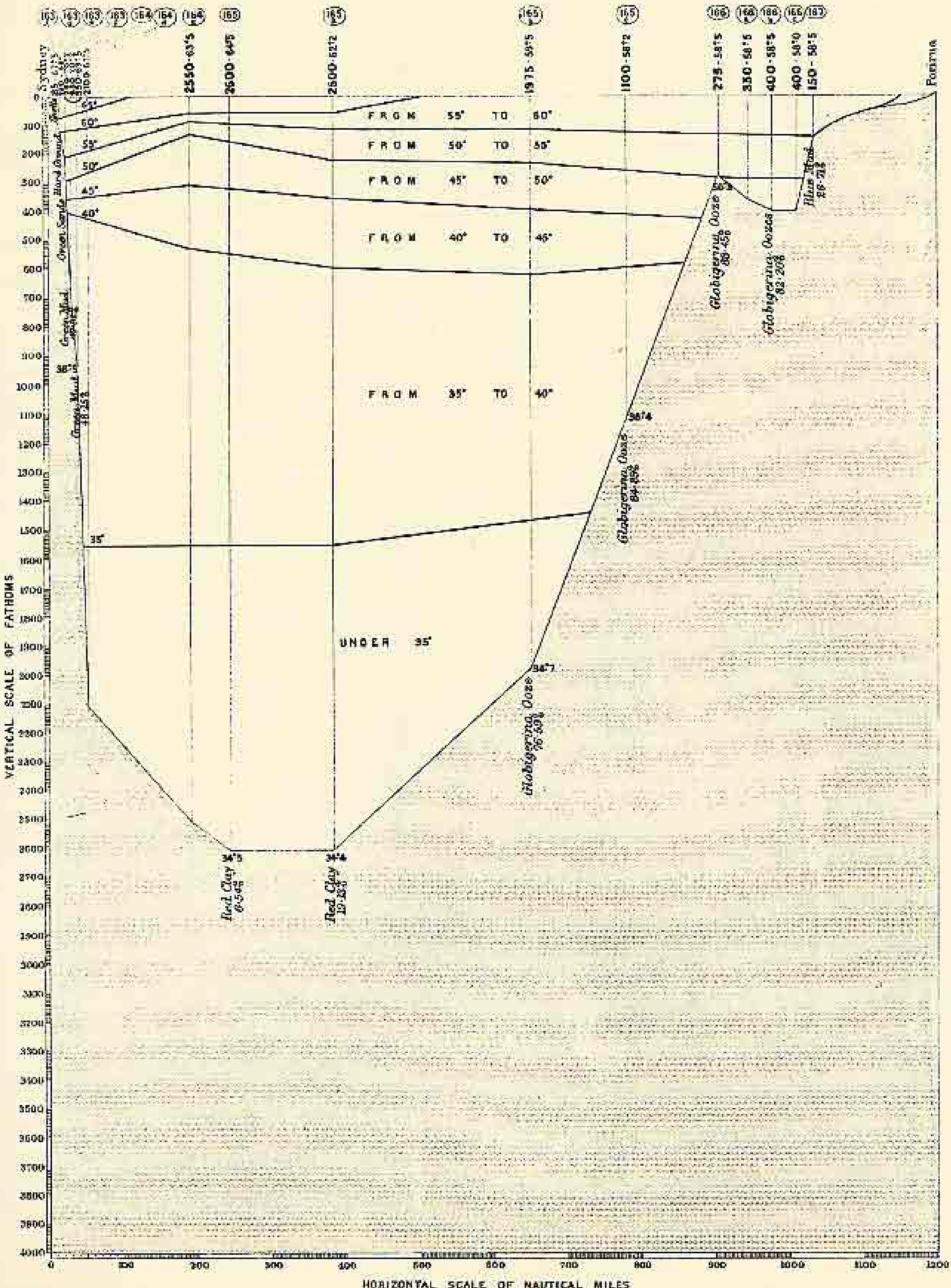
Engraved by Malby & Sons

PACIFIC OCEAN

Longitudinal Temperature Section

Sydney, New South Wales, to Porirua, Cook strait, New Zealand.

For explanation of Symbols see Appendix I.

