

**REPORT ON RV SONNE RESEARCH CRUISE
TO MANIHIKI PLATEAU, BGR CRUISE SO67-1,
February-March 1990**

by

P.J. Hill

Bureau of Mineral Resources, Geology and Geophysics,
Canberra, Australia

and

A.T. Utanga

Department of Internal Affairs,
Rarotonga, Cook Islands

Prepared for: South Pacific Applied Geoscience Commission (SOPAC)

Contributed by: Federal Republic of Germany, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)

[2]

[CR133 - Hill & Utanga]

TABLE OF CONTENTS

	Page
INTRODUCTION	4
PRELIMINARY RESULTS AND CONCLUSIONS	7
APPENDICES	
1 Cruise Narrative	9
2 Shipboard Personnel	19
3 Survey and Sampling Equipment	21

List of Figures

Figure		
1	Cruise location map	5
2	Profile locations	6

INTRODUCTION

In February/March 1990, a 24-day geological and geophysical research cruise to Manihiki Plateau in the Cook Islands was conducted by the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) of Hannover, Federal Republic of Germany. The research ship *Sonne* left Suva on 17 February and returned to the same port on 16 March 1990, at the conclusion of the cruise. The complete cruise narrative is appended at Appendix 1.

The primary objective of the cruise was to study an unusual complex of volcanic cones discovered a few years earlier during Tripartite II expeditions of HMNZS Tui (1986) and RV Moana Wave (1987). The volcanic complex is located on the NE edge of Manihiki Plateau and centred at 10° 18.5'S; 161° 27.5'W.

Geophysical and bathymetric mapping, plus minor investigations of specific geological targets, were carried out during the transits to and from the NE Manihiki Plateau study area. The survey work was carried out in the EEZs of Fiji, Western Samoa and the Cook Islands - with approval and encouragement of the governments of the respective island countries.

The attached location and track maps (Figures 1 and 2) provide an indication of the areas covered by the investigation and the extent of survey work undertaken.

This report provides an initial post-cruise account of the research activities and some of the preliminary results of the investigations. A more comprehensive and definitive cruise report is being prepared by the cruise leader and scientific party, and this will be available at a later date.

A list of shipboard personnel and a list of equipment used during the cruise are given in Appendices 2 and 3.

