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The Nares 2001 Geoscience Project: An Introduction

by Ian D. Reid[1], H. Ruth Jackson[2] and Franz Tessensohn[3]

Abstract: Nares Strait forms a rather straight set of narrow marine channels between Greenland and the Canadian Arctic Islands. Since 1982, the Nares Strait dilemma forms a classical case of conflict between plate tectonics and regional geology without obvious solution. Plate tectonics postulated a sinistral continental transform through the strait, whereas regional geological mapping results could not find evidence for the required offsets. Between 1982 and 2000 new data were gathered in northern Baffin Bay and on either side of the Strait, yet the Strait itself had still not been investigated. We report on an expedition carried out in 2001 in the previously unexplored water covered area. In spite of the difficult ice conditions, we gathered new marine, aeromagnetic and geological data relevant to the problem. The results are presented in this volume together with compilations of the related geological and geophysical data bases. The new results narrow the gap between plate tectonics and regional geology although we have not yet reached a final solution of the controversy.

Zusammenfassung: Die Nares Strait bildet eine ziemlich gradlinige Aneinanderreihung von engen Meereskanälen zwischen Grönland und den kanadischen Arktis-Inseln. Seit 1982 bildet das Problem Nares Strait einen klassi-schen Konfliktfall zwischen Plattentektonik und regionaler Geologie, bisher ohne eindeutige Lösung. Die Plattentektonik postulierte eine sinistrale Trans-form-Störung durch die Meeresstraße, während regionalgeologische Kartier-ergebnisse keine Hinweise auf die resultierenden Versatzbeträge fanden. Neue Feldergebnisse wurden zwischen 1982 und 2000 in der nördlichen Baf-fin Bay und an beiden Rändern der Meeresstraße gewonnen, aber sie selbst war immer noch nicht direkt untersucht. Wir berichten hier über eine Meeres-Expedition in dieses Gebiet im Jahr 2001. Trotz schwieriger Eisverhältnisse konnten neue seismische, aeromagnetische und geologische Daten zur Nares-Problematik gewonnen werden. Die Ergebnisse werden in diesem Band vor-gestellt, zusammen mit Kompilationen aus den existierenden geologischen und geophysikalischen Unterlagen. Die neuen Ergebnisse verringern die Diskrepanz zwischen Plattentektonik und regionaler Geologie, obwohl sie noch keine endgültige Lösung des Problems darstellen.

INTRODUCTION

The set of narrow marine channels between Greenland and the Canadian Arctic Islands, collectively known as Nares Strait (Fig. 1), has played a significant role in the development of the theories of continental drift and plate tectonics. TAYLOR (1910) and WEGENER (1912) both noted the apparent eastward shift of Greenland relative to North America, and WEGENER, in his classic "Origin of Continents and Oceans" (1915), discussed the substantial left-lateral motion as the only example of strike-slip movement at a boundary between continents. WILSON (1965) gave credit to these early ideas when he gave the name "Wegener Fault" to the tectonic boundary in the Strait. The subsequent development of plate tectonics, and the identification of the Labrador Sea and Baffin Bay as oceanic basins formed by seafloor spreading, seemed to confirm this interpretation, requiring over 200 km of sinistral motion (SRIVASTAVA & FALCONER 1982). Onshore geological evidence, however, implied that no more than 25 km of offset had taken place (MAYR & DE VRIES 1982), and this discrepancy has given rise to a long-standing controversy. The situation is complicated by the fact that in addition to the postulated Wegener Fault two more important tectonic boundaries are mapped to lie under the waters of the northern part of Nares Strait (Fig. 1). The question: Did Greenland drift along Nares Strait? has been argued for more than 90 years, and was the subject of a major symposium in 1980 (DAWES & KERR 1982). The papers in this volume describe results obtained during a recent geological/geophysical survey of Nares Strait, that may help to resolve some of these problems.

[1] Geological Institute, University of Copenhagen, Øster Voldgade 10, 1350 Copenhagen K, Denmark.
[2] Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, P.O. Box 1006, Nova Scotia, B2Y 4A2, Canada.
[3] Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, Postfach 30655 Hannover, Germany.