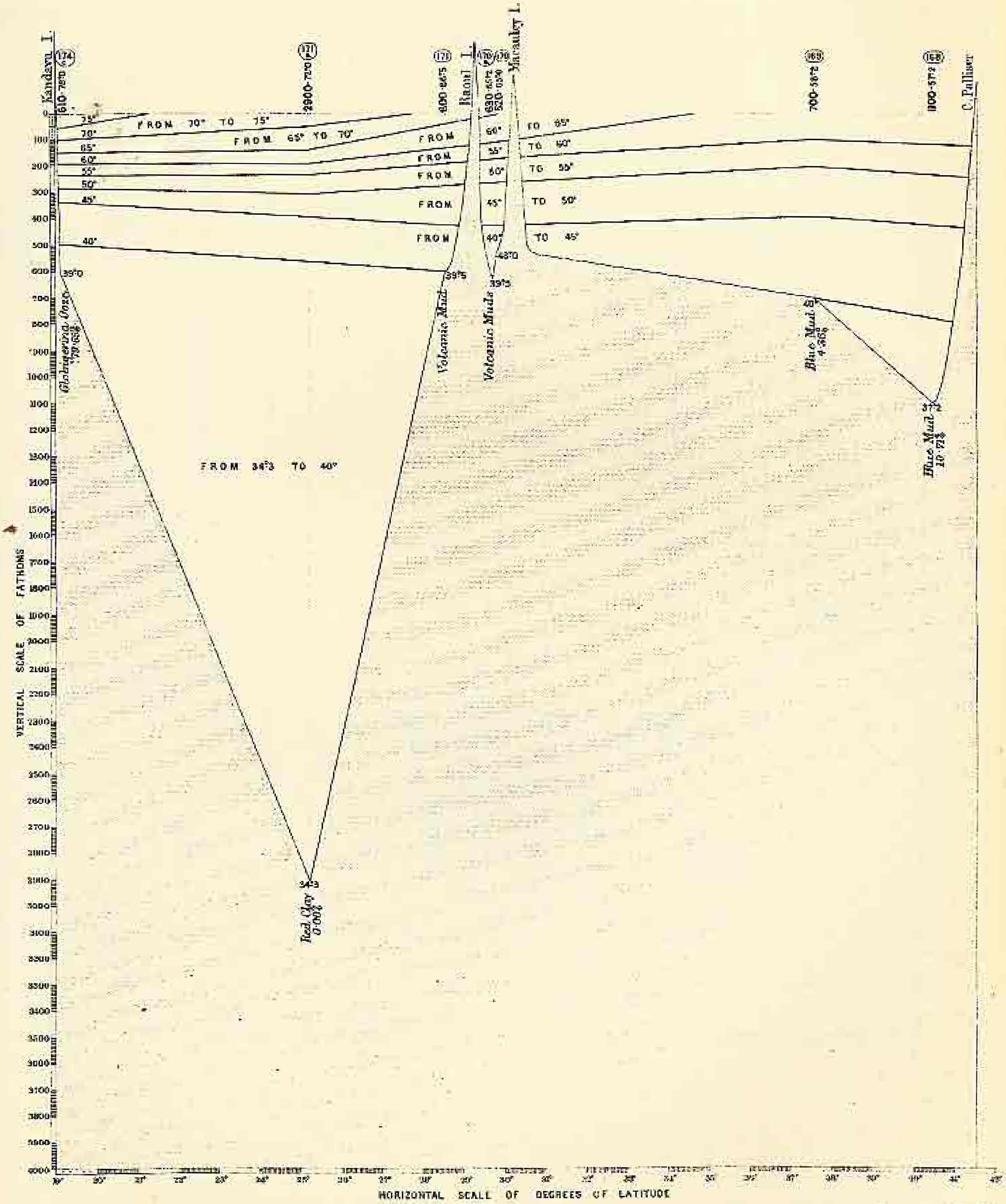


Engraved by Malby & Sons

PACIFIC OCEAN

Meridional Temperature Section. Kandavu I. to C. Palliser, New Zealand.

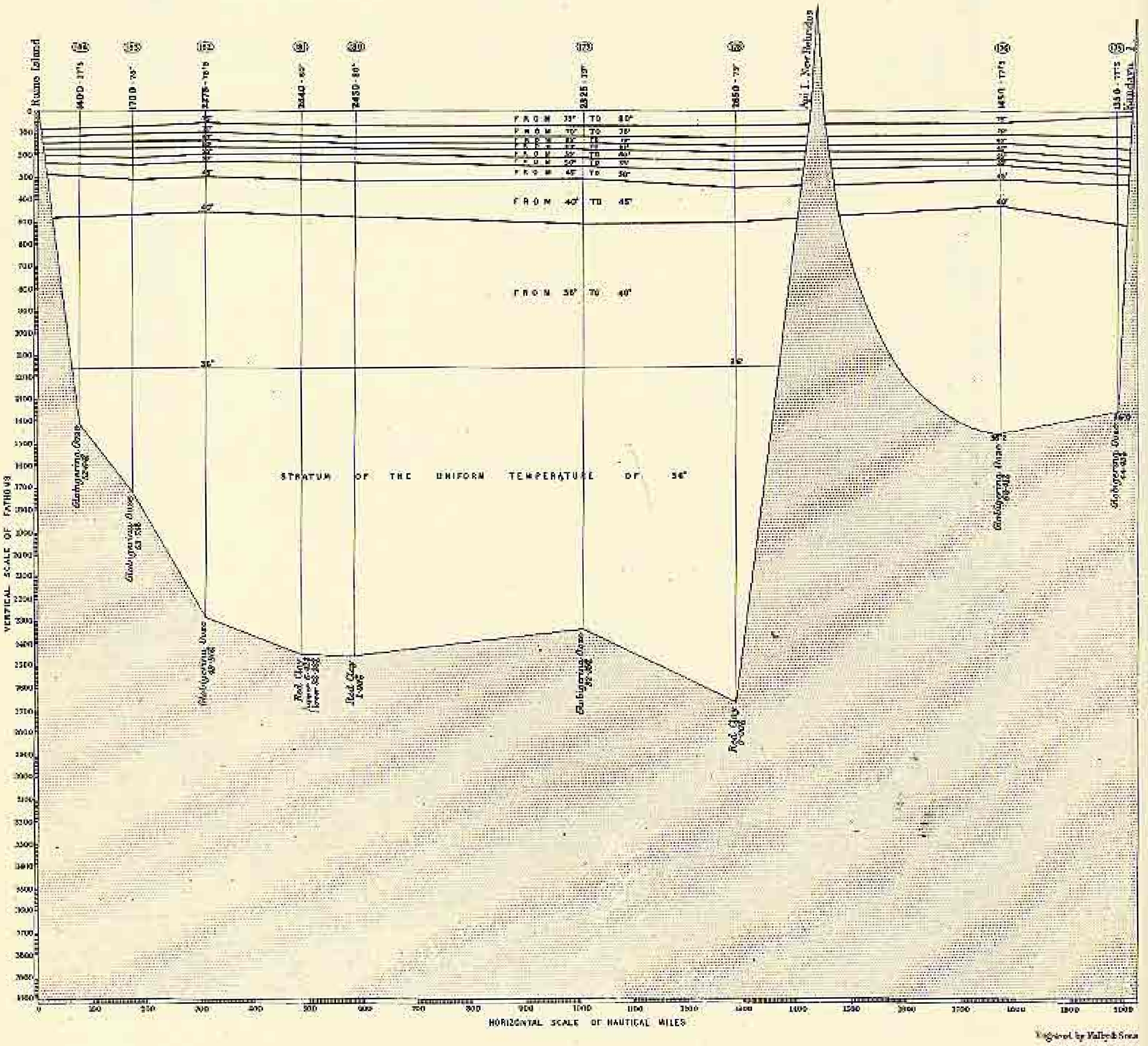
For explanation of Symbols see Appendix I.



Engraved by Malby & Sons

PACIFIC OCEAN. Longitudinal Temperature Section Fiji Islands to the Barrier reef, Australia.