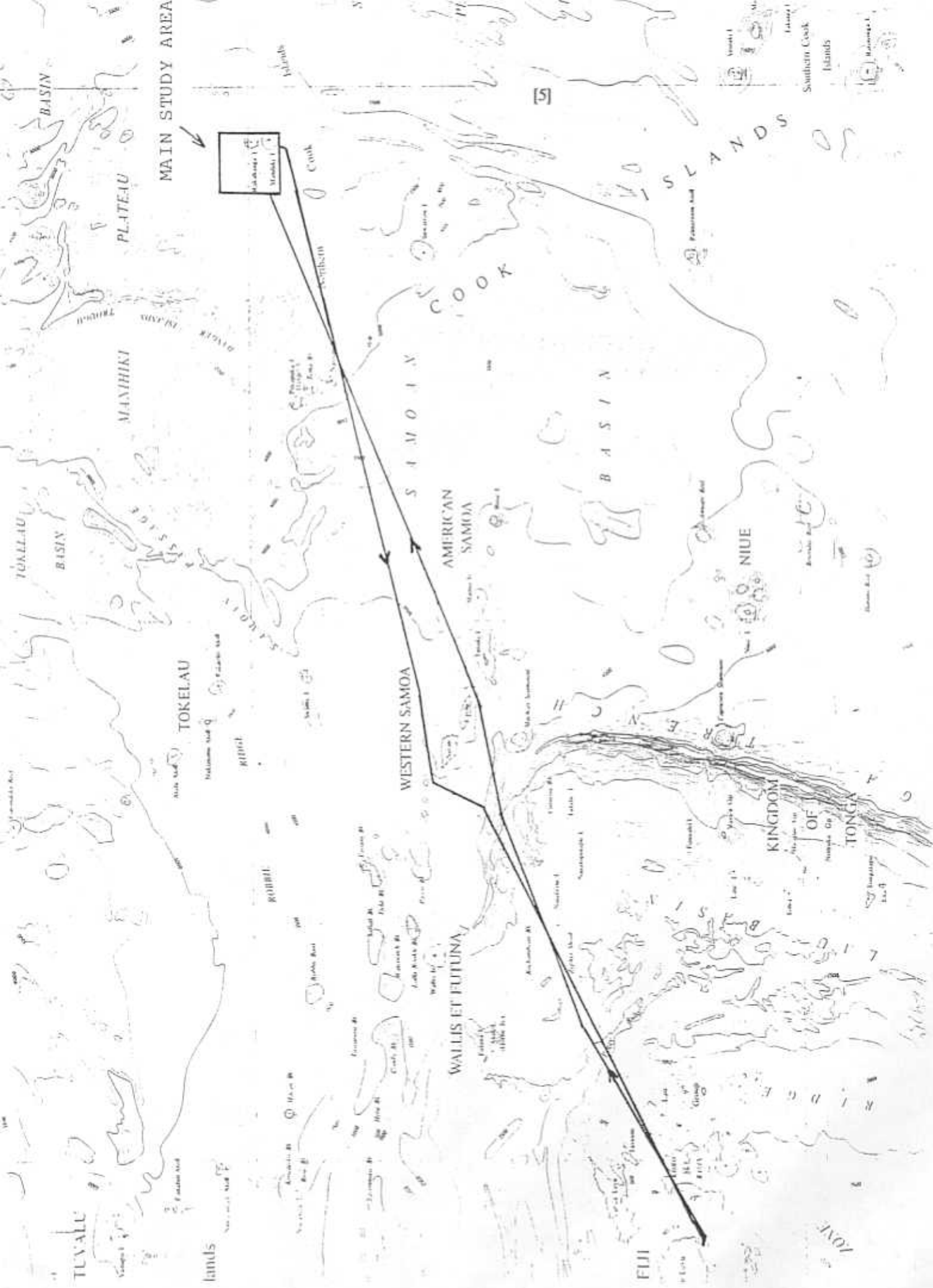


Figure 1. Cruise location map; main study area and approximate transit lines.

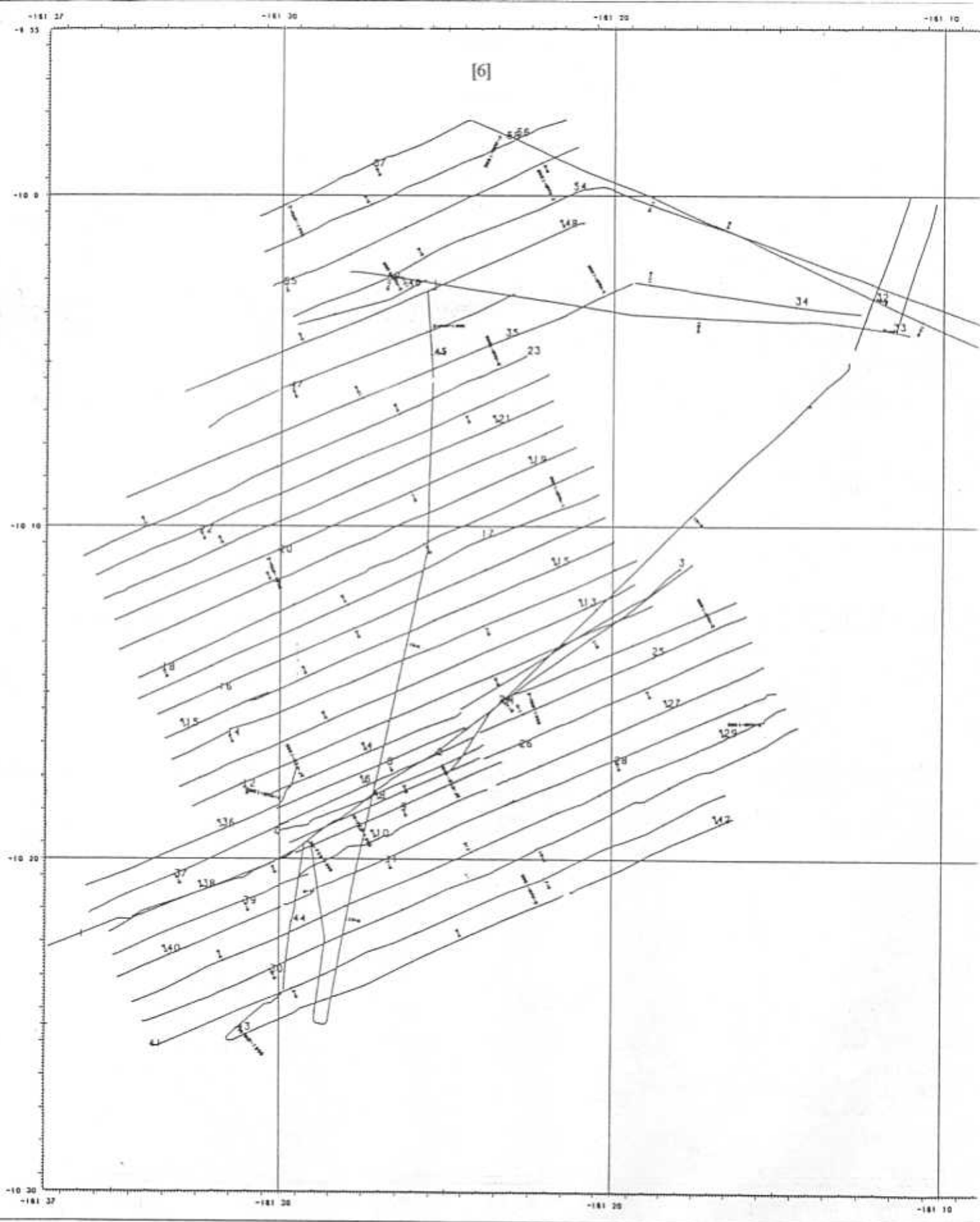


Figure 2. Profile locations in the volcanic complex area, NE Manihiki Plateau.

