PROCEEDINGS OF WORKSHOP ON

**"SCIENTIFIC DRILLING IN THE ARCTIC OCEAN
PLANNING FOR THE 1990'S"**

JUNE 23 - 24, 1988

OTTAWA

SPONSORED BY THE

The I.U.G.G.- I.C.L., The I.U.G.S.- C.M.G.

and

The GEOLOGICAL SURVEY OF CANADA (G.S.C.)

LIST OF PARTICIPANTS

Dr. L. Johnson
Geophysical Sciences
Office of Naval Research
Arlington, VA 22217
U.S.A.

Dr. Y. Kristoffersen
Seismological Observatory
University of Bergen
Allegate 41, N-5000
Bergen, Norway

Dr. M. Peterson
Chief Scientist
NOAA, Dept. of Commerce
14t and Constitution N.W.
Room 5808
Washington, D.C. 20230

Dr. T. Pyle
JOI Inc.
1755 Massachusetts Ave., N.W.
Suite 800
Washington, D.C. 20036

Dr. J. Backman
Dept. of Geology
University of Stockholm
S-10691 Stockholm
Sweden

Dr. C. Barnes
Director General
Sedimentary and Marine Geoscience Branch
Geological Survey of Canada
601 Booth Street
Ottawa, ON K1A 0E4

Mr. W. McCloy
Project Director
Polar Icebreaker Project
Canadian Coast Guard
344 Slater Street
Ottawa, Ontario
K1A 0N7

Mr. J.F. Searle
Senior Naval Architect
Polar Icebreaker Project
Canadian Coast Guard
344 Slater Street
Ottawa, Ontario
K1A 0N7

Mr. S. Blasco
Atlantic Geoscience Centre
Geological Survey of Canada
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

Dr. D. Ross
Assistant Director
Atlantic Geoscience Centare
Geological Survey of Canada
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

Dr. B. Bornhold
Pacific Geoscience Centre
Geological Survey of Canada
P.O. Box 6000
Sidney, BC
V8L 4B2

Dr. M.J. Keen
Director, Atlantic Geoscience Centre
Geological Survey of Canada
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

Dr. P. Mudie
Atlantic Geoscience Centre
Geological Survey of Canada
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

Dr. R. Jackson
Atlantic Geoscience Centre
Geological Survey of Canada
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

Mr. K.S. Manchester
Atlantic Geoscience Centre
Geological Survey of Canada
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

Dr. T. Vorren
Institute of Geology/Biology
University of Tromso
Tromso, Norway

Dr. Herman Zimmerman
Polar Programs Division
National Science Foundation
Washington, DC 20550

Dr. Yu P. Neprochnov
Institute of Oceanography
USSR Academy of Sciences
Krasskova Str. 23
117218 Moscow, USSR

Dr. L. Merklin
Institute of Oceanography
USSR Academy of Sciences
Krasskova Str. 23
117218 Moscow, USSR

Dr. Bruce F. Molnia
United States Dept. of the Interior
Geological Survey
Office of International Geology
Reston, VA 22092

Dr. Dieter Fuetterer
Head of Geology
Alferd Wagener Polar Institute
Columbus Circle
Bremerhavn, W. Germany

Dr. J. Mienert
Research Centre for Marine
Geosciences
Wischhofstrasse 1-3, Bldg.4
D2399 Kiel
F.R. Germany

Capt. P.R.M. Toomey
Senior Marine Officer
Polar-8 Operations
Coast Guard Northern
344 Slater Street
Ottawa, ON
K1A 0N7

Marie Schingh
Geological Survey of Canada
Department of Energy, Mines &
Resources
580 Booth Street
Ottawa, NS
K1A 0E8

Dr. David A. Forsyth
Seismology & Electromagnetism
Section
Geological Survey of Canada
1 Observatory Crescent
Ottawa, ON
K1A 0Y3

INDEX

PART I: TRANSCRIPT OF MEETING REPORTS AND DISCUSSIONS

SCIENTIFIC DRILLING IN THE ARCTIC OCEAN
PLANNING FOR THE 1990'S
JUNE 23-24th, 1988
OTTAWA

I. INTRODUCTION:

Dr. Chris Barnes, Director-General of Sedimentary & Marine Geoscience Branch of the Geological Survey of Canada, opened the workshop with the statement that much new information on the stratigraphy of the Arctic must be obtained before scientific problems regarding past and future changes in the Arctic environment can be solved. During the 1986 Canadian ODP workshop (Gradstein and Horne, 1987), many problems were discussed including the following technical questions:

- Can we drill in the Arctic?
- What are the mechanisms to do this?
- Can the drilling be done by the Ocean Drilling Program?
- Can we drill from icebreakers in the Arctic Ocean?
- Can we use ice island field stations operating in various parts of the Arctic - either at their present locations or or in the future at other sites?

During this workshop new technologies will be discussed and hopefully some questions will be answered. The need to interface this technology with other technical issues must also be addressed. For example, there are plans of embarking on a series of ocean mapping projects; the main question is WHEN? Timing, funding, uncertainties, strain from other scientific programs are all critical factors that constrain planning for Arctic drilling. The international political and scientific attitude of the 1990's for the Arctic is also a factor of the uncertainties of our own nation's strategies. During this Arctic planning workshop, we hope to address key scientific issues and get Arctic nations to cooperate together, obtain drilling information and try to establish a Committee on Arctic drilling.