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BACKGROUND

The debate on the origin of Nares Strait revolves round three hypotheses: the Strait is a major strike-slip fault (TAYLOR 1910, WEGENER 1915, WILSON 1965, SRIVASTAVA & FALCONER 1982, SRIVASTAVA 1985), plate motion has been taken up in a zone of distributed deformation (HUGON 1983, MIALL 1984), or the Strait is not a plate boundary and the geology can be correlated across it (CHRISTIE et al. 1981, DAWES & KERR 1982, HIGGINS & SOPER 1989).

The actual problem, in both its plate tectonic and its geological aspects, is in fact more complicated. In addition to regional plate reconstructions that require transform motion of about 150 km in the region of Nares Strait (Fig. 2) during the opening of the Labrador Sea and Baffin Bay (ROEST & SRIVASTAVA 1989), a general analysis of plate motions in the western North Atlantic region (SRIVASTAVA & TAPSCOTT 1986) indicates that Greenland later moved northward, between magnetic anomalies 24-13 (56-35 Ma), with resultant convergence of about 100 km across the Strait.

The complexity of the tectonic history is reflected in the geology, especially in the contrasting regimes on the two sides of the Strait (Fig. 1). On northern Ellesmere Island there is a folded mountain belt, whereas on Greenland, only 25-100 km away, there is a flat-lying carbonate platform (Fig. 3). Further south along the Strait, in the Smith Sound region, the Archean shield and the Proterozoic sedimentary rocks of the Thule Group on either side (Fig. 1) appear to be correlatable (DAWES & KERR 1982b), but the lack of marine data has prevented definite confirmation of this. The onshore geological evidence has been interpreted as allowing an offset of no more than 25 km. MAYR & DE VRIES (1982) described sinistral strike-slip faults on Judge Daly Promontory compatible with such an offset. OKULITCH & TRETTIN (1991) suggest that the total amount of plate tectonic shortening is considerably reduced by