PRELIMINARY RESULTS AND CONCLUSIONS

1. The field of volcanic cones and composite edifice at the NE edge of Manihiki Plateau are of igneous origin (rather than sedimentary i.e. mud volcanoes). These structures are composed mainly of volcanoclastic sediments, volcanic breccia and basalts. They are partly covered by a thin layer of Recent foram ooze. The volcanism dates back to at least Maestrichtian (about 70 Ma).
2. Detailed bathymetric contour maps of the cones and main edifice, as well as some areas around Rakahanga and Manihiki atoll have been produced. The 20 m contour interval Seabeam maps cover an area of about 2,000 sq. m. Magnetic and 3.5 kHz seismic profiling was also done in conjunction with the Seabeam mapping.
3. The cones and main edifice bear thick Mn crusts, and may therefore have mineral resource potential. Dredging has shown that these crusts are commonly 6 cm thick; at one site Mn crust 10 cm thick was recovered.
4. No significantly anomalous methane concentrations were recorded in the water column in the NE Manihiki Plateau area.
5. The investigation of seafloor structures first identified in the GLORIA side-scan images of the 1989 SOPAC survey revealed that -
 - (i) a previously unmapped seamount north of Upolu is 1.5 km high, rising from the surrounding abyssal plain at depth 4,840 m to a height of 3,330 m.
 - (ii) a circular structure to the SW of Savaii appears to be a volcanic cone 150 m high and 2 km across. It lies at a water depth of 4,300 m.

APPENDIX 1

CRUISE NARRATIVE

DAY 1 (Wednesday 21 February, Julian day 051/052)

Ship left Suva wharf at 1230 (local time) and headed for Manihiki Plateau.

Began collecting Seabeam data once in area of Koro Sea Basin.

DAY 2 (J. day 052/053)

Stopped Seabeam acquisition on reaching Fiji EEZ boundary (approx. 15° 59.9'S; 170° 30.0'W) at 0805 GMT day 052. The reason for this was that approval for surveying in Tongan waters was not received in time. It had been agreed before the cruise that no survey work would be conducted in the EEZs of Fiji, Tonga and Western Samoa unless SOPAC obtained the necessary approvals from the governments of these countries in advance.

DAY 3 (J. day 053/054)

Set up magnetometer and deployed sensor for testing. Functioned well. Moderately rough seas. Seabeam not switched on in the Western Samoan EEZ since the requisite approval (via SOPAC) was not received in time.

DAY 4 (J. day 054/055)

Continued transit to Manihiki Plateau. Passed between Upolu and Tutuila, then north of Manua Island. Seas abating to low swell,

DAY 5 (J. day 055/056)

Transit across Samoan Basin and into EEZ of Cook Islands. Commenced Seabeam acquisition south of Nassau Island (base of western Manihiki Plateau) - longitude 165° 45'W - at 0129 GMT day 056. Line designated as SO67001. Continued on course 069 deg. at speed of 11 knots.

Started collecting magnetic and 3.5 kHz seismic data just west of Suwarrow Trough (about 164° 10'W) at 0940 GMT day 056. Several symmetrical cones to about 700 m high were mapped on the western plateau.

DAY 6 (J. day 056/057)

Crossed Suwarrow Trough in the early hours of the morning and by late morning had passed over the eroded eastern edge of Manihiki Plateau. Ran line SO67002 across the NE Manihiki volcanic edifice to a location in deep water west of Rakahanga Island. At this location (10° 11.6'S; 161° 18.9'W; water depth 3,693 m) the ship was stopped and a multi-probe (IMS)

deployed. The main aim of the MS was to establish the variation of the velocity sound with depth in the area so as to calibrate Seabeam.

At about 0500 GMT day 057 profiling (with Seabeam, 3.5 kHz seismic and magnetics) of the summit area of the edifice commenced. Lines were oriented in an ENE direction. Lines SO67003-007 were completed but navigation was poor due to GPS being unavailable. The top of the edifice was at about 1,310 m water depth. Profiling was discontinued and the ship proceeded to the summit area to begin an OFOS transect down the eastern flank of the edifice. The transect (20OFOS) began at about 0930 GMT day 057.

DAY 7 (J. day 057/058)

Ran the OFOS through much of the night. Video monitor showed the edifice as having about 60% foram ooze cover and about 40% exposure of Mn (more correctly FeMn-oxide) encrusted rock. The exposures often appeared as sheet-like structures, and gave the impression of being lava flows or, possibly, dipping sedimentary strata. The surface of the carbonate ooze was generally rippled and worm trails were commonly observed.

The upper eastern flank was sampled by rock dredge (3KD). Several pieces of Mn crust (1-2 cm thick) plus a short length of weathered and abraded 'staghorn' coral were recovered. The lower eastern side of the edifice was then dredged (4KD), and about 6 pieces of Mn crust (also about 1-2 cm thick) were recovered. Some of the pieces had a distinct botryoidal surface, while one sample had a thin layer of substrate attached - possibly highly altered vesicular basalt.

Lines SO67004(II)-0011 were surveyed with Seabeam, 3.5 kHz seismic and magnetics over the summit area, repeating some of the earlier coverage because of the earlier poor navigation control (no GPS).

After completion of the profiling, the ship proceeded to the western side of the edifice to a sampling site selected on a sediment mound adjacent to the edifice in 2,900 m of water.