There are 5 key elements for success in this area:

1. Clear scientific objectives (priorities must be set nation wide and internationally).
2. The Frontier challenge and the sovereignty issue.
3. International collaboration (nature of the political stability, the Free Trade Agreement).
4. Ensuring industrial participation.
5. Effective organizations (we must each establish our own priorities on Arctic Drilling).
   - Ocean Drilling Program - Canadian Participation
   - International Arctic Committee

II. STATUS OF INTERNATIONAL EFFORT

(A) CANADA:

Dr. Michael Keen summarized the Canadian perspective as seen from his view as Director of the Atlantic Geoscience Centre (now Dr. D.I. Ross), and the Canadian representative on the Executive Committee of ODP (now Dr. C.R. Barnes). He stressed the fact that High latitudes are especially sensitive areas. Canada, because of its northern location and extensive polar margin has many interests in the Arctic Ocean.

He thought that the following factors would be the main issues to dictates the direction of Arctic research funding in Canada in the near future:

- territorial devolution
- indigenous people's rights
- sovereignty
- resources: now: Beaufort Sea
  future: Arctic Islands
- environment
- global change

(Canada is not a race of Philistines, and M. Masse, Minister of Energy, Mines and Resources, recently announced a program of aid for travel in the Canadian Arctic for Canadian writers and artists).

Examples of Canada's scientific interests in the Arctic come from recent conferences, in which Canadians participated: 1. The Dahlem conference on productivity in the oceans (see New Scientists, 19 May 1988); 2. Arctic Interactions: Institute for Arctic and Alpine Research and Royal Society of Canada (see Report OIES-4, April 1988, University Corporation for Atmospheric Research, Boulder, Colorado); 3. Conference on Scientific Ocean Drilling (COSOD II), Ocean Drilling Program, Strasbourg, 1987.

The Arctic is especially sensitive to variations in insolation, surface temperatures, ocean heat transported to and from the Polar regions, global and circumpolar biological activity and orbitally induced variations. Changes in a climatic forcing function (e.g. solar insolation, volcanism) may cause a catastrophic change in climate. Keen pointed out that we need to be able to predict how short and long term climatic change will alter for example the development of cold deep water circulation, and East and West Antarctic ice sheets, and the Arctic ocean ice cover (see Appendix 1). (He drew attention in this respect to the paper: Crowley, T.J. and G.R. North, 1988, Abrupt climate change and extinction events in earth history: Science, v. 240, pp.996-1002. He drew attention to the program elements drawn up for the International Geosphere and Biosphere Program in the proposal Arctic Interactions mentioned above (under the auspices of the Royal Society of Canada and the University of Colorado's Institute for Arctic and Alpine Research):

- Solar and geomagnetic inputs; atmosphere dynamics and heat balance; atmospheric composition, ocean circulation, and sea ice formation;

snow and glaciers; permafrost and hydrology; coastal processes; nutrient flux, carbon storage and biological communities; geological records of environmental change.

- Multidisciplinary themes are emphasized in this proposal concerning Arctic interactions. Examples include:

  - The history of Arctic sea ice and its effect on Arctic haze;
  - Glacier and ice sheet changes and their effect on sea level, biota and the ocean margin;
  - Peatlands, ground ice and climate change;
  - Paleoenvironmental records from ice cores and ocean sediments.

- The main themes from the Conference on Scientific Ocean Drilling - which will govern the program in the 1990's are:

  - changes in global environment;
  - mantle-crust interactions;
  - fluid circulation in the crust;
  - stress and deformation of the lithosphere;
  - evolutionary processes in oceanic communities.

He pointed out that many of these and other proposals demand Arctic drilling if the questions posed are to be answered. Since the questions are central to the future of the planet, Arctic drilling has to be of global importance.

(B) REPUBLIC OF WEST GERMANY:

Dr. Dieter Fuetterer, Head of Geology from the Alfred Wegener Institut of Polar Science (AWI), Bremerhavn, presented the following notes on the current atmosphere of interest in West Germany.

- We will concentrate on certain regional aspects in the area north of the Arctic basin between Greenland and the Eurasian Shelf.

- Presently there are important discussions between the Polar Institute (AWI) and geoscience specialists at German universities and other institutions.

- The recent Gorbachov Murmansk (October 1, 1987) speech which proposes an international Arctic scientific committee, and the Reagan-Gorbachov speeches of 1988 are part of the discussions for the German Community.

- For the Arctic Ocean drilling, we must include ODP; Germany is a member of ODP.

- Arctic drilling represents big money and to obtain support we must come up with a scientifically integrated product.

- International coordination is a problem for us.
- Will the Republic of Germany become a member of the Arctic Club?
- A joint Russian-German expedition to the Laptev Sea for the 1990's is in the very early stages of planning and discussions.
- We have plans to build another small icebreaker, which is not to be another PVRS POLARSTERN equivalent ship. It is expected to cost around 160 million Marks, and it will be a much smaller platform than the POLARSTERN. It will be designed especially for Arctic purposes.
- Since we have poor geophysical data coverage in the Arctic, site survey work is essential but requires big money. These again are only in the early discussion phase and we estimate investments of 200-300 million Marks for the next 3-5 years.
- The German Community needs support from World-wide agencies and support from other scientific communities.