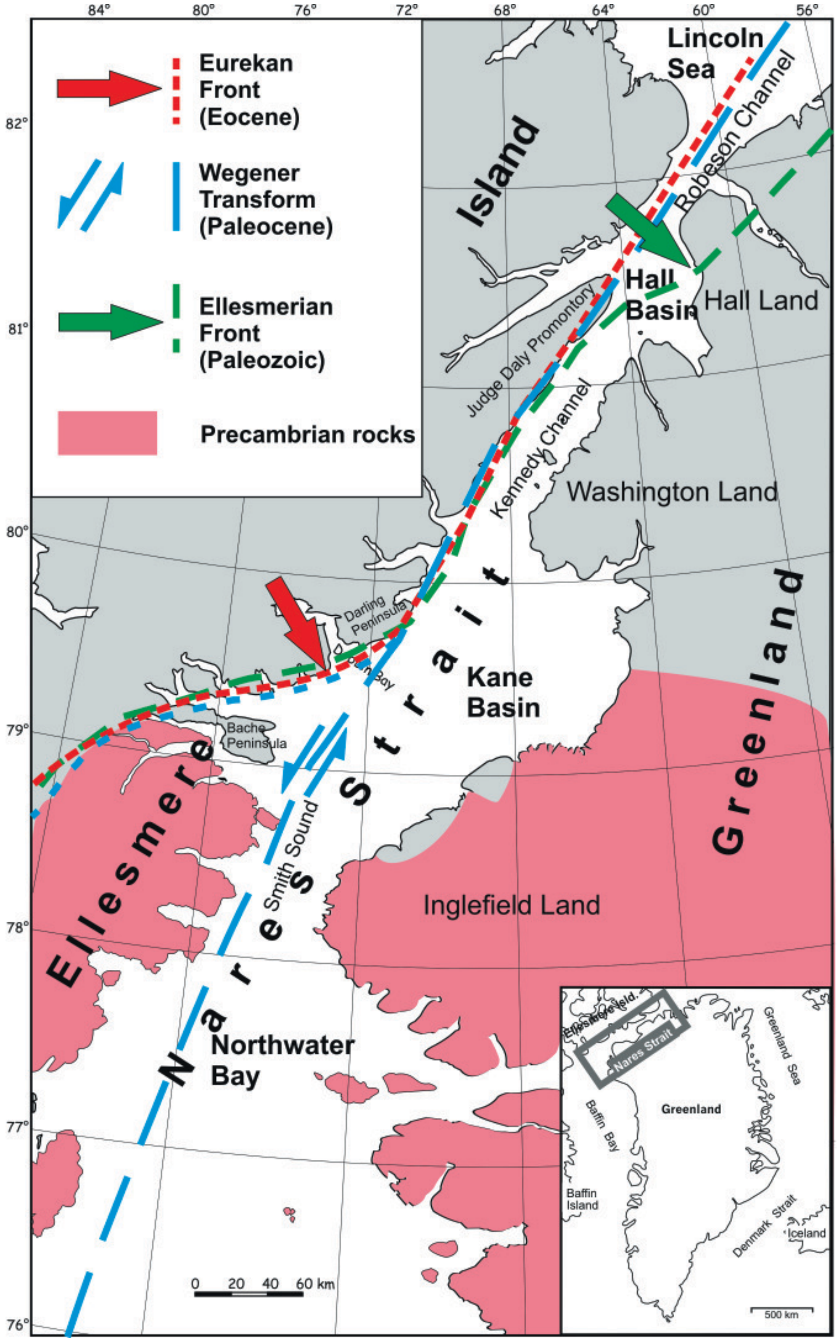

Fig. 1: Locality map of Nares Strait with some geological and tectonic features.

rifting in the areas of Jones and Lancaster sounds. A recent collaborative geological mapping program between Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and the Geological Survey of Canada (GSC) on Ellesmere Island verifies narrow elongate Tertiary basins onshore associated with sinistral strike-slip faults (Mayr in press).

There remains, however, a discrepancy between the large lateral movements that are implied for Greenland and North America, and the apparent lack of geological evidence for such an offset. The evidence could possibly have been obscured by subsequent convergence (Fig. 1) or might be detected by geophysical methods in the offshore areas.

In addition to the purely scientific interest, there are economic reasons for wanting a more accurate understanding of the motion of Greenland relative to North America. The motion between Greenland and Ellesmere Island is coupled with the more southerly translation between Greenland and Baffin Island in Davis Strait. This region is undergoing exploration for hydrocarbons and drilling activity took place in 2001. The first well in the new phase of drilling was dry and information that can constrain the evolution of the region is useful.

Since the publication of Dawes & Kerr (1982a) new onshore (Miall 1983, Okulitch & Trettin 1991, Tessensohn et al. in press) and offshore data (Jackson et al. 1992, Reid & Jackson 1997) have been collected that are relevant for elucidating the geological problems in the area. The results of this work emphasized the need to have direct information from the Strait itself. The scope of the project required a multi-institution programme and the application of a wide range of techniques,