DAY 8 (J. day 058/059)

5 m of Recent foram ooze was recovered by piston corer from the site (5KL). The 6 m heat flow probe was then deployed (6 HF). At the first attempt it fell over, as indicated by the inclinometer. A second attempt to insert the probe was made, and some penetration (about 1 m) was achieved - but the probe was severely bent and some of the internal electronics were damaged by droplets of condensation. No useful data were obtained.

A proposed MS was also aborted because of problems with the winch instrumentation.

The ship then moved to a site on the western flank of the edifice (10° 18.30'S; 161° 28.45'W, 2,000 m water depth). Rock dredge 7KD was deployed and by mid-morning the dredge haul was on board. The samples comprised one large block (about 0.5 m diameter) of thickly Mn-encrusted Eocene limestone (crust up to 5 cm thick) plus a number of crust fragments and broken lumps of Mn-encrusted limestone.

The next dredge site, 8KD, was on a cone located on the NE flank of the edifice at 10° 15.9'S; 161° 25.1'W in water depth of 2,600 m. It was planned to pull the dredge upslope to 2,100 m in direction 285°. The dredge returned almost full; the haul consisting of heavily Mn-

encrusted boulders, cobbles and smaller fragments. Mn crusts were up to 6 cm thick, and averaged about 3 cm in thickness. Lithologies included burrowed Eocene foram limestone, highly altered volcanoclastic material (often greenish or mottled grey colour), altered volcanics (?basalt) and volcanoclastic breccia (in a hard white matrix -?siliceous limestone).

Surveying of 15m-long profiles with Seabeam, 3.5 kHz seismic and magnetics began at about 0130 GMT day 059. These ENE-oriented lines (SO06712-17) extended the previous data coverage to the north of the main edifice.

DAY 9 (J. day 059/060)

The ship transited to the eastern side of the main edifice and located the top of a previously-mapped cone on the mid-slope at water depth of about 2,400 m. This location (approx. 10° 17.1'S; 161° 24.9'W) was the starting point of transect 90FOS+BS, which commenced at about 1300 GMT day 059. The video monitor pictures showed a rounded cone summit with steeply descending sides. Outcrop of thickly Mn-encrusted rock appeared to be stratified (? flow structures) with down-slope dip. The upper part of the cone was covered by a veneer of ?Recent foram sand (about 40% coverage). What appeared to be an old debris slide, recemented by Mn crust, was observed on the steep upper flank. The feature was several metres wide and at least 25 m long. Towards the base of the cone the slope flattened out and Mn-encrusted outcrop was no longer visible. The bottom consisted of foram ooze, marked every so often by sinuous (worm) feeding trails. At the end of the transect some low-relief outcrop was again seen. During the entire transect there was no indication of even a slight current. The water column appeared to be perfectly still.

After the OFOS survey, the dredge wire was played out behind the ship so as to remove kinks which had made spooling difficult.

The top of the cone surveyed by 90FOS+BS was then dredged (10 KD). The dredge was back on board at about 0000 GMT day 060, with a large haul of boulder-size and many smaller samples. All samples were thickly Mn-encrusted (crust to 4 cm thick). Rock types were about 50% foram limestone, partly cherty, and about 50% stratified volcanoclastic sandstone (altered). Forams in limestone immediately overlying the volcanoclastic material were dated as Maestrichtian and were of neritic types.

At 0042 GMT day 060, profiling of the grid to the north of the main edifice recommenced. The Seabeam, 3.5 kHz seismic and magnetic profiling began with line SO67015 (part 2) and ended with completion of line SO67019 at 0836 day 060, when GPS navigation was no longer available.

Some then steamed SE to a sample site at the NW base of the main edifice. The site was located at 10° 17.0'S; 161° 33.3'W, on a local high point at 3,050 m depth. According to the 3.5 kHz record, the hillock was covered by young sediment. A 10-m piston corer was deployed at 0950 GMT day 060; 5 m of Recent foram ooze was recovered at about 2330 GMT.

DAY 10 (J. day 060/061)

A short (4 m) heat flow probe was then lowered at the same site (12 HF). The probe came back bent, and no useful heat flow data were obtained. The ship steamed to the summit of the composite edifice (water depth 1320 m) and multisonde 13 MS was lowered and the usual measurements made and water samples taken at various levels for geochemical analysis.

Sonne then moved SW to a cone on the flank of the edifice in 1,820 m depth that was to have been dredged previously (former 11KD). The dredge from this station (14KD) was brought aboard at 2300 GMT day 060. A full bag of boulder-size and smaller material, mainly limestones (commonly fractured) and a few Mn-encrusted amygdaloidal basalt cobbles, was recovered. As in previous dredge hauls, Mn crusts were on most samples. In this haul, fractured Mn crust up to 10 cm thick was present on some limestone blocks.

Sonne then proceeded NW to the start of profile SO67020. Seabeam, 3.5 kHz seismic and magnetic profiling continued to the end of SO67023, which was completed at 0715 GMT day 061.

The ship then headed to the summit of a prominent 600 m high cone located about 15 km north of the top of the main edifice. The cone is a composite of two cones, and stands out strongly in the SeaMARC II side-scan images. 15OFOS began with the lowering of the unit at about 0830 GMT. The OFOS traverse started at the summit of the cone in water depth of about 2,800 m, and continued down the side of the structure in a NW direction.