QUESTIONS:

M. Peterson: When do you anticipate the launching of the new icebreaker?

These are only at the discussion stage now ... possibly 1991.

H. Zimmerman: Does this mean that the Polarstern will be permanently based in the Antarctic ocean?

We plan to continue working in the Antarctic Ocean; however, for scientific efficiency, it is better to have two vessels: one in the North and one in the South.

R. Jackson: With the problems of platform stability and noise are there any plans to shockmount the engines?

It is still only at the discussion stage

T. Vorren: Your participation in the Arctic Drilling Program depends on your participation in the "Arctic Club" as you called it, is this correct?

The problem is that we will have problems in obtaining the big money, and this is our main concern.

T. Vorren: Is the cruise in the Laptev Sea a bilateral cruise?

It is an international program but since we need two ships the discussions are bilateral (Germany-USSR), for logistic purposes.

T. Vorren: As you mentioned more site surveys are required. The data collected on any of these site survey cruises should be prepared in the format of the ODP Drill site proposals. These proposals then should be held in one location. (Note! The Atlantic Geoscience Centre at the Bedford Institute of Oceanography would be willing to provide this service.)

(C) NORWAY:

Dr. Ynge Kristoffersen, geophysicist from the University of Bergen, began his presentation with the main questions regarding the importance of the Arctic Ocean to Norway:

- What is the importance of the Arctic Ocean as a source of deep water near the top of Greenland?

- What is the effect of the source of deep water on the Norwegian Sea and the magnitude of interactions with the Arctic Ocean?

Reference was then made to a recent workshop with 10 European ODP nations, where the main themes were as follows:

  - The gateway between the Norwegian and Greenland Sea
  - The gateway over the Iceland-Faeroes Ridge in the N.E. Atlantic
  - The Norwegian Sea and Arctic Ocean gateway

- How can work in the Atlantic compliment the gateway concept?

- The Nansen Centennial Arctic Program (NCAP) is a national initiative for research in the arctic, the chairman of this committee is Dr. T. Vorren.

What is on the table now:

1. Ice drift with a ship in the Eurasia basin
2. Air supported over-ice geophysical surveys and geological mapping in the Arctic ocean

- How can we contribute to the general issue of scientific drilling, an issue which is of site surveys?

- We need a complete stratigraphic section that will cover a wide range of time, this will require us to find the optimum location for the selection of sampling (coring) sites.

- Mobility is a key issue.

- Norway's contribution and participation in ocean drilling is best augmented through international cooperation which will gain political momentum.

QUESTIONS:

H. Zimmerman: What is your current state of mobility in the Arctic?

The best way is with air supported geophysical surveys which can travel on the ice collecting data. A Twin Otter type of air craft can support these surveys and it does not have all the problems a vessel encounters when passing through ice.

(D) SWEDEN:

Dr. Jan Backman, geologist from the University of Stockholm presented a brief history of Sweden's recent efforts as related to Arctic scientific drilling.

- In 1982 the Polar Research Committee of the Royal Academy of Sciences was established.

- In 1984, the Swedish Polar Research Secretariat (SPRS) was established by the Government. Its task is to promote the management of the government's polar affairs. It is responsible for planning and organizing research expeditions to cover both the Arctic and the Antarctic, and to carry the logistic costs for the expeditions. Its current budget is equivalent to 23 million Canadian dollars. In 1984-87, much of the focus was on Antarctica where a new station was established in January 1988.

- In 1987, the Arctic Research Program was initiated.

- The SPRS is currently planning for a Swedish expedition to the Arctic during the 1990's. Logistics and finance aspects have not yet been solved, but the proposed program includes: marine biology and geology, physical oceanography, marine chemistry, meteorology and technology.

- We are currently building a new ship, ODEN II (see Appendix 2), which will be tested in the Fall. The target area for the 1990 planned expedition is identified in Appendix 3.

QUESTIONS:

H. Zimmerman: What will happen between the time when the ship is tested in the Fall and the planned expedition in 1990?

It will be tested during the upcoming winter as well.

COMMENT by M. Peterson: ODEN II is primarily a commercial icebreaking ship which can be charted for scientific purposes also.

(E) U.S.A.:

Dr. Leonard Johnson, Chief, Geophysical Sciences for the Office of Naval Research, began by explaining that there are several USA agencies which deal with Arctic science. Where feasible the US will cooperate with other countries in basic marine geology and geophysics and on ocean drilling.

The US government and agencies will respond to proposals which fall within their missions. For example, there is a proposal for a bottom mounted drill with the National Science Foundation designed for soft rock, mud and hard rock drilling (Appendix 5).

The science agencies of the US government will also cooperate with other countries to accomplish these tasks. The four major agencies involved with Arctic research are in some ways overlapping:

1. The National Oceanographic and Atmospheric Administration
2. The National Science Foundation
3. The Office of Naval Research
4. The US Geological Survey

QUESTIONS:

M. Keen: Are you building another icebreaker?

No, but still talking about it.

K. Manchester: I heard a rumour about an NSF Arctic research vessel?

It is entirely an Antarctic vessel.