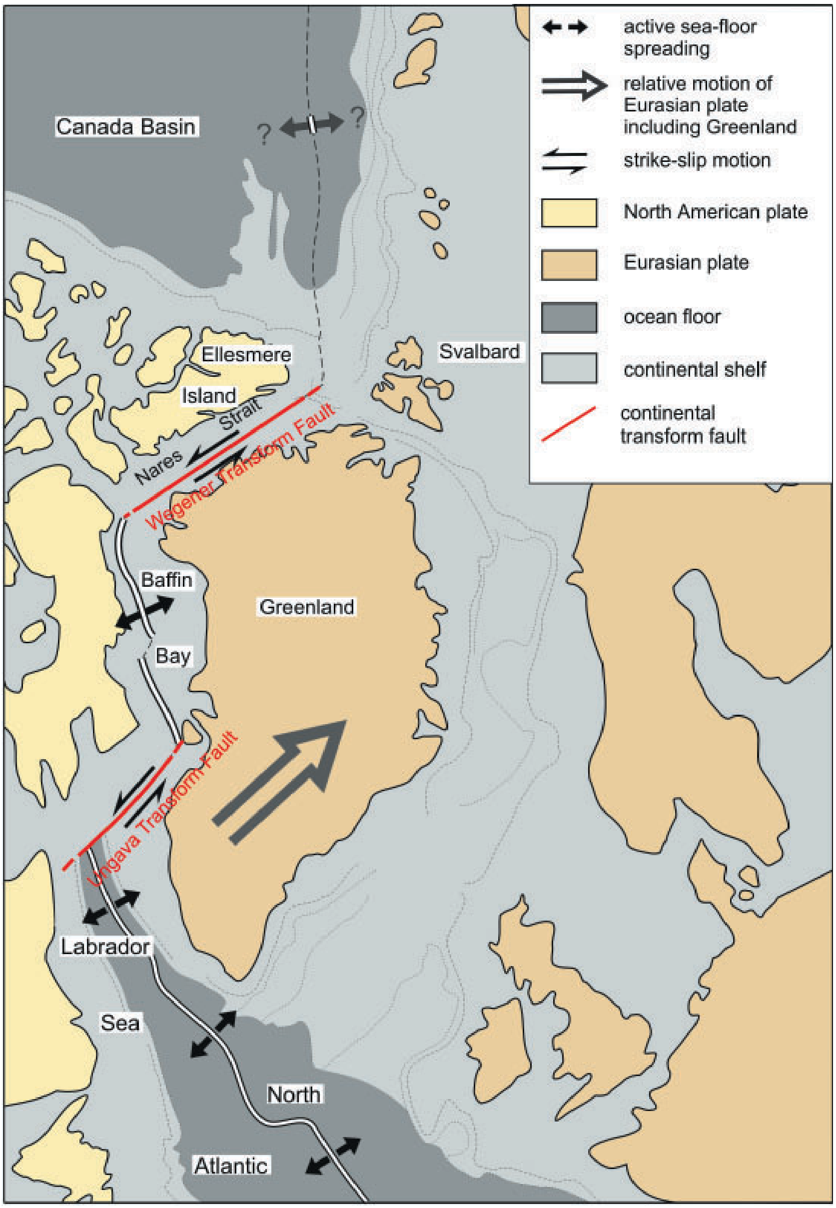

Fig. 2: Plate tectonic setting during the Paleocene (66-55 my), pre-anomaly 24, after SRIVASTAVA & TAPSCOTT 1986 and TESSENSOHN & PIEPJOHN 2000. Greenland is part of the Eurasian plate, seafloor spreading takes place in the North Atlantic Ocean and the Labrador Sea, possibly also in the Arctic Ocean.

as reflected by the number and diversity of the papers in this volume.

PROGRAMME

The Nares 2001 project was primarily a collaboration between the geological surveys of Germany (BGR) and Canada (GSC). The Geodetic Survey of Canada also collaborated. There was Danish participation from the National Survey and Cadastre (KMS), Danish Lithosphere Centre (DLC) and University of Copenhagen. Canadian and Dutch universities also contributed to the programme, together with personnel from Grise Fiord, the nearest hamlet in Nunavut.

The primary objectives were to apply a combination of sampling, seismic and magnetic surveying, to the offshore areas, and correlate the observations with onshore geological features such as unconformity-bound sequences, inverted grabens, major folds and faults, and dyke swarms.

Three seismic techniques were used. A high resolution (Huntec) boomer system was used to investigate the upper sedimentary layers. A multichannel reflection system was deployed with a 1230 cu.in. GI airgun array as source and a 1200 m hydrophone streamer, shortened to 300 m when necessary, as receiver. Land seismometers and digital ocean bottom seismometers were used together with the airgun array for a wide-angle seismic reflection/refraction profile across northern Baffin Bay, and two shorter lines were recorded by the land seismometers in Kennedy Channel.

Helicopter-based aeromagnetic surveys with close line spacing and at low altitude were carried out across the Strait in Kennedy Channel and southern Kane Basin, in both cases linking onshore and offshore areas. Aeromagentics had the additional advantage of providing data in areas too heavily ice-covered for seismic work.