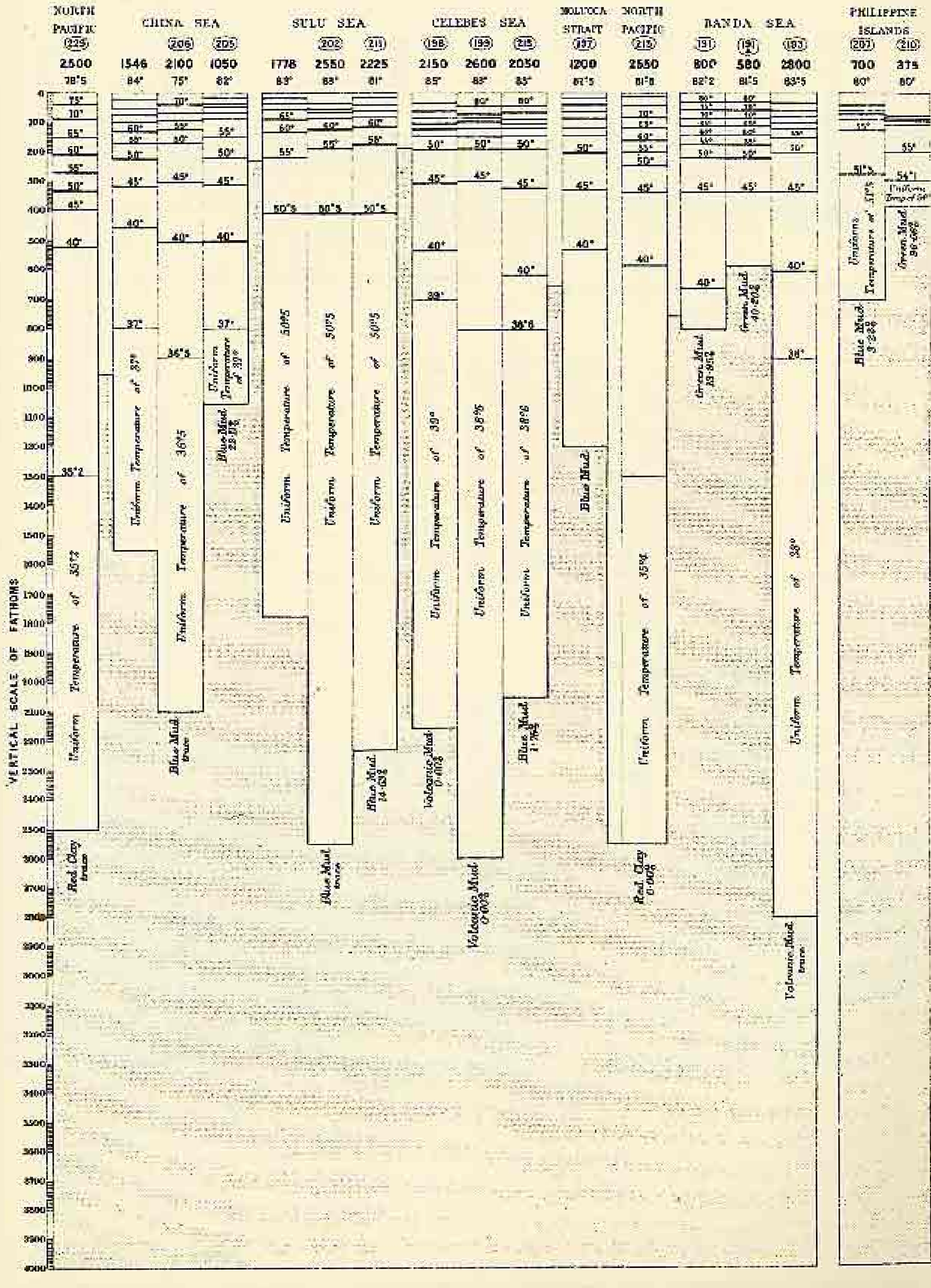
For explanation of Symbols see Appendix I.



Engraved by Malby & Sons

Diagram showing the Distribution of Temperature in the Seas enclosed by the Islands of the EASTERN ARCHIPELAGO.

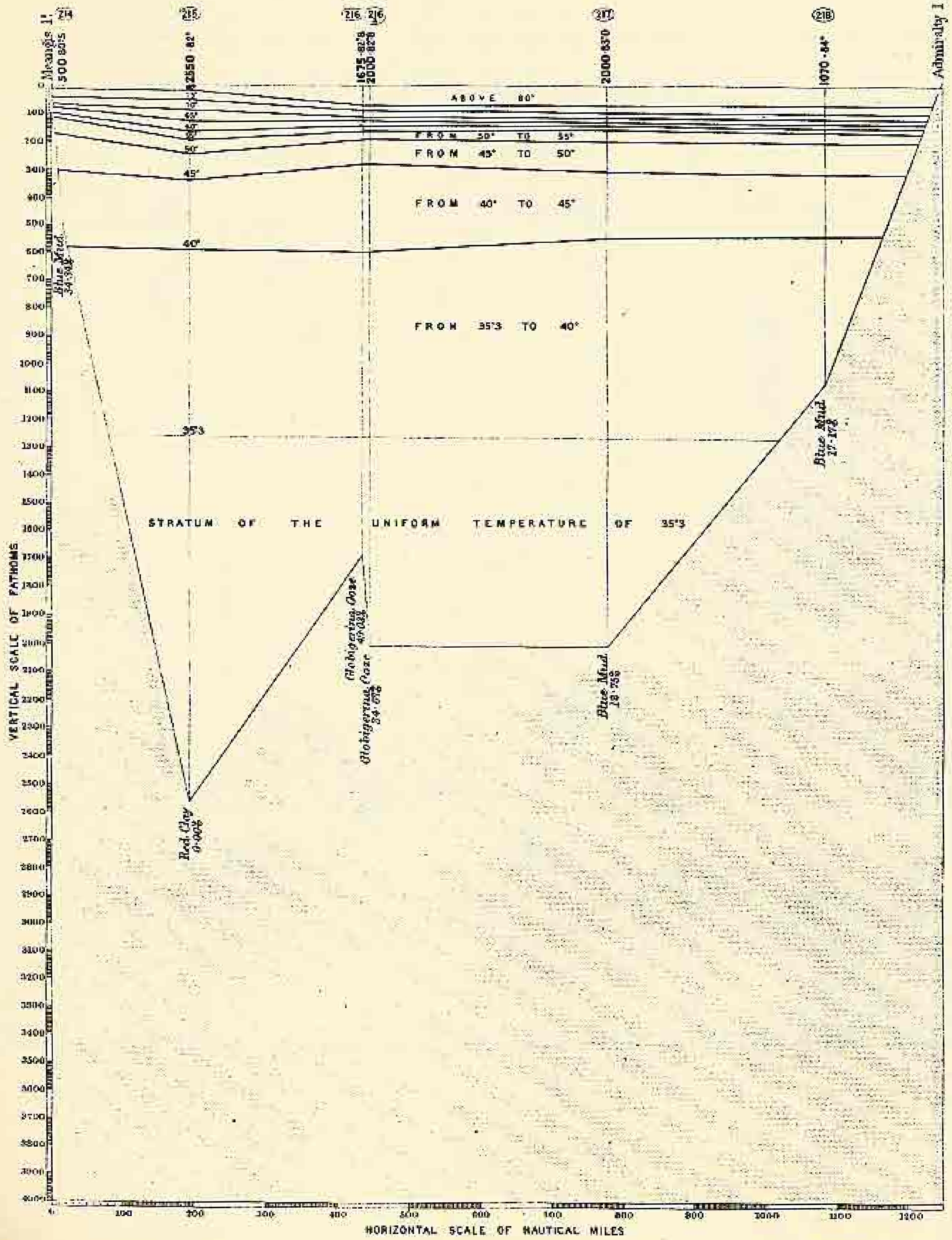
For explanation of Symbols see Appendix I.



