Marine Physical Laboratory

Sea MARC II Investigation of the Norwegian-Greenland Sea

Final Report for
Office of Naval Research
Grant N00014-89-J-1963
Period of Award: 05-15-89 - 09-30-90
Principal Investigator: Christian de Moustier

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Scripps Institution of Oceanography

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19. ABSTRACT

More than 80,000 km^2 of SeaMARC II imagery was obtained in the northern Norwegian-Greenland Sea during the months of October and November, 1989. Regions insonified included the Bjørnøya Fan, a transect at 73°N from the continental margin to the Mohns Ridge, an along axis section of the entire Knipovich Ridge (the slowest spreading center in the world), the Molloy Deep, the Spitsbergen Transform Fault, a portion of the Yermak Plateau and the 1,000 m isobath from Svalbard south to the Norwegian margin. The internal structure of the Knipovich Ridge is highly en echelon and oriented obliquely to the regional trend of the ridge. Unusual sedimentary features, perhaps related to ancient glacial activity, scour the margin of the Barents Sea at its intersection with the Norwegian-Greenland Sea. Pockmarks dot the sediment surface off the northwestern margin of Svalbard. These may be attributed to bubbles escaping from subjacent natural gas fields. Further north on the Yermak Plateau, iceberg plough marks criss-cross the terrain. In addition to routine surveying, we carried out acoustic experiments in three locations attempting to analyse the SeaMARC II system related effects on the acoustic measurements and to test different processing algorithms to try to improve the bathymetric function.

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I. Summary

More than 80,000 km^2 of SeaMARC II imagery was obtained in the northern Norwegian-Greenland Sea during the months of October and November, 1989. Regions insonified included the Bjørnøya Fan, a transect at 73°N from the continental margin to the Mohns Ridge, an along axis section of the entire Knipovich Ridge (the slowest spreading center in the world), the Molloy Deep, the Spitsbergen Transform Fault, a portion of the Yermak Plateau and the 1,000 m isobath from Svalbard south to the Norwegian margin. The internal structure of the Knipovich Ridge is highly en echelon and oriented obliquely to the regional trend of the ridge. Unusual sedimentary features, perhaps related to ancient glacial activity, scour the margin of the Barents Sea at its intersection with the Norwegian-Greenland Sea. Pockmarks dot the sediment surface off the northwestern margin of Svalbard. These may be attributed to bubbles escaping from subjacent natural gas fields. Further north on the Yermak Plateau, iceberg plough marks criss-cross the terrain. In addition to routine surveying, we carried out acoustic experiments in three locations attempting to analyse the SeaMARC II system related effects on the acoustic measurements and to test different processing algorithms to try to improve the bathymetric function.

II. Introduction

The high-latitude northern Norwegian-Greenland Sea and adjacent part of the Arctic Ocean north of Spitsbergen comprise an unequaled natural laboratory for the study of several important processes involving the generation and/or modification of sea-floor topography, subbottom structure, and material properties. These processes, active now or in the geologically recent past, include (1) tectonism (faulting), volcanism, magma intrusion into rift valley seafloor sediments; (2) erosion and redeposition of sediment by bottom currents; (3) slumping and other downslope processes on glaciated margins; (4) sedimentation from sea ice/icebergs/ice sheets, at water depths less than 500-100 m, (5) erosion and redeposition by icebergs and grounded ice shelves/sheets. SeaMARC II is the ideal tool for investigating the results of these processes, i.e. the present bathymetric and back-scatter characteristics of the seafloor. The investigation area is probably unique in terms of diversity of processes which can be examined in a relatively small region.

It is likely, particularly after appropriate data processing is complete, that the specific types of small scale topographic and acoustic backscatter characteristics of each process can be quantitatively isolated on the 50m depth range (the SeaMARC II depth uncertainty) and on the 5m horizontal range, which is the average pixel dimension of the SeaMARC II textural image at the 10 km swath width. These horizontal characterizations can be analyzed with regard to the amplitude of the backscattered signal and qualitatively with regard to the textural relationship from one pixel to the next.