The geophysical data were accompanied by onshore geologic mapping in targeted areas, for which the ship acted as a moving base camp. Critical horizons that included dykes and magnetic sandstones were identified and traced. It was hoped that the age and directions of matching dykes in Proterozoic dyke swarms on either side of the Strait might provide calibration for a possible estimation of strike slip motion, independent from facies belts. Samples for fission track measurements were collected and analyzed in order to constrain the age and amount of uplift. The material was collected in basement rocks and sandstones throughout the area.

A geodetic program was undertaken to determine possible vertical and lateral neotectonic motions on either side of Nares Strait. Existing base stations in Greenland and on Ellesmere Island were used for re-measurements.

Nares Strait is also of broader scientific interest. The Strait is a significant passageway between the Arctic Ocean and Baffin Bay and thus into the North Atlantic. Seabed sampling (box and piston cores) and seabed characteristics profiling were carried out to obtain paleoceanographic proxy data from the marine record, in order to reconstruct numerical records of sea surface temperature, sea ice and plankton production for the past 10,000 years. These data will allow a decadal–centennial scale quantitative comparison of anthropogenic climate change with pre-historical natural cycles of warming and cooling. An oceanographic program studying the currents was integrated with marine geological sampling.

OPERATIONAL ASPECTS OF THE PROJECT

The CCG "Louis S. St Laurent", Canada's largest icebreaker, sailed from Resolute Bay, Canada on 08 August and arrived at Thule, Greenland on 10 September 2001. Two ship-based BO-105 helicopters were used to support the onshore programme, for ice reconnaissance, and to carry out the aeromagnetic investigations. The combination of ship and helicopters enabled simultaneous collection of different and complementary types of data. From time to time, surveying was interrupted to take seabed samples including box and piston cores.

Ice conditions have prevented systematic mapping in the past and were a severe problem for this project. Ice was a major constraint on the seismic surveying programme (Fig. 4). The complete length of the seismic streamer (1.2 km) was used in open water, despite the hazards presented by icebergs, but in