PACIFIC OCEAN

Longitudinal Temperature Section. Meangis I^s to Admiralty I^s

For explanation of Symbols see Appendix I.

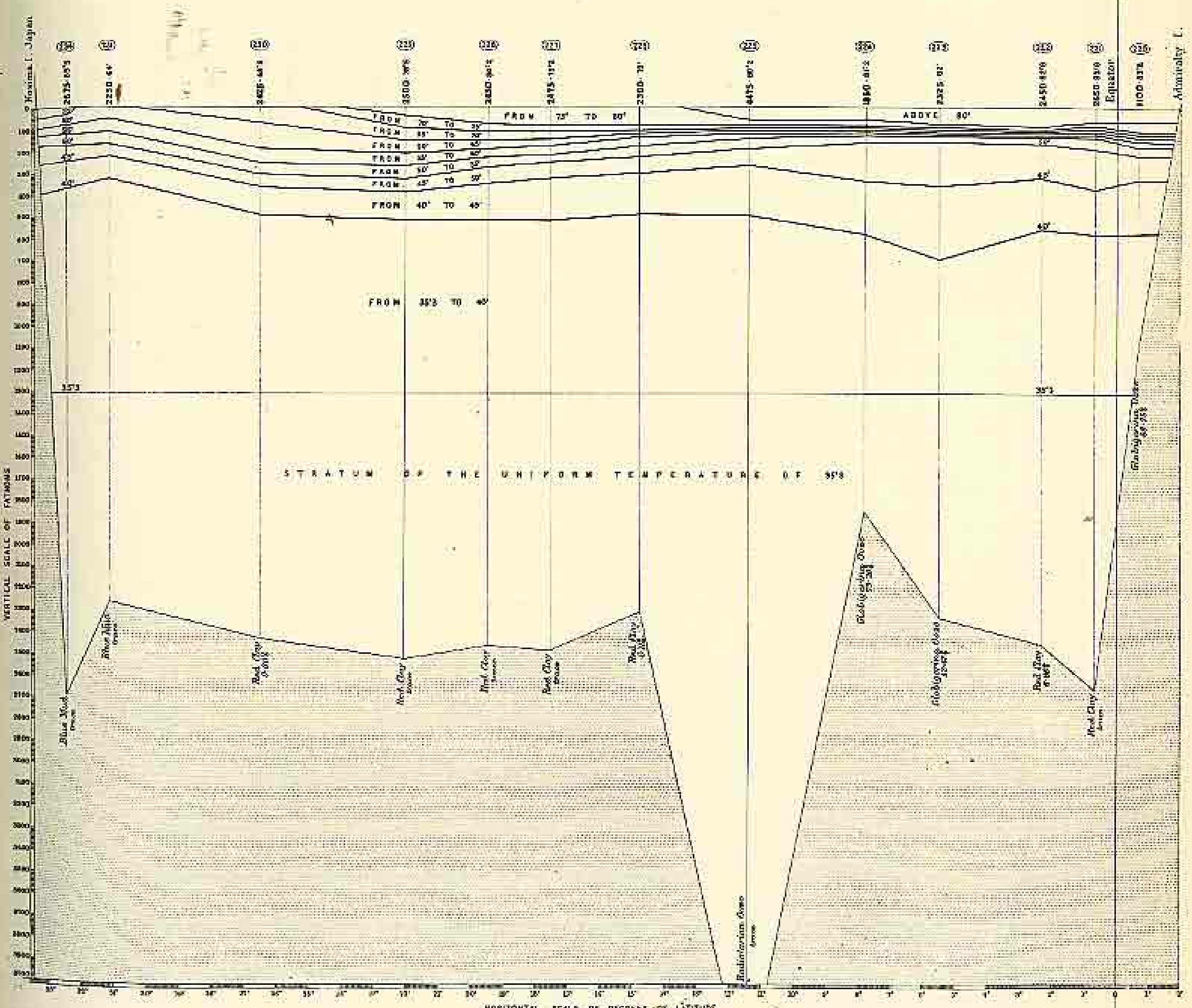


Engraved by Malby & Sons

PACIFIC OCEAN

Meridional Temperature Section : Admiralty Island to Japan.

For explanation of Symbols see Appendix I.