(F) U.S.S.R.:

Dr. Yuri Neprochnov, a geophysist with the Institute of Oceanology of the USSR Academy of Sciences in Moscow began by noting that in the past, from 1974 to 1985, the USSR was a member of the Deep Sea Drilling Project and valued this participation in International scientific studies of the World's oceans highly and hope to be invited to join ODP soon. Other comments pertaining to the Arctic drilling were as follows:

- The Arctic Ocean is an international region and international scientific cooperation in studying this region is very important.

- Recent discussions of scientific motives and possible international cooperation in studies of the Arctic Ocean began in November 1987 with a meeting of U.S.A. and U.S.S.R. scientist.

- West Germany and the U.S.S.R. started discussions in March 1988 on a possible joint two-ship study in the Laptev Sea for 1990.

- U.S.S.R. scientists from Leningrad have also had recent discussions with Canadian scientists on possible future joint research in the Barent Sea in 1989 and in the Beaufort Sea in 1990 under and existing agreement between the two countries.

- He also noted that they were interested in other possible cooperative geological or geophysical studies in marine non Arctic areas.

III. The JOI/ODP PERSPECTIVE:

Dr. Tom Pyle, JOI liaison to ODP PCOM is here at the workshop to offer moral support for Arctic drilling and to reaffirm our statement that we are willing to co-operate in planning for scientific Arctic Ocean drilling. Our planning committee (PCOM) is interested in listening to and reviewing any proposals. What **we** wish to hear from members of the workshop is a perception that ODP is not complacent, but the organizations wish to avoid any duplication of scientific endeavour in the Arctic (because of the very large logistical and financial problems of working in the ice).

He is primarily here to listen and offer advice where possible.

QUESTIONS:

M. Peterson: Will there be discussions of the sites that we are looking at?

COMMENT by K. **Manchester:** The sites that people have suggested to us have been listed and plotted on the posted map including the just recently given ones from the U.S.S.R. but this does not mean that others still can't be suggested. This list of drilling sites proposals illustrates the large range of areas and water depths that are of interest at this time.

M. Peterson: Are any of the sites accessible by ODP?

RESPONSE by P. Mudie: Yes, sites at both the Pacific and Atlantic gateways to the Arctic essentially can be drilled from JOIDES RESOLUTION, with some additional support from an icebreaker.

COMMENTS:

T. Pyle: The major impact here is financial. Exactly how will this be packaged?

P. Mudie: At present, we are operating on the concept of international scientific collaboration, combined with the celebration of Nansen's Centennial. We plan to get the assistance of several polar research vessels (one from each of at least 3 nations: Canada, West Germany, and Russia) to provide the necessary support for the JOIDES RESOLUTION which will be funded as usual through multi-national scientific participation.

QUESTIONS:

T. Vorren: When do you anticipate this organization schedule for JOI/ODP?

T. Pyle: Within a year.

T. Vorren: When do you plan to deal with the North and East Pacific and the North Atlantic?

T. Pyle: The Eastern Pacific is planned for the end of 1991-1992. There are yet no approved proposals for the North Pacific. We just have a 4-year plan with the US National Science Foundation; however, we have proposed to leave the Pacific in mid-1992 to go to the Atlantic.

COMMENT by S. Blasco: The two concerns that ODP has are: 1) the forward costs of support vessels, and 2) that proposals must fit in the future planning of the schedule. Other concerns which arose in the Arctic drilling workshop last November and the Montreal Canadian ODP meeting are:

- we have strong interest in using the ODP scientific scrutiny independent of whether or not we can use RESOLUTION in the Arctic Ocean, such as the safety panel recommendations.

- much of the technology on RESOLUTION (such as the hydraulic piston corer) which is appropriate for drilling at the gateways, may also be appropriate for drilling in the central arctic.

COMMENT by M. Peterson: The technology development of an advanced recovery piston corer and the improved and extended core barrel made recently have worked well. There are also plans to develop a mining type coring system: this would involve a marriage of land drilling and ocean drilling techniques. The system can be described as a narrow kerf, high speed diamond drilling system similar to those land drills used in programs such as CYPRES.

COMMENT by S. Blasco: Another point is if we receive approvals for drilling from the ODP safety panels we are much more likely to receive approvals from the Canadian and U.S. government regulatory agencies (COGLA & MMMS) for their Arctic margin areas.

IV. SCIENTIFIC OBJECTIVES AND SPECIFIC TARGETS:

Dr. Peta Mudie, geologist from Atlantic Geoscience Centre, began with an historical outline of the progress made so far in delimiting the scientific objectives and attaining the major Arctic scientific drilling objectives. (Note also the presentation by Joergen Miernert (Appendix 8) which summarises the objectives delimited by scientists collaborating with Joern Thiede at GEOMAR in Kiel).

Appendix 4, Table 1, outlines the recent history of efforts to accomplish Arctic scientific drilling.

1. From July to October 1985, drilling on ODP Legs 104 and 105, aimed at linking high latitude subarctic biostratigraphic data with the standard North Atlantic biochronologies. It then became possible to data endemic Arctic biota, to establish the ages of major sediment reflectors, and to suggest mechanisms for their formation. These drilling programs included both tectonic and paleoceanographic objectives. For example, Leg 104 aimed at drilling at sites on a transect across the Voering Plateau in the eastern Norwegian-Greenland: 1) to understand the evolution of passive margins which are often flanked by submarine high plateaus; and 2) to investigate the evolution of high latitude paleoclimate and ocean circulation.