A SeaMARC II investigation (1989-1990) was planned for the area of interest (Fig. 1), a collaborative project involving Co-Principal Investigators Dr. Kathleen Crane (CUNY/L-DGO), Dr. Eirik Sundvor (Uviv. of Bergen, Norway) and Dr. Peter Vogt (Naval Research Lab). The Univ. of Bergen agreed to supply the research vessel (HAAKON MOSBY) for both seasons and the U.S. Navy was resonsible for raising the funds for the SeaMARC II instrumentation for the first field season (1989)

The area of interest can be subdivded into (A) the active plate boundary; (B) the continental margin; and (C) the Yermak Plateau. Area (A) comprises the median rift valleys of the Mohns, Knipovich and Molloy Ridges and the Spitsbergen-Molloy Transform Faults. This active plate boundary zone features (1) very slow plate motion; (2) dramatic along-strike variations in plate boundary geometry, - from normal spreading centers through variously oblique spreading to transform faults; (3) a young ocean basin where the plate boundary is closer to the continental margin than anywhere else in the Atlantic; and (4) a high flux of continent derived glacial sediment into a volcanically/tectonically active rift valley (one of very few examples world-wide). Area (B) is characterized by rapid but variably prograded continental margins heavily influenced by geologically recent glaciation, and possibly bottom currents; Area (C), the Yermak Plateau, is an enigmatic feature of uncertain origin (Iceland-like hot spot volcanism? oceanic crust uplifted as a result of northward propagation of the Knipovich ridge? Thinned, subsided continental crust?) possibly affected by geologically recent volcanism, probably sculpted by bottom currents and ice, and certainly littered with glacial debris. (fig. 2)

Of the above problems, the effects of rapid sedimentation on volcanic/tectonic morphology in an active rift valley with high heat flow and probably hydrothermal activity, is of primary interest. The acoustic/sedimentological small-scale topographic character and down-slope processes affecting the continental shelf edge-slope-rise system is the second major problem area. Although riverine deltas/fans like the Amazon or Mississippi have been