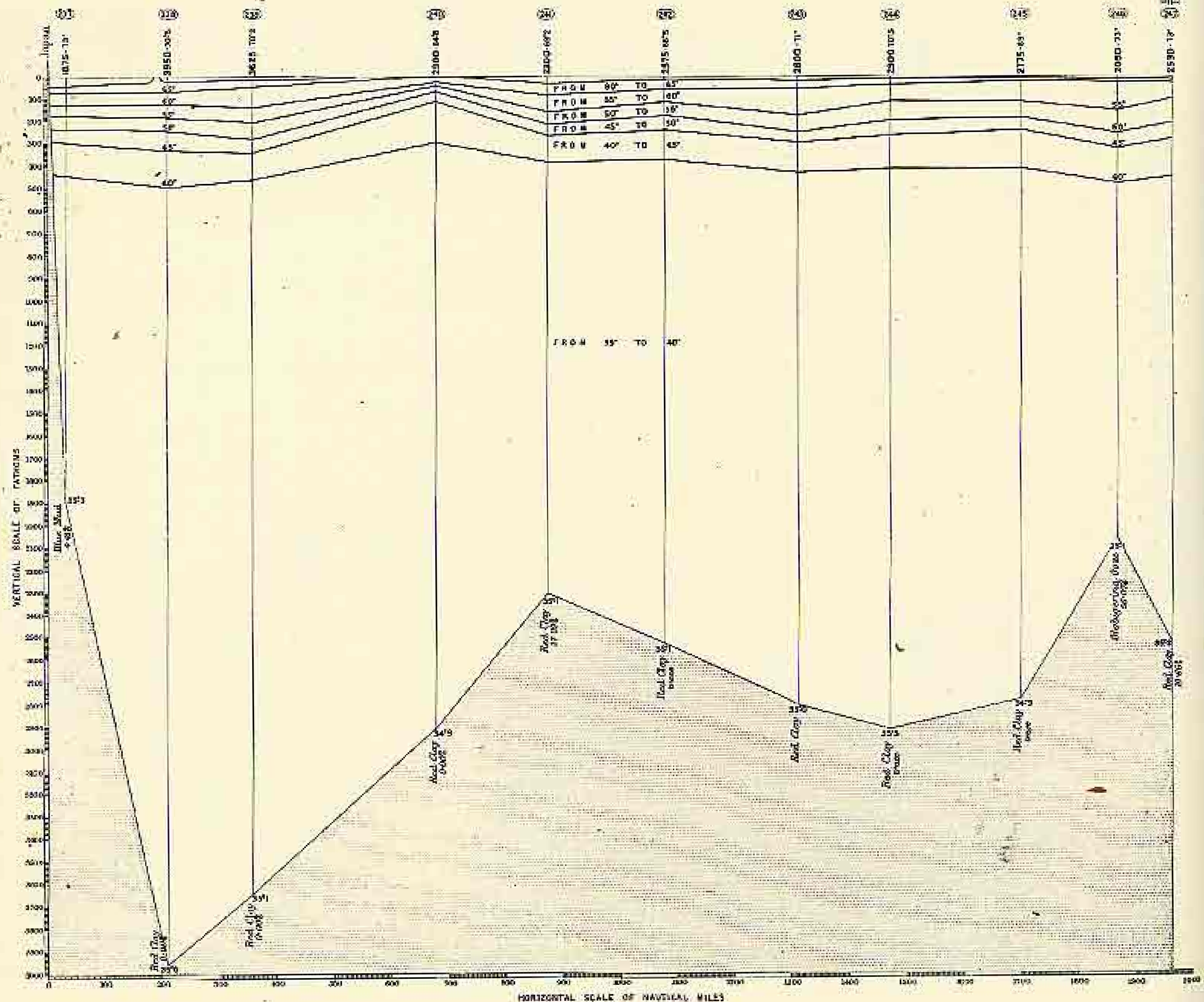


Engraved by Malby & Sons

PACIFIC OCEAN

Longitudinal Temperature Section. Japan to a position in Lat. 35°49' N. Long. 180°

For explanation of Symbols see Appendix I.



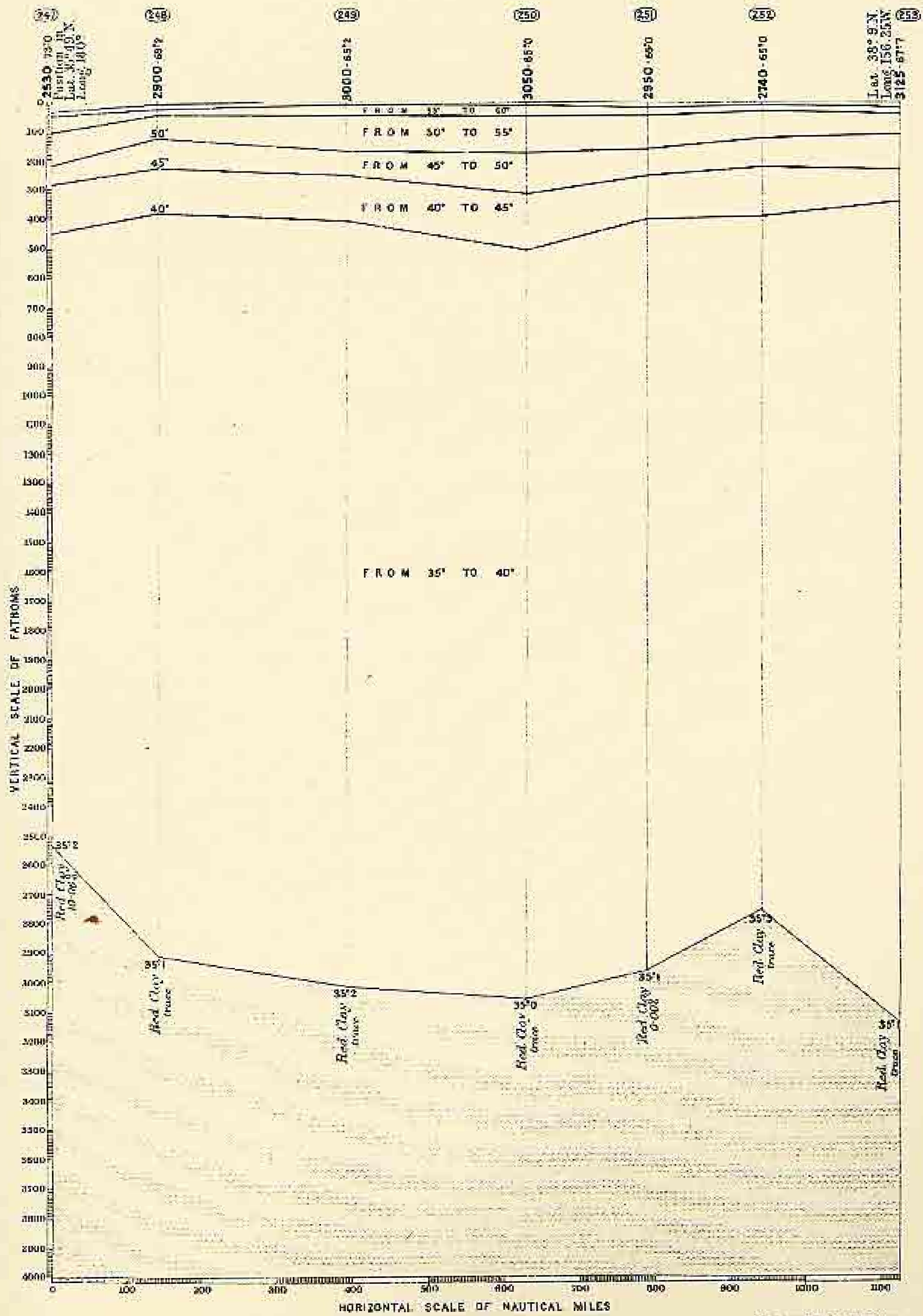
Engraved by Malby & Sons.

PACIFIC OCEAN

Longitudinal Temperature Section

From a Position in Lat. 35°49'N. Long. 180°W. to a Position in Lat. 38°9'N. Long. 156°25'W.