   This work in the circum-Arctic area is important because it gives us an idea of nature and age of samples we can expect to obtain from drilling on Arctic submarine highs like the Yermak and Chukchi Plateaus, or in volcanic features like the Nansen-Gakkel Ridge. For example (Appendix 4, Fig. 1), on the Voering Plateau, JOIDES RESOLUTION was able to drill through 1200 meters of volcanic basalts and intercalated sedimentary layers. In terms of the paleoecological objectives, the Leg 104 and Leg 105 drilling has enabled us to make the first links (Appendix 4, Figure 2) between the standard North Atlantic and Pacific temperate region chronostratigraphies and the formerly isolated stratigraphies that existed for the high Arctic regions, e.g. Beaufort Sea and Svalbard.

2. With respect to Canadian input, the next major step towards Arctic scientific drilling was the Montreal Canadian ODP Workshop (Sept. 1986) where 11 proposals were submitted by universities, industry and government agencies (see Gradstein and Horne, 1986). These proposals can be grouped into three categories:

   1. Mesozoic-Late Cenozoic paleoenvironmental history

   2. Mesozoic-Lower Cenozoic stratigraphy and tectonic evolution

   3. Site Survey investigations

   Most of these studies concentrate on the Canadian polar margins in the Beaufort Sea and the Arctic islands. Drilling in the Arctic deep basin drilling faces the problems of the great distances which must be covered between presently known potential drill sites, and the need to obtain international financial and polar icebreaker logistical support.

3. At the first Arctic Drilling Workshop (Nov. 1986), several additional sites were proposed by various countries:

   - 8 on Yermak Plateau (Y. Kristoffersen, Norway)
   - 6 on Alpha Ridge (P. Mudie, Canada; D. Clark, USA)
   - 2 on Chukchi Plateau (Grantz, USA)

   Joern Thiede (Germany) proposed the possible selection of sites on seamounts near the Nansen Ridge, depending on the results of survey work from POLARSTERN in summer 1987 (see item 5 below).

4. At the COSOD II Meeting in July 1987, the Sediment and Ocean History Panel (SOHP) of ODP supported the Arctic drilling recommendation of Larry Mayer which addressed the global importance of Arctic scientific drilling as outlined below:

   - The Arctic Ocean is a key corridor linking the polar entrances of major ocean basins; tectonic evolution of the Arctic has controlled the depth and width of these gateways and has had a major impact on global ocean circulation and climate systems.
   - Cooling surfâce waters of the Arctic are the source of much of the world's bottom waters; evolution of the cold Arctic hydrosphere is linked to the evolution of global deep-sea circulation patterns, ocean ventilation and paleoproductivity.
   - The changes associated with the transition from an ice free to ice covered Arctic ocean have had a fundamental effect on global thermal gradients, climate, geochemical reservoirs and biological evolution.

5. From July to September 1987 an international team of scientists (Germany, Norway, Sweden and Canada) conducted site surveys of possible sites on the Nansen-Gakkel Ridge, Yermak Plateau, and in the Senja Basin south of Fram Strait during the Arktis IV/3 cruise of PVRS POLARSTERN. Initial results are reported by Thiede (1988): briefly, it appears that sediments on seamounts flanking Nansen-Gakkel Ridge are not ideal for paleoceanographic studies because of turbidites and calcite dissolution. Good sites, however, may be located in the Sofia Basin on the northeast side of Yermak Plateau, and in the Molloy Deep South of Fram Strait.

6. In January 1988 representatives of the ODP regional panels and SOHP urged me to submit a preliminary Arctic drilling proposal which included specific sites where the major scientific objectives could be met (Appendix 4, Figure 3). An initial proposal was needed as soon as possible because the ODP PCOM and regional panels were already discussing alternative plans for JOIDES RESOLUTION when it completes drilling in the northeast Pacific. The ODP PCOM had a strong interest in Arctic drilling, but it needed specific

information on ice conditions, depth to proposed drilling basement, etc., to be able to evaluate the possibility of moving from the North Pacific to the North Atlantic via the Arctic Ocean. A preliminary document was hastily compiled by me, Steve Blasco and Ruth Jackson, and it was submitted to ODP PCOM on June 1, 1988. Copies of the proposal (Appendix 5) are also distributed here today for discussion at this workshop, and for post-workshop transfer to interested colleagues in Europe, Russia, and USA.

QUESTIONS:

J. Backman: Do you intend to involve the JOIDES RESOLUTION in this program?

P. MUDIE: Yes.

COMMENTS:

Y. Kristoffersen: It is fair to say that the European interest in terms of specific sites has been haphazard; nonetheless, the June 1st proposal for drilling in the Arctic for ODP was a big surprise.

S. Blasco: That list contains only four possible sites. These are not necessarily the ultimate sites and we are certainly not limiting the number to four. It is important to understand that this is only an initiative document, and it was never intended to be a definitive or an exclusive final proposal.

Dr. P. Mudie:

To complete today's discussion about scientific objectives and specific targets, I shall first summarise the salient features of our present knowledge concerning the tectonic and paleoenvironmental evolution of the Arctic Ocean.

1. From magnetic lineations, we think that the oldest part of the ocean, the Canada Basin, is about 120 - 150 m.a., but we have no direct evidence to support this interpretation of the geophysical record.