DAY 11 (J. day 061/062)

The summit area appeared to be rounded and was about 50% covered by foram sand. The sides of the cone dropped away steeply. The Mn-encrusted rock exposures were of low relief and mainly blocky, though some down-slope dipping strata or 'flow' structures were visible. Much of the 'outcrop' had a dusting or veneer of foram sand. Two sea pens attached to rocks were seen, suggesting some current activity in the area. No major areas of outcrop were observed below the base of the cone. From here, the seafloor sloped gently downwards and was covered by foram ooze. The depression (? channel) at the base of the cone was marked by ripples; but generally the bottom was relatively featureless, apart from occasional feeding trails and burrows. At one point the bottom suddenly dropped away, and the OFOS descended down the sheer vertical walls of a canyon (about 100 m high). Blocks of Mn-covered rock were seen embedded in the walls, which appeared to be mainly of pelagic carbonate; some stratified ?in-situ outcrop was present. The bottom of the canyon and seafloor lower down on the slope was, as before, covered calcareous ooze and appeared relatively featureless. The OFOS was raised at about 1400 GMT day 061 to avoid possible collision with rising topography (canyon wall/small cone). Dredging of a seafloor knoll in about 3,400 m water depth was attempted next in order to obtain samples of older volcanic/volcaniclastic material. Station 16KD was located at 10° 13.1'S; 161° 23.0'W, NE of the main edifice. Only 3 small Mn-coated pebbles were recovered in the dredge at about 2200 GMT.

Profiling of lines SO67024-30 to the east and south of the edifice commenced at 2255 GMT day 061 and ended at 1059 GMT day 062.

DAY 12 (J. day 062/063)

The ship then steamed across to dredge site 17KD located on the NW flank of the cone previously dredged (10KD); this cone is situated on the eastern side of the main edifice. The dredge was retrieved at 1620 GMT day 062, and contained 2 large cobbles of Mn-encrusted amygdaloidal basalt. A layer of cemented volcaniclastic material was attached to some of the basalt samples. Pores of the core of the basalt cobbles were filled with white calcite. At about 2200 GMT Sonne anchored about 1 km off the landing and village on Rakahanga Island. By arrangement with the local people, outboard-powered dinghies were used to ferry

members of the scientific party and crew ashore for a brief visit. Tony Utanga of the Cook Islands government went ashore to meet with the local council and government representatives.

The ship departed at about 0130 GMT day 063, and headed for dredge site 18KD at the base of the Rakahanga edifice (SW side) in 3,200 m of water (approx. position 10° 05.4'S; 161° 09.7'W). Dredging started at about 0300 GMT. A large dredge haul of Mn-encrusted rocks was recovered; crusts were up to 4 cm thick. The rocks comprised laminated volcanoclastic sandstones, volcanic breccia and basalt (part of flow). Clasts in the breccia ranged to cobble size, and were angular to sub-rounded and composed of basalt and volcanoclastite. Multi-probe 19MS was lowered at a site just to the west (10° 03.7'S; 161° 12.0'W), where the depth was 3,600 m.

After completion of 19MS, profile SO67034 was begun at 1015 GMT day 063. This profile plus the next (SO67035) were to take the ship to a point in a water depth of about 3,200 m on the plateau edge to the NW of the edifice for a piston core and heat flow measurement.

DAY 13 (J. day 063/064)

Both coring operation and heat flow measurement were successfully completed at stations 20KL and 21HF respectively. The 15-m piston corer recovered 12 m of Recent - mid-Pliocene foram ooze. The core included at least two graded turbidite layers, each about 1/2 m thick. The short 4 m heat flow probe yielded an anomalously low temperature gradient, possibly because of the high permeability of the foram sand.

Moving back east, rock dredge 22KD was deployed on the cone investigated earlier north of the main edifice. The cone was the site of the 15OFOS run. Dredging began at 10° 09.2'S; 161° 28.3'W in a water depth of 3,340 m and ended on the cone at about 2,900 m depth. The dredge sample was on deck at 2330 GMT day 063, and comprised 2 blocks each about 40 cm across plus a quantity of smaller material. The samples were encrusted Mn crust up to 7 cm thick. The rocks included relatively fresh-looking vesicular basalt (possibly suitable for K/Ar dating), grey laminated fine-grained tuff and beige-coloured silicified foram limestone. The latter contained both planktonic and benthic forams (in ratio of about 1:1), but apparently no index forms. Though the sample could not be accurately dated, onboard analysis indicates that it may be early Late Cretaceous. The forams present suggest a palaeo - water depth of about 200 m and open marine environment.

Profile SO67035A was begun at 2347 GMT day 063 and run to the south (providing useful data to tie earlier magnetic profiles). Profiling of the area to the SW of the edifice continued with lines SO67036-43 being completed.

DAY 14 (J. day 064/065)

Lines SO67044 & 45 were then run in a NNE direction across the summit area of the edifice, the main objective being to acquire a key magnetic profile. Minimum water depth recorded (directly beneath the ship) was about 1,550 m, with profile SO67044 located just east of the highest point (about 1,310 m depth).