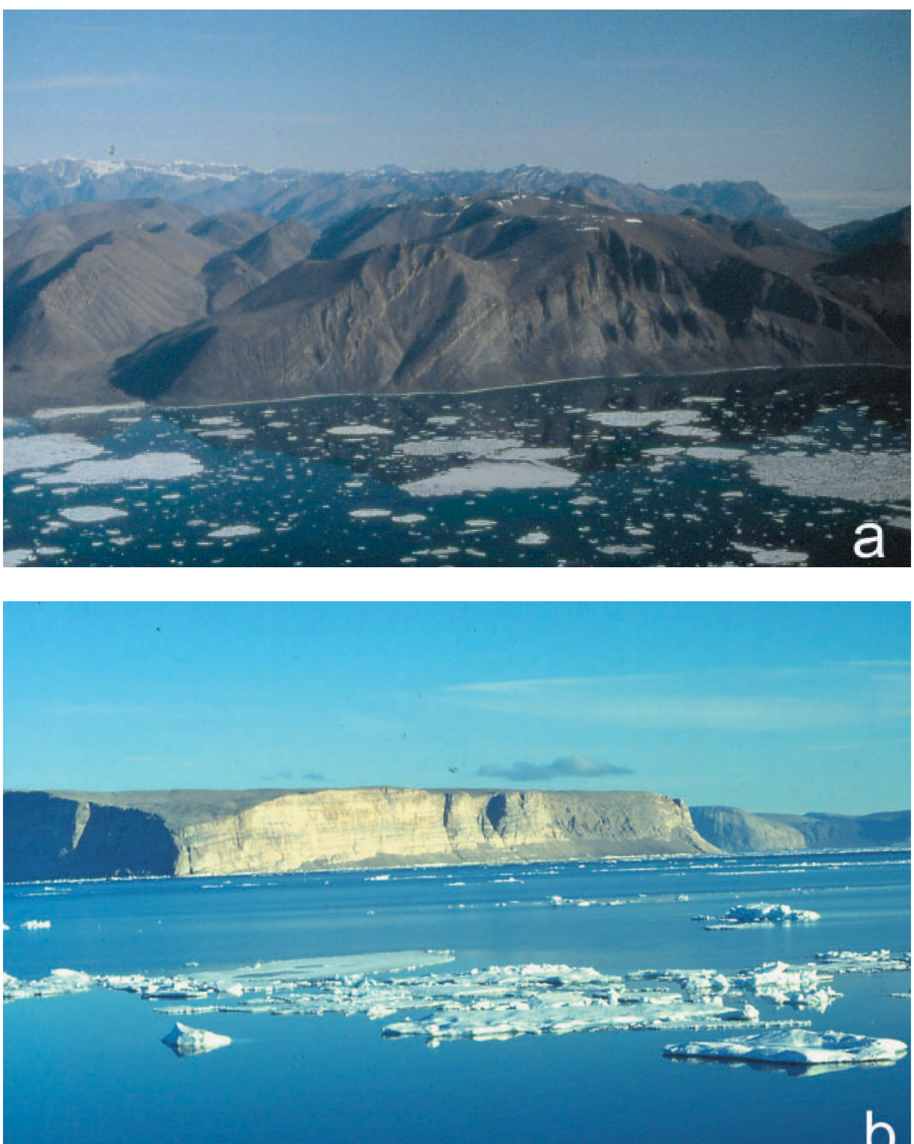

Fig. 3: The two different coastal areas of Ellesmere Island, Canada (3a) and Washington Land, Greenland (3b).
The rugged terrain on Ellesmere Island (a) is caused by thrusting and folding through both, the Paleozoic Ellesmerian and the Tertiary Eurekan Foldbelts, whereas Greenland (b) formed the undeformed foreland in both cases. View in (a) towards the west, in (b) towards the east.