2. From the Jurassic (150 -120 m.a.) to Campanian (80 m.a.), we have no data to test various models for opening of the Canadian Basin, origin of Alpha Ridge and formation of Chukchi Plateau.

3. The interval from 60 m.a. to 40 m.a.is represented by 4 short Alpha Ridge cores with biogenic sediments. Two cores contain diatom assemblages which suggest that the Arctic was fully marine and relatively warm, with highly productive surface water, high sedimentation rates (possible annual varves are present), and with oxygen deficient deep water. One core, however, suggests slow

sedimentation rates and low, cyclical primary productivity, with geochemical characteristics that suggest periodic thermal venting. Another core suggests an organic-rich paralic environment, at least during the Late Campanian.

4. For the interval from 60 m.a. to 5 m.a., we have no data to test paleoclimatic models for the critical Oligocene and middle Miocene periods when the main Antarctic icesheets formed and when Northern Hemisphere alpine glaciations started. We also lack data to test models for the origin of Yermak and Morris Jesup Plateaus, and for the early evolution of the anomalously slow-spreading Nansen-Gakkel Ridge.

5. From 5 m.a. to the Recent, several hundred cores indicate large differences in sedimentation rates and geochemistry of bottom sediments of the eastern and central/western Arctic. Interpretation of the response of the Arctic Ocean to late Cenozoic climatic fluctuations is also strongly debated. For example, the age of the first sea ice formation, as indicted by presence of ice rafted detritus on Alpha Ridge, is dated as 5 m.a. Oxygen isotope evidence for the first perennial sea ice cover, however, is dated at 2.8 m.a., and foraminiferal evidence suggests that the start of a continuous perennial sea ice cover is as young as 1.8 m.a. The possible influence of shifts in the CCD and its effect on preservation of calcareous marker foraminiferal species is also vigorously debated. Totally unknown is the possible magnitude of late Cenozoic isostatic changes in the depths of sill separating the Arctic basins and constraining ocean circulation through the Arctic Ocean gateways.

Specific scientific problems that are addressed by this initial drilling proposal (Appendix 10) include the following items.

1. Characterization of pre-glacial Arctic deep sea paleoenvironment.

2. Timing and characteristics of initial climatic cooling and glaciation.

3. Timing, magnitude and periodicity of high amplitude late Cenozoic climatic oscillations and resultant ice sheets.

   - for example, what is the role of Milankovic variations in solar radiation with respect to the cooling of polar regions?

   - for example, what is the deposition rate of the rhythmically laminated biosiliceous sediments in short cores of pre-Pleistocene sediments from the Alpha Ridge? These sediments have ages ranging from late Mesozoic to Eocene. Iridium measurements were done on the CESAR core and the results indicate that this core spans the Cretaceous-Tertiary boundary. These Iridium measurements thus support the age determined magnetostratigraphy, by palynology and silicoflagellates. In contrast, diatoms in this CESAR core were dated as Campanian age on the basis of correlation with similar diatom assemblages found in the Ural mountains of USSR. International collaboration in resolving these biochronological questions is essential for proper interpretation of the history of Arctic paleoenvironments.

4. The main tectonic problem is to resolve the question: what is the age and structure of Alpha Ridge? Outcrops of this feature has been dated as Eocene using palynology, but we have no direct evidence for the supposed middle Cretaceous age of the basal volcanic rocks. We also need to know the age of the Lomonsov Ridge and the submarine plateaus presently fringing the Arctic. Drilling of the anomalously slow-spreading Nansen-Gakkel Ridge located at the northernmost end of the Atlantic mid-ocean ridge will help us to understand the crustal processes involved in seafloor spreading.

5. Paleoceanographic and paleontologic (flora and fauna) responses to global climatic change partly depend on knowledge of tectonic evolution (depth and width) of the corridors linking Arctic and global oceans, and separating basins within the ocean. For example, there is need to determine the structure and subsidence history of Alpha and Lomonosov ridges, Chukchi and Yermak plateaus, and the Nares Strait Lineament.

6. Arctic drilling may determine the nature of crustal generation at Nansen-Gakkel Ridge, which provides us with a rare opportunity to sample the rocks formed during the evolution of a very slow mid-ocean spreading center.

In view of the urgent need for ODP long-term planning, therefore, the initial proposal for Arctic Drilling (Appendix 10) has suggested four multiple drill sites for hydraulic piston coring and rotary coring in order to address first-order paleoceanographic,organic, geochemical, sedimentary and plate tectonic objectives. These sites presently include a transect across Alpha Ridge, two sites on Yermak Plateau and one on the south end of Nansen Ridge (Atlantic gateway sites), and three locations in the Chukchi Basin at the Pacific gateway (Appendix 4, Figure 3). These proposed sites are described in detail in Appendix 10.

In conclusion, this ODP initiative is a start towards defining the main scientific objectives and possible sites for Arctic drilling. In addition, we have also received lists of objectives from Tony Mayer (U.K. Natural Environmental Research Council) and David Roberts (BP Petroleum Development Limited) as shown in Appendix 4, Table 3, and from Arthur Green (Exxon Production Research Company) as shown in Appendix 4, Figure 4. These scientists independently have identified drilling objectives which are essentially the same as those discussed here today; hence, they support our belief that we have correctly defined major objectives ofinternational interest and high scientific priority.