Profiling of these lines ended at 1417 GMT day 064. Seabeam and 3.5 kHz seismic mapping continued along line SO67046 to the west across the marginal slope of the plateau until 1544 GMT. This was in preparation for traverse 23OFOS.

The OFOS was deployed at about 1700 GMT in a water depth of about 3,400 m, and observations of the seafloor were made for about 1 hour to a depth of about 3,600 m. The bottom was covered by foram ooze and was relatively featureless apart from a few small isolated Mn-encrusted outcrops.

The scientific work came to a halt when a problem developed in the winch room. The OFOS cable had jumped off a pulley and became damaged on gear teeth. It took about 8 hours to make the winch system operational again to allow recovery of the OFOS. The cable had to be cut and spooled onto a spare winch. The cable length was now reduced to 3,200 m. Rewinding slowly, the OFOS was back on board at about 0700 GMT.

DAY 15 (J. day 065/066)

When out of the GPS window, the ship steamed to dredge station 24KD on the plateau margin. The target was a canyon wall with ledges at depth 3,500 m. The dredge hit the bottom at 1349 GMT day 065 and was back on deck at 1538 GMT.

A large haul of Mn-encrusted volcanoclastic sedimentary rock was obtained; some blocks were up to 40 cm across. Crusts were up to 2 cm thick. The sediments were interbedded volcanoclastic sandstones/siltstones/mudstone. Beds typically ranged from 1 to 12 cm in thickness. Deposition by currents was evident from the cross-bedding and erosional surfaces present. The sediments appear to have been deposited in a terrestrial rather than marine environment.

Line SO67049 was then run across to the southern flank of Rakahanga atoll. A grid of three lines (SO67050-52) was surveyed over a spur on the flank to locate suitable dredge sites. No magnetic data were collected along SO67049-52. Station 25KD was dredged in water depth of about 1,1440 m. The dredge was on the bottom at 2240 GMT day 065, and on board again at 2350 GMT. Dredge location was approximately 10° 03.5'S; 161° 06.1'W. A large haul of carbonate rubble was recovered; it included Recent corals and bryozoa and Mn-coated foram limestone of early Pliocene age. The forams were planktonic. Station 26KD was dredged next at a lower level on the spur (about 2,200 m depth), at about 10° 04.9'S; 161° 06.3'W. The dredge returned with large cobbles of relatively fresh vesicular basalt, volcanic breccia and burrowed chalky limestone. Mn crust was up to 2 cm thick, and on all rock types present. The forams in the limestone are mainly planktonic; some are benthonic. Eocene forms may be present, though this still needs to be verified by examination of the limestone in thin section. Sonne left the Rakahanga area and proceeded NW along line SO67053, to continue further profiling along the plateau margin north of the previous coverage. On startup the magnetometer was found to have developed a fault, which was traced to an open-circuit in the cable at the winch connector. The OFOS cable was streamed behind the ship to test the operation of the winch system, and while this was in progress a new short cable and connector was fitted at the magnetometer winch. The magnetometer was back in operation at 0710 GMT day 066 on line SO67055.

After completing lines SO67053-57, profiling was continued on line SO67058 which was a traverse back to the area dredged on the southern flank of Rakahanga.

DAY 16 (J. day 066/067)

The profiling ended just south of Rakahanga at 1219 GMT day 066. The third dredge in the area was then begun. Station 27KD was the deepest of the sites at water depth of about

2,600 m. A good haul of rocks was obtained. Most samples were Mn coated or encrusted (maximum thickness 12 mm). The material consisted of, (i) volcanic breccia containing large (to about 20 cm) sub-rounded clasts of moderately altered basalt, (ii) foram limestone with some angular clasts of volcanoclastic/foram sandstone, (iii) breccia of volcanoclastic clasts in a matrix of foram limestone (some of the clasts were of foram/volcanoclastic sandstone, with forams dated as late Palaeocene - early Eocene), and a very coarse grained red-brown volcanoclastic sandstone/tuff (containing broken amphibole grains).

After the dredge at 27KD, the ship moved into calm water in the lee of Rakahanga Island (about 1 km off the village wharf). This was done to allow the spooling of a new 7 km long conductor (OFOS) cable onto the winch to be done in safety. For this operation a new drum of cable had to be extracted from the bottom of the hold and firmly secured for unwinding. Winding the cable onto the winch was a major task that took all day, with some testing done in the early evening. The ship left the area off SW Rakahanga at 0821 GMT day 067 and started profiling of line SO67059 (with magnetics and Seabeam), heading NNW to a way point at 09°55.0'S; 161° 06.0'W. Due to shortage of time, about 500 m of OFOS cable was initially streamed over the stern to test the operation of the winch system. There appears to have been no adverse effect on the magnetic data, probably because the heavy OFOS cable ran quite deep. Profile SO67060 (which included 3.5 kHz seismic) then continued to the NW towards the SO35-1 survey area.

DAY 17 (J. day 067/068)

After crossing a 400 m deep canyon at the plateau margin the profile continued onto the eroded plateau edge, after which the ship turned NNE onto line SO67061 back across the plateau margin and into deep water. The line ended at 1351 GMT day 067.