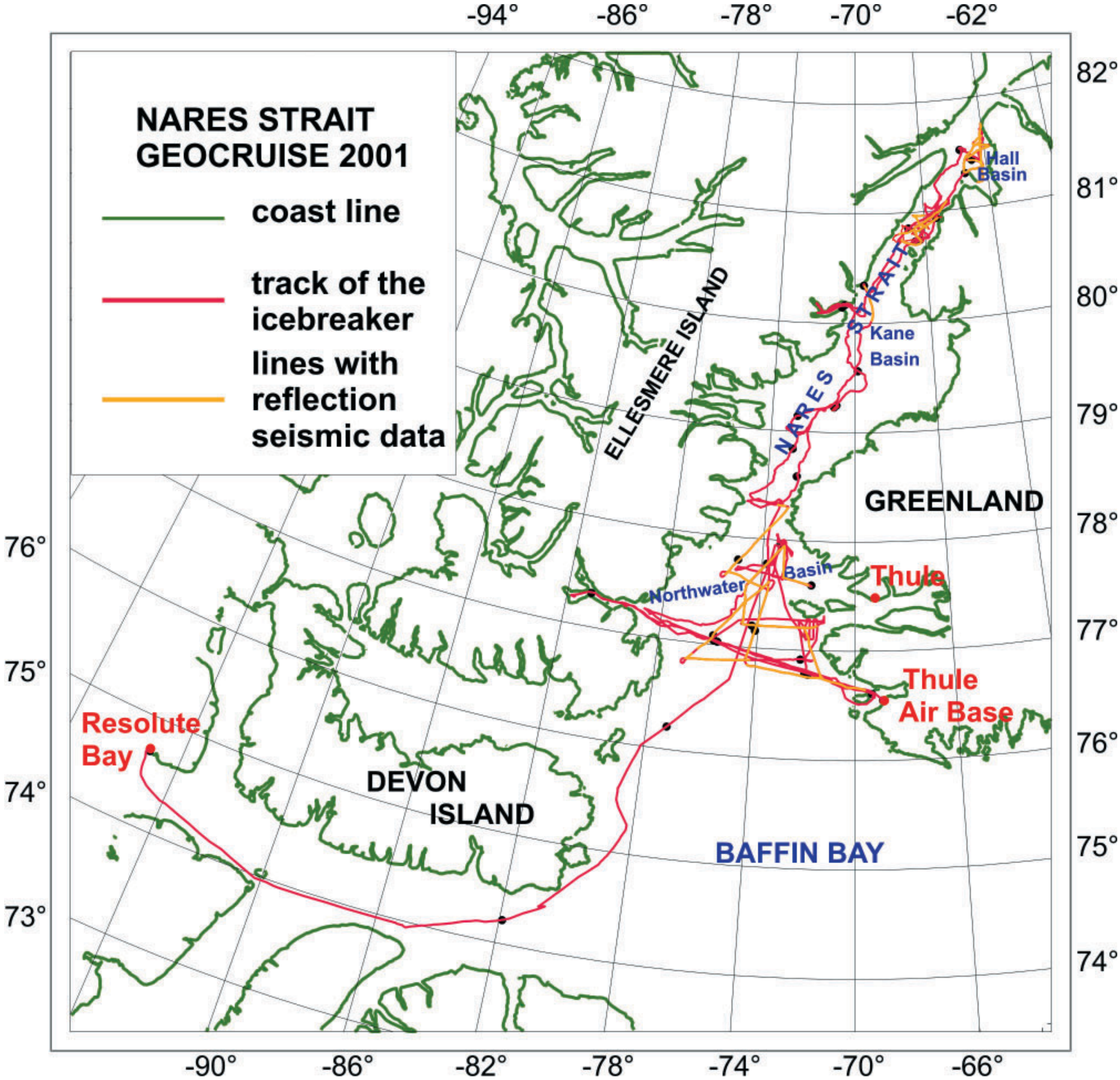

Fig. 4: Ship's track of the Nares Strait Geocruise 2001. with black dots marking days.

loose sea ice the streamer had to be shortened to 300 m, and the ship's bubbling system used to keep the wake free of ice (Fig. 5). Frequently, ice was so heavy that it was not possible to acquire any seismic reflection data. It was particularly difficult to get complete coast-to-coast seismic profiles, due to a persistent ice fringe along the Ellesmere Island side of Nares Strait. In addition, Kane Basin was continuously ice-covered during our expedition and no seismic lines were possible. It was also necessary to modify the planned wide-angle seismic profiles. Nevertheless, valuable new seismic data were aquired in previously unexplored areas of Nares Strait.

The other components of the project were less influenced by ice conditions, and were carried out essentially according to plan. The aeromagnetic survey (Fig. 6), in particular, provided a large amount of new information, and an extensive onshore mapping and sampling programme was undertaken. Subsequent compilations of physiography, potential field data and industry seismic profiles were done to constrain interpretations and accompany the regional geological map. Consideration was given to the economic potential of the region. A co-operative effort between the GSC, the Geological Survey of Denmark and Greenland (GEUS) and KMS produced a new series of physiographic, gravity and magnetic maps at a scale of 1:1.5 million. The maps cover the Labrador Sea to the Arctic Ocean.

The papers in this volume describe the initial results from the project, and integrate them with previous studies. Together, they provide a summary of our present knowledge of the area. This is still far from complete, and many of the interpretations remain speculative, but the work described here is unquestionably a major contribution to our understanding of the geology and tectonic evolution of the Nares Strait region.

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Fig. 5: The Canadian Coast Guard icebreaker "Louis S. St. Laurent" towing the seismic gear. Airguns are visible behind the ship. The bubble system designed to free the ship in dense ice, was successfully used to keep the wake free of small ice floes and growlers during streamer work.

Fig. 6: Helicopter taking off for aeromagnetic survey flight (inset with bird) from the helideck of the CCG "Louis S. St. Laurent".

ledged for enthusiastic and competent assistance (Fig. 7). The pilots and mechanics of the helicopter crew enabled the successful aeromagnetic program to be run during long hours of flying under low light conditions. The professional streamer work of the crew of the UK Exploration Electronics Co. was appreciated especially under the difficult operating conditions. We thank the technical support crew from GSC and BGR for their resourcefulness and improvisation in ice choked waters. The program was initiated under the auspices of the bilateral Germany/Canada Agreement on Cooperation in Scientific Research and Technological Development. The BGR received travel funds under this umbrella.

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Fig. 7: The ship's company of Nares Strait Project.

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