COMMENTS:

R. Jackson: There is a program called RIDGE which is to look at the world-wide spreading ridges. The Arctic oceanic ridge is an end member of an entire system from which we need much data.

S. Blasco: The main purpose of this proposal is to put together a primary reference stratigraphy for the whole area of the Arctic. The sites suggested here are examples only and it would be better to improve them, and then to define key areas together with other groups interested in Arctic work.

QUESTIONS:

M. Keen: Are there any comments about the RIDGE proposal?

J. Mienert: As far as I know regarding this mid-oceanic ridge program there are no proposals in yet.

L. Johnson: They are really organizing the science now, once the science plan is promulgated specific proposals will be sent to the appropriate funding agencies for possible funding.

COMMENTS:

T. Pyle: The idea for doing some site surveying using the drilling vessels causes great dissension within the discussions of scheduling the expensive drill ships on areas with such poor data.

D. Fuetterer: Clearly there is a need for science surveys prior to drilling.

K. Manchester: Traditional site surveying will not be possible in the Arctic, but there are submarines in the world now that may be available by the 1990's that could do this site surveying beneath the ice.

Y. Kristoffersen: We have interest in drilling sites in northern Amundsen Basin and Northwind slope but are not certain of availability of site survey data.

L. Merklin: From scientific investigations concluded last year, we have concrete results from this area; there are also two seismic vessels now in this area.

V. REVIEW OF ALTERNATIVES FOR DRILLING PLATFORMS AND SUPPORT VESSELS

(A) Mr. Steven Blasco:

- Have we in fact sufficient data to have picked the optimal sites to resolve the scientific objectives we have set before us?
- Will the half the sites selected have gas in them or will there be any gaps in the stratigraphy? i.e. have we selected the correct sites?
- Can we in fact extrapolate beyond the sites?

Drilling alternatives for the Arctic:

Mr. S. Blasco, a scientist at the Atlantic Geoscience Centre with extensive experience in the Beaufort Sea pointed out that this subject was discussed in detail at a previous Arctic drilling workshop held at the Bedford Institute of Oceanography in December 1986. (Geotimes, August 1987). Present alternatives are:

- **Artificial Islands** can be built and are possible up to a water depth of 20 meters.
- **Bottom mounted heavily ice reinforced drilling platforms** can be used in water depths of more then 40 meters if a subberm is built but are generally limited to a maximum depth of 60 meters total. There has been a number of this type of drilling unit built and used in the Beaufort Sea.
- **Ice reinforced drillships** have been used during the summer drilling period in areas of the Canadian Arctic where ice concentrations are not to heavy and the water not too deep.

These structures and ships are not very appropriate for scientific purposes:

- They are very expensive to run: ($1 million a day to operate and maintain).
- Gravity base structures have limited mobility and are good up to only a depth of 60 meters, whereas the floating drill ships are good to up 200 meters and ice islands can be put just about anywhere but have no mobility and are only good to water depths of 20 meters.
- Sea ice conditions: Drill ships are limited in the amount of time they can drill (4-5 months) per year; gravity base structures are fine in any kind of sea ice conditions.

- Among the coring techniques are wire line tools, adapted to standard drilling techniques.

- What kind of water depth are we dealing with? The answer to this has a large bearing on what type of drilling platform can be used.

- Drilling mud problems: There have been environmental problems of discharge of drilling muds into the sea which has not been allowed in Canada. Could we adapt?

What are the viable alternatives for drilling in the Arctic?

a) Piggy back on industry drilling: would we adapt ODP technology to existing industrial drilling systems?

b) Diamond drilling from various types of islands, platforms or ships.

c) Bottom coring systems. There are a number of designs for systems to do this but none have been proven that recovers more then a few meters of near surface rock.

d) POLAR 8, this ship is to have the capability of limited drilling using a geotechnical type of system.

We need to find viable options for drilling methods for the Arctic as well as resolving the financial aspects.

(B) Dr. M. Peterson:

The Chief Scientist at NOAA with a long interest in Arctic drilling outlined his proposal to drill in the Arctic Ocean from a frozen in, drifting ship with the capability for drilling of the old GLOMAR CHALLENGER (see appendix 7). General limitations are:

- Maximum water depths of 14,000 feet.

- Using of the CHALLENGER, our policy was that we would not move the ship at speeds in excess of one knot with the drill pipe streaming.

- Speed that the ship will drift and depth of water has a great effect on the depth of penetration one can core to with continuous coring being attempted. Continuous coring to 100 meters subbottom (in 5000 feet of water) will take 11 hours; for 10,000 feet of water where the coring time is 60 minutes, it will take 12 hours for a 100 meters of continuous coring.

- 1 nautical mile a day is the maximum drifting rate for realistic continuous drilling.

- 5 nautical miles per day would be the fastest drifting rate for other than what we would call the hit and run method of coring.

- the important point to note is that one must try to associate drift rates with the drilling and coring styles one is employing.

Needed studies:

- drill water intake
- improved bottom hole assembly
- analysis of ice motion, predictability
- logistic demands and contributions
- geophysical program
- longer cores:
  - rotary
  - hydraulic piston corer
- shorten coring cycle time

An example of a type of platform which is ice resistant that could be used is our Beaufort Sea type of platform.