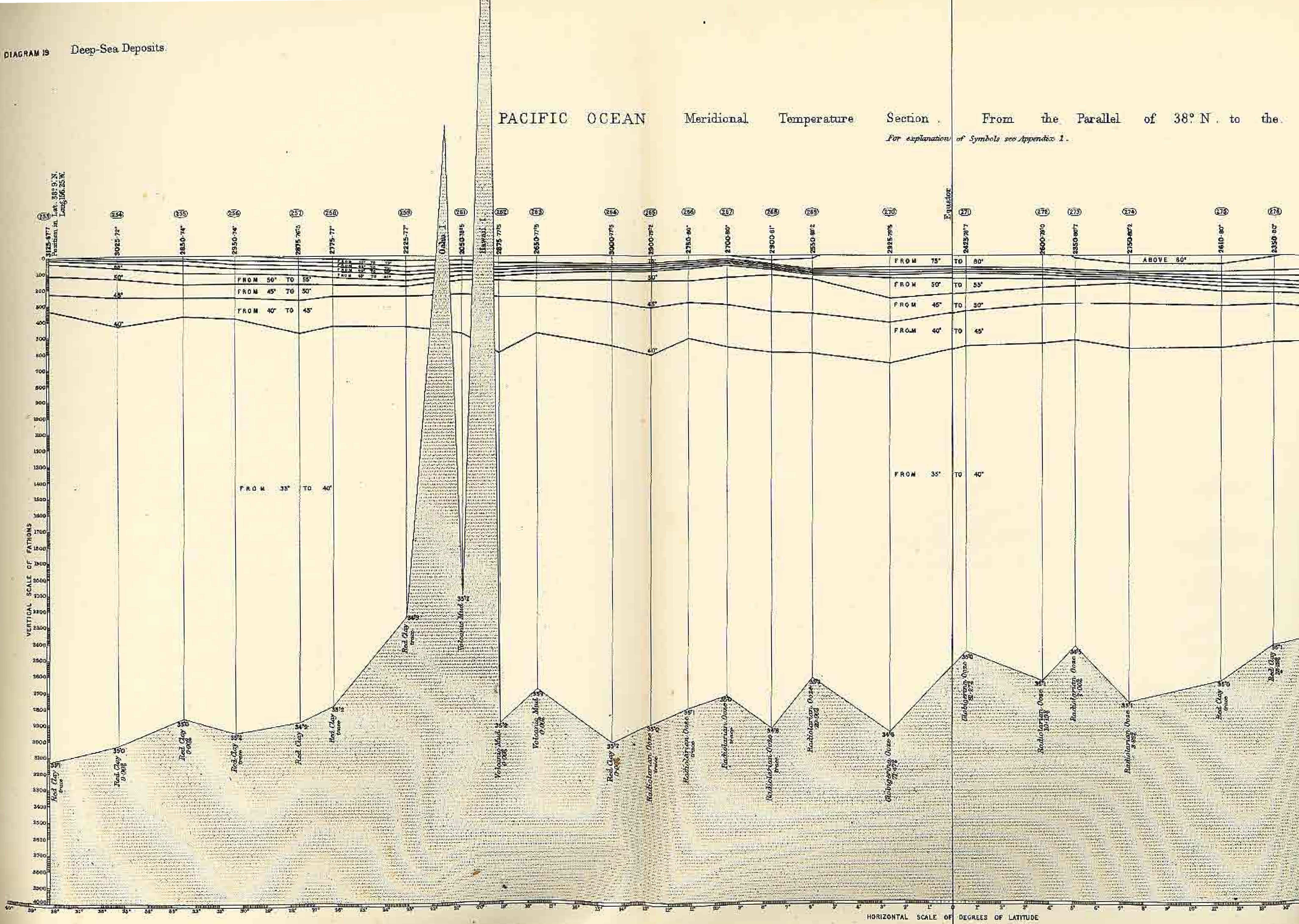
For explanation of Symbols see Appendix I.



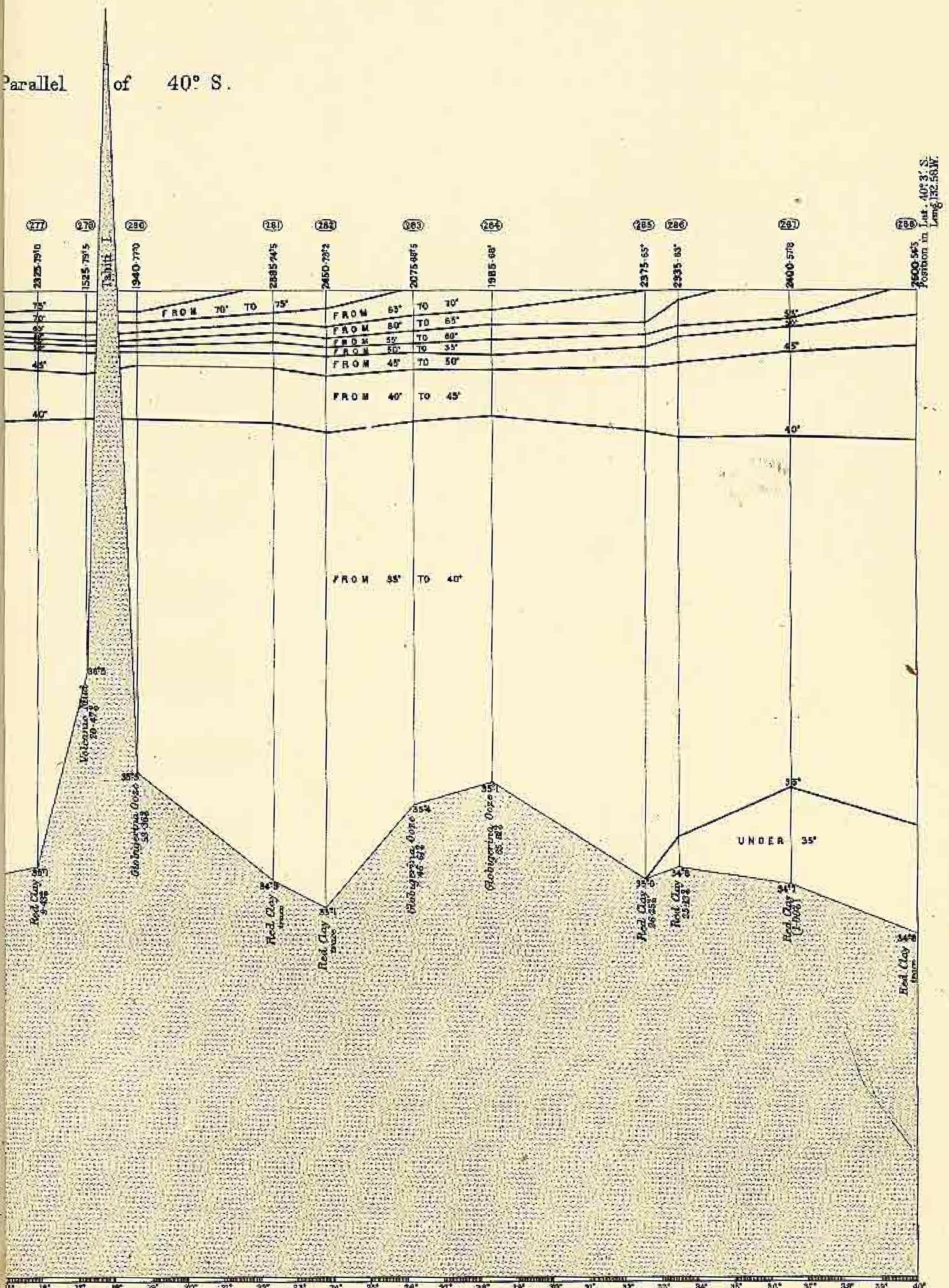
Engraved by Malby & Sons

PACIFIC OCEAN Meridional Temperature Section. From the Parallel of 38° N. to the.