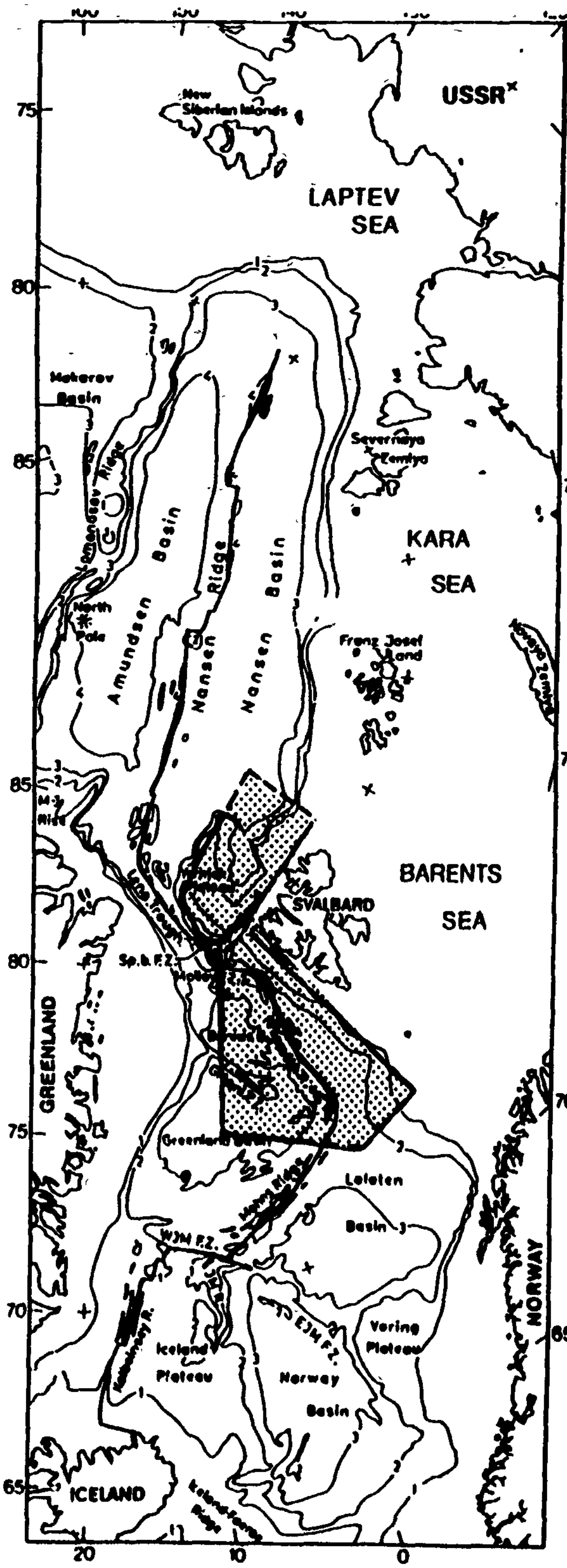
USSR
New Siberian Islands
LAPTEV SEA
Makarov Basin
Amundsen Basin
Nansen Ridge
Nansen Basin
North Pole
Severnaya Zemlya
KARA SEA
Franz Josef Land
BARENTS SEA
SVALBARD
Sp.b.F.Z.