28MS was deployed at 09° 24.0'S; 161° 29.6'W in water depth of 4,200 m. No methane anomalies were recorded.

The ship then went back onto the plateau to take a piston core at station 29KL at about 09° 35.5'S; 161° 34.0'W in water depth of 3,567 m. The 15-m corer was on the bottom at 2043 GMT and returned with 10 m of soft-firm calcareous ooze (Pleistocene - Recent).

A short 4-m heat flow probe was then lowered at the same location at 2209 GMT and was on the bottom by 2321 GMT. The results indicate a heat flow of 22 mW/m, which is lower than expected and may be due to water circulation through the permeable near-surface ooze.

The ship then moved across to 09° 30.4'S; 161° 32.7'W in 3,640 m of water to begin the 31OFOS traverse over the margin of the plateau. The traverse direction was NNE. The OFOS was on the bottom at about 0330 GMT day 068; and after a relatively long seafloor traverse, the OFOS was winched back up at 0912 GMT from a water depth of 4,139 m. The upper slope down to 3,670 m was covered by a blanket of calcareous ooze; from this level to 3,820 m, a few Mn-covered outcrops were sighted and much of the slope surface was pock-marked, free of loose sediment and light coloured (? chalk or siltstone). The slope then began to drop steeply and became an escarpment between 3,900-4,010 m, with much in situ outcrop. Talus covered the foot of the escarpment. The slope flattened out to a terrace at a depth of about 4,050 m and was largely sediment covered (? ooze); wide tracks of a bottom dwelling creature were observed. At 4,115 m depth the seafloor was paved by loose rocks.

DAY 18 (J. day 068/069)

Two dredge hauls were made on the escarpment, 32KD in water depth of about 4,120-3,870 m and 33KD between about 4,100-3,830 m. At 32KD only 3 pebbles were recovered - one was a burrowed chalky limestone containing small clasts of highly altered volcaniclastic material; while the other two were flat pebbles of grey fine-grained volcaniclastic sediment with a 6 mm thick Mn crust.

A large haul of Mn-encrusted cobbles (to about 4 cm across) and pebbles was recovered from 34KD. The rocks were all of grey volcaniclastic siltstone, laminated and with cross-bedding structures. The thickness of the Mn crusts was commonly ranged to 6 mm, though a few pieces of crust (without substrate) were about 15 mm thick.

At 2248 GMT day 068, profile SO67062 was started in a SE direction to a point (09' 50.0'S; 161' 04.8'W) north of Rakahanga. A traverse was then run to the south past the eastern side of Rakahanga in water depth of 1,050 m, and then past the western side of Manihiki atoll in water depth of 730 m. The traverse was completed at 0617 GMT day 069 at about 10' 38.0'S; 161' 02.0'W.

The electronics unit of the heat flow probe was then tested for water tightness to a depth of 1,000 m, after which the ship proceeded WSW to the DSDP 317 site on the High Plateau.

DAY 19 (J. day 069/070)

A 20-m piston corer (34KL) was deployed at the drill-site at 1500 GMT day 069. The corer hit the bottom at 1616 GMT in 2,609 m of water. A record 16.2 m of core was recovered - the sediment was foram ooze of Pliocene maximum age. Coring at this location was followed by deployment of a 4-m heat flow probe (35HF). The thermal gradient and thermal conductivity were successfully carried out, but again yielded a relatively low value of 22 mW/m.

Sonne left the site at 2000 GMT day 069 and profiling commenced with Seabeam and 3.5 kHz seismic across the plateau towards Samoa (line SO67065) as part of the return transit to Suva. Acquisition of magnetic data began east of Suwarrow Trough on the High Plateau at longitude 163' 00'W, at 2343 GMT day 069.

DAY 20 (J. day 070/071)

The magnetometer was pulled aboard over the central Samoan Basin at 2017 GMT day 070; the ship's position at this point was 12' 11.7'S; 167' 01.5'W. The return transit continued at 12 knots towards a way point at 13' 12.6'S; 171' 26.3'W. This point was estimated to coincide with the peak of a large seamount first identified in the side-scan images from the August 1989 SOPAC GLORIA survey aboard HMAS Cook.

DAY 21 (J. day 071/072)

Profiling (including magnetics) began in the Western Samoan EEZ at 1711 GMT day 071. The previously unmapped seamount north of Upolu was approached at 1910 GMT. Three NE-SW oriented crossings were made (with Seabeam, 3.5 kHz seismic and magnetics). The seamount was found to be 1,500 m high, rising from the surrounding abyssal plain at 4,840 m

to a summit at 3,330 m depth. The summit was located at about 13° 12.8'S; 171° 26.5'W. The magnetometer was pulled aboard and the ship steamed to the summit, there a multi-probe (36MS) was deployed for hydrographic measurements and collection of water samples.

An attempt to use the TV-grab to sample the top of the seamount was made, but this had to be aborted because of a problem with the grab's hydraulics. Starting at 0414 GMT day 072, three more profiles were run over the seamount (this time with benefit of GPS). The ship then continued the return transit, with the intention of briefly mapping some unusual ring structures observed in GLORIA images from SW of Savaii.