For explanation of Symbols see Appendix 1.

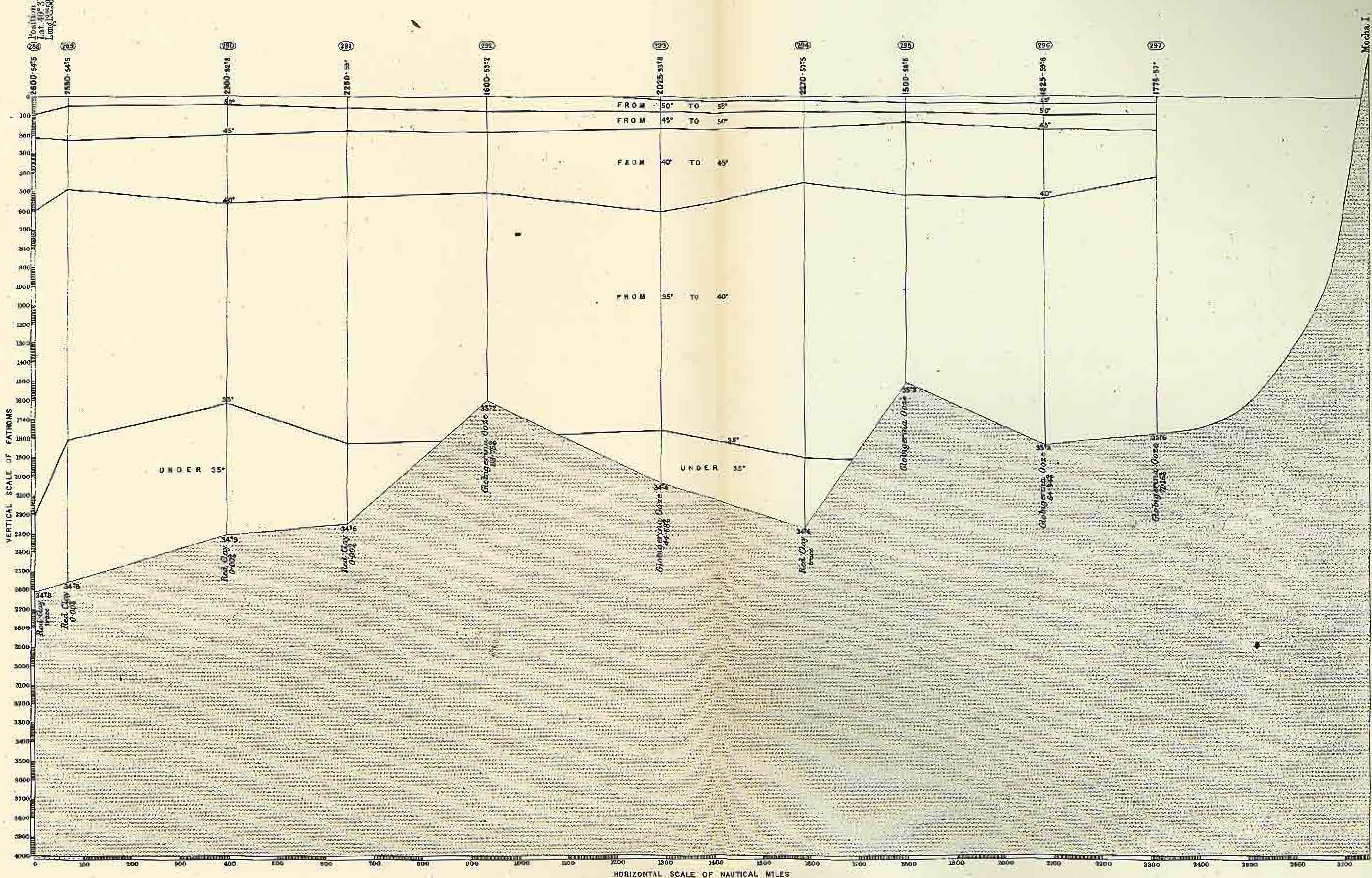


Parallel of 40° S.



PACIFIC OCEAN. Longitudinal Temperature Section. From a Position in Lat. 40° 3'. S. Long. 132° 58'. W. towards Mocha Island.

For explanation of Symbols see Appendix 1.