GREENLAND
Greenland Basin
Lofoten Basin
W.J.M F.Z.
Voring Plateau
Iceland Plateau
Norway Basin
NORWAY
ICELAND
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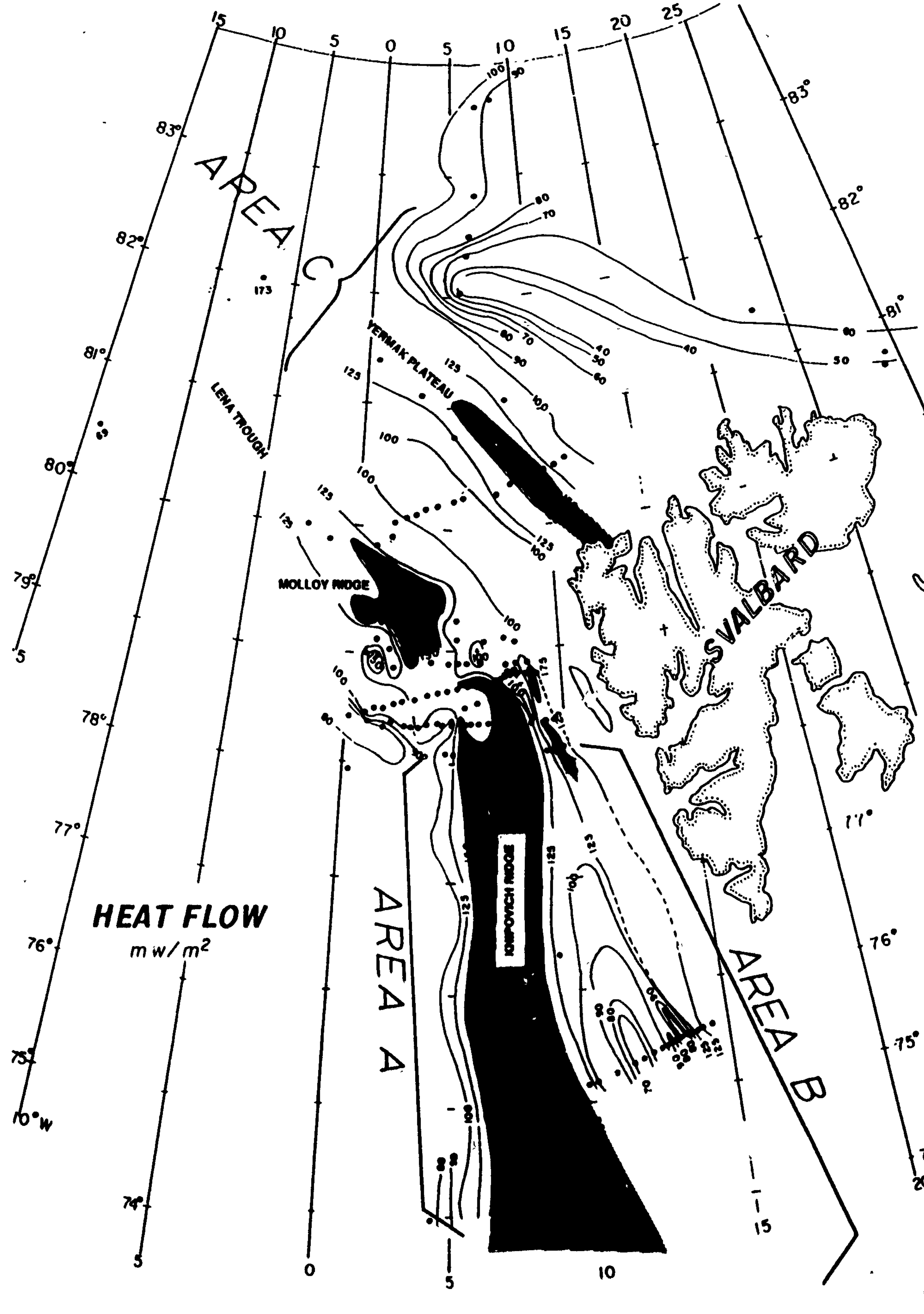
fig 1