DAY 22 (J. day 072/073)

It was hoped to cross one of the ring structures (estimated location 13° 40.2'S; 173° 09.3'W) during the early hours of the morning, and map it with Seabeam. At 1529 GMT day 072, a cone (or to be more exact, 1/2 a cone) about 150 m high and 2 km across appeared in the Seabeam contours - but at the extreme eastern edge of the beam coverage. It seems that this cone was responsible for the circular image in the GLORIA data. The ship may have passed to the west of the feature because of poor navigational control - GPS was not available at the time.

The ship continued to the SW. Profiling was terminated in Western Samoan waters at 1920 GMT day 072, on the upper northern flank of the Tonga Trench. This marked the end of data collection for cruise SO67-1. No survey work was done in Tongan waters because approval was not received in time.

Sonne headed to Suva on a direct course at 12 knots.

DAY 23 (J. day 073/074)

Continued direct transit to Suva.

DAY 24 (J. day 074/075)

Sonne berthed at Suva wharf at 8.00 am local time, thus ending the cruise.

APPENDIX 2

SHIPBOARD PERSONNEL

Shipboard Scientists & Science Technicians

Cruise leader	Helmut Beiersdorf
Marine geology	Hermann-Rudolf (Herrud) Kudrass Michael Wiedicke-Hombach Doug Bergersen (Hawaii Institute of Geophysics)
Marine geophysics	Peter Hill (Bureau of Mineral Resources, Canberra)
Micropalaeontology	Wolfgang Weiss
Geochemistry	Eckhard Faber Manfred Teschner Dieter Panten
Heat Flow	Georg Delisle Dieter Steinman
National representative	Tony Utanga (Cook Islands)
Technicians (marine geology) :	Helmut Kawohl Rainer Goergens
Geophysics/data acquisition :	Thomas Liebe Karsten Reinhard
Technicians (Preussag)	Hilmar (Yogi) Hoffman Martin Klingbeil
Ships doctor	Juergen Tollgaard

Ship's Officers & Crew

Captain	Martin Kull
Chief mate	Juergen Riemenschneider
1st mate	Martin Niedermeier
Radio operator	Horst Bruhns
Chief engineer	Hand-Juergen Neve
Engineer 2	Helge Beyer
Engineer 2	Andreas Rex
Engineer 2	Hans-Wilhelm Neimann
Electrician	Heinz-Dieter Arndt
Electrician	Ulrich Luetticke
Electrician	Burkhard Rehberg
Storekeeper	Rudolph Tschardtke
Engineer	Roland Teske
Engineer	Kurt Bochert
Engineer	Rainer Rosemeyer
Chief cook	Hans Dieter Scheel
Cook	Peter Neumann
Chief steward	Ernst Horzella
Steward	Peter Lack
Steward	Peter Eller
Boatswain	Kurt Ranalder
A.B.	Harald Boldt
A.B.	Peter Harjes
A.B.	Hermann Roepti
A.B.	Guenter Lude
A.B.	Frank Wehrhane
Seaman	Michael Bruns

APPENDIX 3

SURVEY AND SAMPLING EQUIPMENT ABOARD SONNE

SEABEAM SYSTEM (SBS)

12 kHz multi-beam echo-sounder, 16 transducers hull-mounted, 30 deg. beam across track providing a swath width of 70% water depth.

SUB-BOTTOM PROFILER (SBP)

3.5 kHz 10 kW transceiver (Ocean Research Equipment model 140); EPC graphic recorder.

MAGNETOMETER (MAG)

Geometrics G801/803 proton precision magnetometer with strip-chart recorder; sensor towed 250 m behind ship.

OCEAN FLOOR OBSERVATION SYSTEM (OFOS)

Built by Preussag, with

- (i) video camera and onboard monitoring and recording system
- (ii) 2 x still cameras for taking colour slides (35 mm film), up to 760 stereo shots
- (iii) sensors
 - temperature
 - salinity
 - conductivity
 - depth
 - speed of sound
 - pressure
 - density(water)

OFOS + SUCTION SAMPLER (OFOS + SS)

Unit attaches to OFOS frame and allows sampling of soft sediment from the ocean floor, 4 x 20 litre bags

OFOS + BOTTLE SAMPLER (OFOS + BS)

Unit also attaches to OFOS frame; contains 8 Niskin bottles which can be individually closed as required from the ship - for analysis of seawater geochemistry

MULTIPROBE (MS)

Measures water column profiles, parameters include :-

- (i) sound velocity
- (ii) temperature
- (iii) pressure
- (iv) depth
- (v) conductivity/salinity
- (vi) light transmissivity

also contains 12 Niskin bottles which can sample seawater at required levels by shipboard control.

TV-GRAB TYPE A (TVGA)

Large two-jaw grab with video monitor

TV-GRAB TYPE B (TVGB)

Large multi-jaw grab with video monitor

PISTON CORER (KL)

Can be made up in 5, 10, 15 & 20 m lengths (10 m is standard)

CHAIN-BAG DREDGE (KD)

Standard rock-type dredge with chain-mesh and inner nylon netting.

HEAT FLOW PROBE (HF)

6 m length with 7 sensor elements/4 m length with 4 sensors.
On-board thermal conductivity measuring equipment.