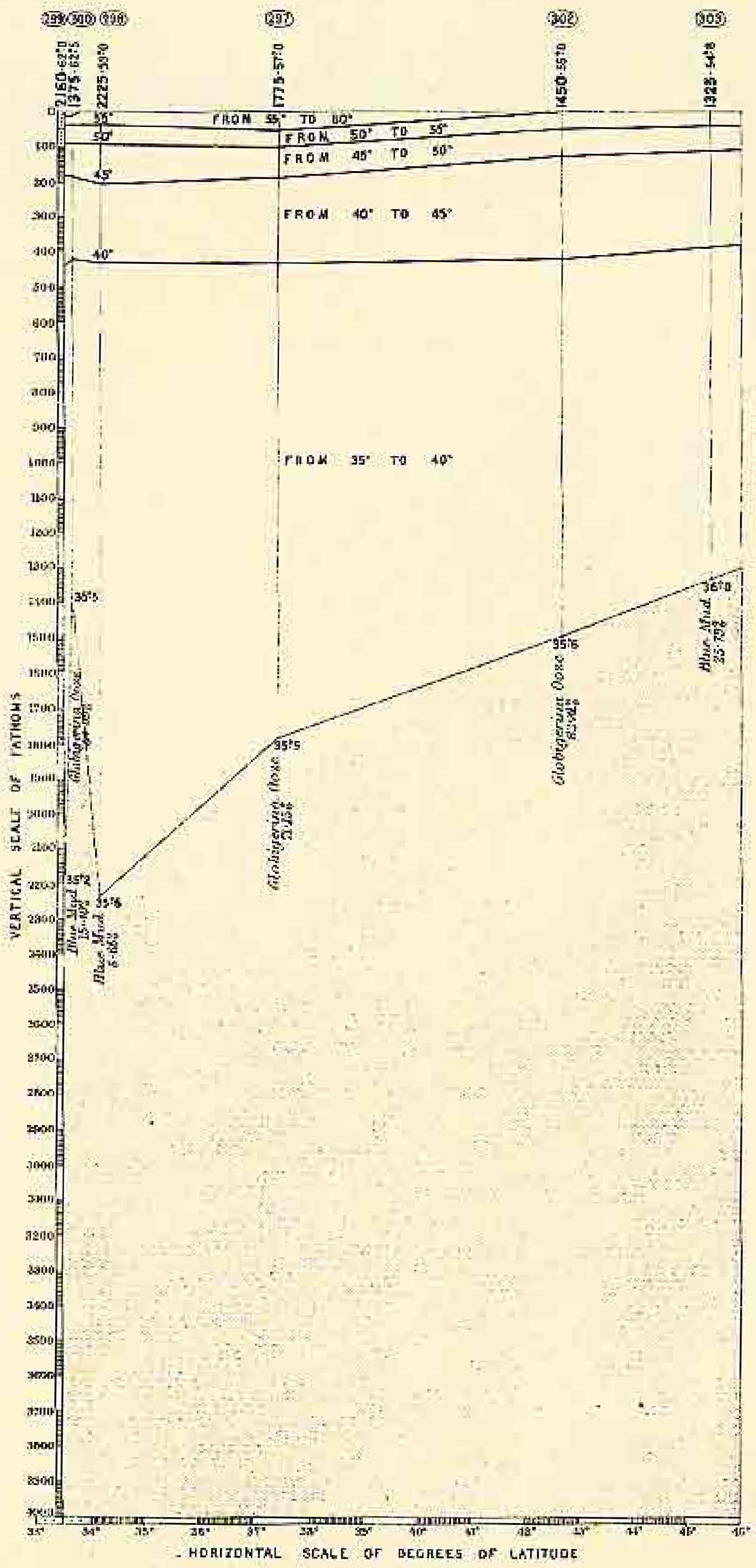


Engraved by Malby & Sons

PACIFIC OCEAN

Meridional Temperature Section off the West coast of South America between the 33rd and 46th Parallels.

For explanation of Symbols see Appendix I.



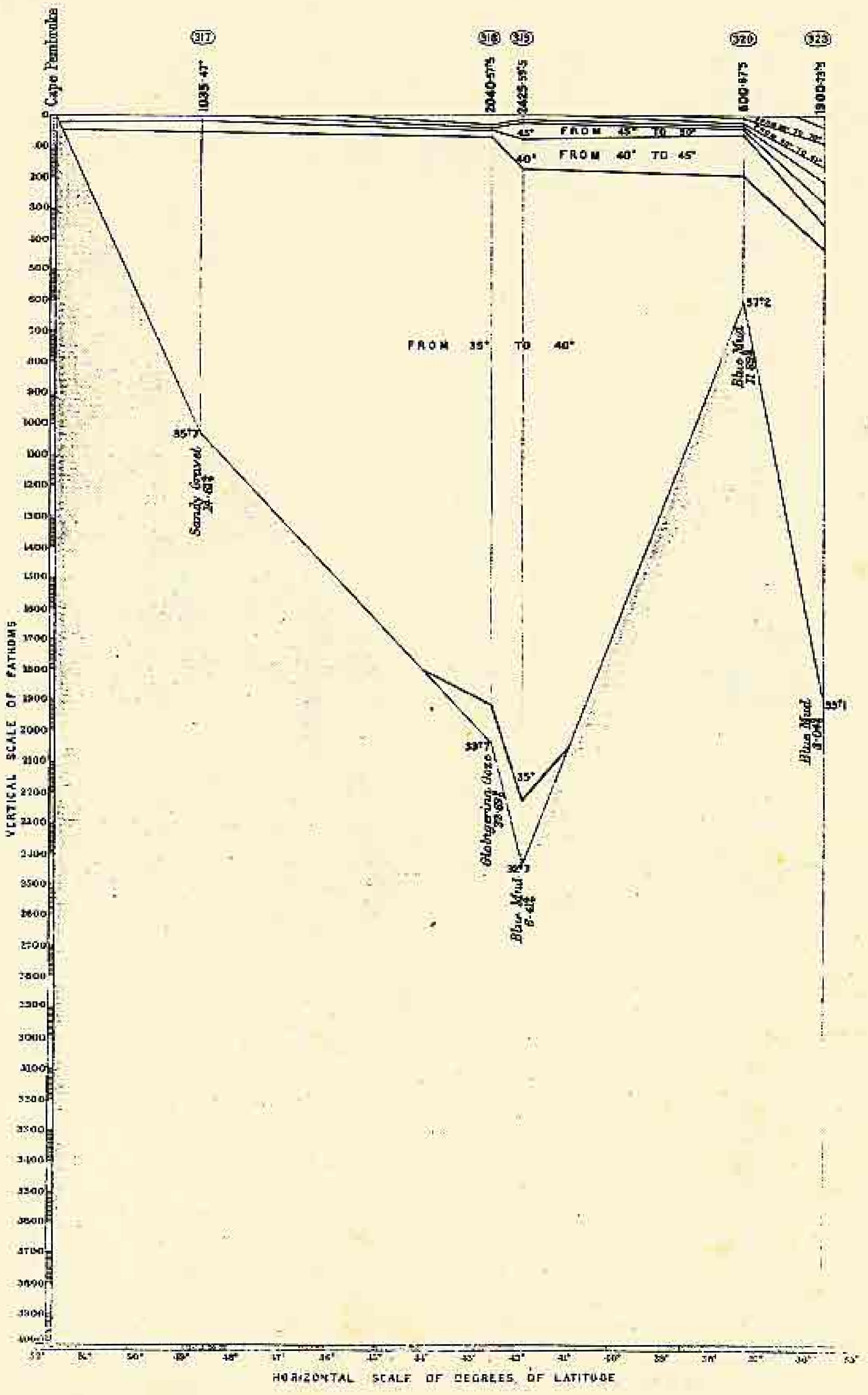
Engraved by Malby & Sons

ATLANTIC OCEAN

Meridional Temperature Section

Falkland Islands to the Parallel of 35°40'S.

For explanation of Symbols see Appendix I.



Engraved by Malby & Sons