figure 2

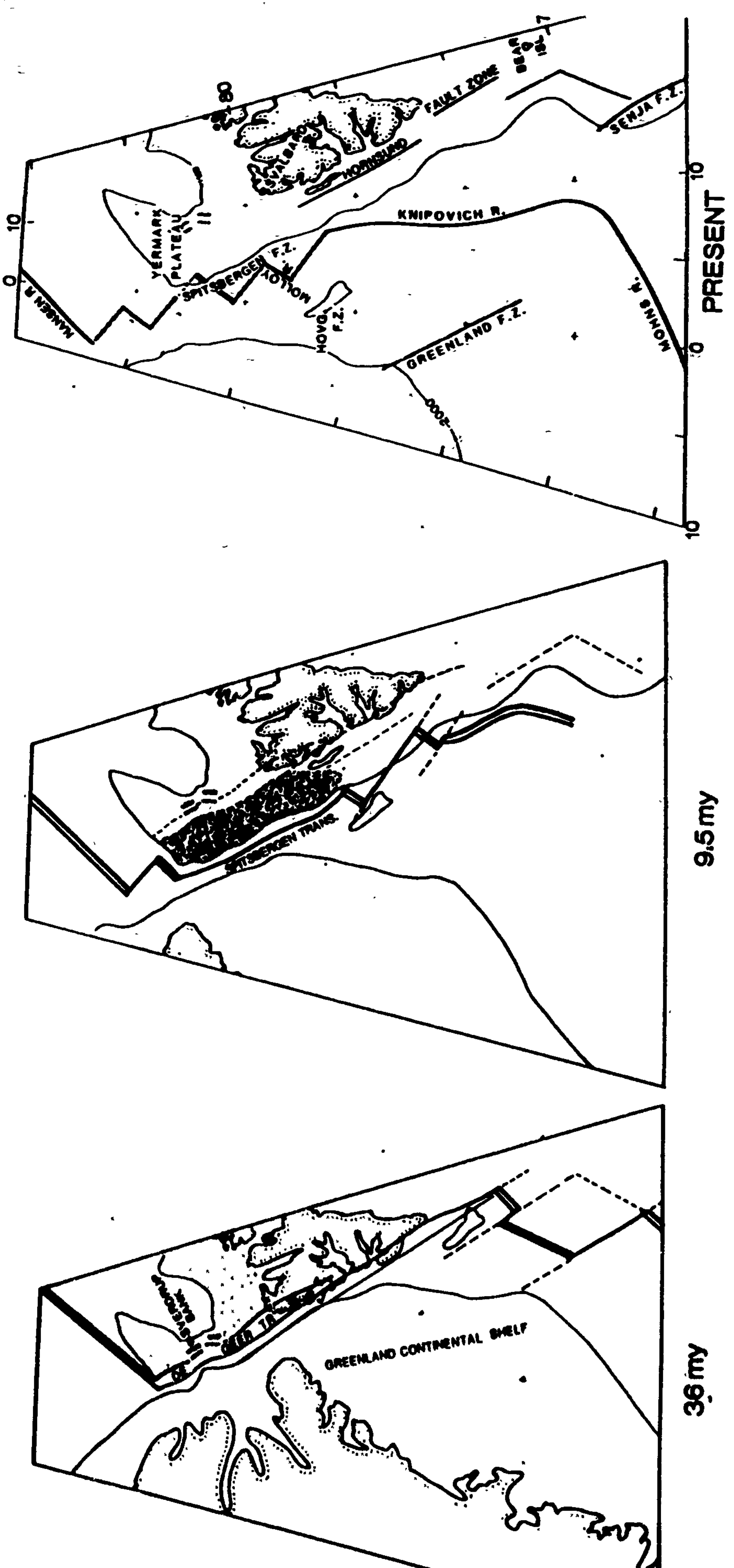


AREA C
AREA A
AREA B
SVALBARD
YERMAK PLATEAU
LENA TROUGH
MOLLOY RIDGE
KNIPOVICH RIDGE
HEAT FLOW
mw/m²
10°W
20°E

investigated, glacial marine deltas/fans are poorly known. Certainly ice streams which have scoured deep depressions (straths) across continental shelves must have moved large sediment volumes to the continental margins.. The third problem area involves possible seafloor evidence of deep water motion through the Fram Strait (Spitsbergen/Molloy Fracture Zone) area. This is the only deep watergate into the Atlantic Basin and is therefore of great interest for modelling of present and paleo-oceanography and global climate. The 'transtensional' separation between Greenland and Svalbard largely in the last 10 m.y. presents resesarchers with one of the most promising laboratories for studying a specific tectonic influence on climate (fig. 3)

Although plate boundary morphology (e.g. in the floor of the Knipovich rift valley) represents the aggregate effect of sedimentation, tectonism, and magmatic activity over the last 10^5 - 10^6 years, the present state of interglaciation only typifies ca. 10% or less of the last few m.y. The great ice streams which delivered sediment masses to the Isfjørd, Storfjørd and Bjørnøya fans/deltas are not present today, so the processes cannot be studied in vivo. (However, some Svalbard glaciers still actively calve into the heads of their fjørds, allowing real-time studies on a smaller scale). It is also not clear how present deep water flow through the Fram Strait compares to the flow during glacial extrema or deglaciations, or to the average flow. The SeaMARC II evidence RE: bottom currents will have to be evaluated in light of these questions; thus the mosaics assembled will serve to focus subsequent more detailed studies using deep-tow sidescan sonars, bottom photography, and bottom current meters. Similarly the SeaMARC images from the Knipovich-Spitsbergen FZ-Molloy Ridge area and the Yermak Plateau will become the basis for subsequent detailed studies, by future investigations in the same region.

As a first step towards remote classification of seafloor terrain using quantitative seafloor acoustic backscatter measurements made with the SeaMARC II sonar system we also planned to conduct acoustic experiments for a few hours at selected sites during the survey work. The goal was to record SeaMARC II acoustic data in their raw form before they were processed by the SeaMARC II real-time computers aboard ship, so that it would be possible to (1) analyse the system related effects on the acoustic measurements, and (2) test different processing algorithms to try to improve the bathymetric function. In addition, to account for potential aspect ratio biases introduced by the sonars, we planned to gather data along tracks intersecting at 90° and 45°. A by-product of this exercise is an assessment of seafloor anisotropy in the area surveyed.


PRESENT
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36 my
KNIPOVICH R.
SPITSBERGEN F.Z.
YERMARK PLATEAU
HORNSUND
FAULT ZONE
SENJA F.Z.
GREENLAND F.Z.
MOHNS R.
NANSEN R.
SPITSBERGEN TRANS.
GREENLAND CONTINENTAL SHELF
2000

figure 3