QUESTIONS:

P. Mudie: Could you consider working in conjunction with similar vessels described by S. Blasco. You might start in Beaufort Sea which is relatively ice free in summer and where sedimentation rates are fast so one can obtain high resolution stratigraphy for a short time interval, then travel to the central Arctic where sedimentation rates are slow and ice movement is also slow because of the jammed ice as you come down the ridge towards Ellesmere Island. The slow movement in this area could be an advantage in holding station while drilling a long sediment sequence in relatively deep water.

In this area you are facing compression, this would be difficult, we will readjust the projectories. To intentionally push yourself into that gyre is something we do not foresee.

P Mudie: Is it possible to conceive pulling out of that gyre with a support vessel?

That gyre is multi-year ice.

P. Mudie: It most probably is but we do not have much data in that particular area. This lack of information is a very big constraint, but the site selection has been made for areas where we do have some good data.

R. Jackson: Is it still very expensive wherever your platform is? Could the ice island be used to avoid the initial costs?

It is not easy to put a price on this type of project.

VI THE POLAR 8

A) STATUS AND PLANNED CAPABILITIES:

Mr. W. McCloy (Canadian Coast Guard):

Mr. W. McCloy, Project Director, for the Canadian Coast Guard Polar Icebreaker Project, has been associated with this project for many years. The ship is in the final design stage now with the intention of construction to start in late 1988 or early 1989 on the west coast of Canada. Facts and plans concerning it are as follows:

MISSION PROFILE:

Sovereignty: Project visible Canadian presence for extended periods in the Arctic region in exercise of sovereignty concerns and enforcement.

Scientific:

- Provide a platform for Arctic Seas scientific studies and data collection.
- Provide a facility for the conduct of mission oriented R&D projects related to Arctic class ship design and operation, regulatory development and operational experience.
- Provide platform for the conduct by other government departments of hydrographic and oceanographic research and surveys.

Strategic/National:

- Provide escort and assistance to all vessels making Arctic voyages of national interest.
- Provide escort and assistance to all oil tankers making exploratory or demonstration voyages in Arctic shipping safety zones.
- Provide a fully capable facility for possible deployment to Antarctica for exploration and R&D purposes.

Emergencies and Logistic Support:

- Provide an all season platform and action center for the co-ordination of large scale Arctic emergencies including search and rescue, pollution, blowouts, pipeline failure and Arctic community disaster.
- Provide manpower, shelter, communications and transport for involved personnel.
- Provide power and supplies to Arctic sites, bases and communities during emergencies.

- Resupply remote sites and communities.

<u>**Shipping Support:**</u>

- Conduct all season Arctic trafficability studies to examine and demonstrate reliability of Arctic shipping season extension.

- Contribute to the safe and efficient movement of all Arctic marine traffic by providing escort and assistance to beset ships and those experiencing difficulty in extreme sea ice conditions.

- Maintain marine aids to navigation in the Arctic areas.

- Provide surveillance and reporting of Arctic ice and environmental conditions along shipping routes.

- We have designed in the last four years two icebreakers, we are presently working on the fourth ship design. We have approval in principle to go into the construction stage of the POLAR 8 icebreaker. The construction might begin before the end of this calendar year.

- For POLAR 8 icebreaker characteristics and research facilities, see Appendix 6.

- The only remaining problem is one of dollars. Provided the financial matters are solved we will have this ship operational by late 1992. Because of the unique nature of the ship and its complexity, we will spend approximately the first six months of it's operation on proof of performance trials and tests but there is likely to still be significant time available for science if the scientists are willing to be flexible in demands for use of it.

<u>**QUESTIONS:**</u>

D. Fuetterer: What are the cargo facilities?

We have two cargo holds, most of the cargo will be taken on via containers in the after part of the ship. We do not expect to carry cargo for land based settlements on land, only equipment or supplies for use by the ship's staff or scientists. There are also two large cranes, one on each side of the ship, that can be used lift equipment or supplies from the ice on to the ship or from the ship on to the ice or landing barge.

B. Molnia: As far as the planned multi-purpose use of the ship, do you have any ideas as to what percentage of the time will be allocated for research purposes?

I was reluctant to mention this but we did have to do this in the early planning for the ship. The general figures we produced for the various tasks the ship was anticipated to do are very preliminary and must take into account many other factors. These are being revised at the present time by the ship's operation planners but it is safe to say that after the proof of performance tasks in the first year and in the second and third years of operation there will be significant time available for science particularly if the scientists can be fairly flexible in their demands.

T. Vorren: Can you use the ship for ODP drilling technology?

It is not primarily designed for ocean drilling, but it has room for a geotechnical type drill rig that will operate through the moonpool.

M. Peterson: Are there any particular considerations given to dynamic positioning?

There is no specific dynamic positioning equipment, however there is a hull lubrication system that can provide lateral thrust.

VI. (B) EARLY OPERATIONAL PLANNING FOR POLAR 8:

P.R.M. Toomey (Canadian Coast Guard):

Captain Toomey is the Senior Marine Officer attached to the Polar 8 Icebreaker Project and will likely be one of the ship's two rotating Captains that will be assigned to the ship when it is launched. At present he is heavily involved in planning it's first five years operation.

Preliminary operations outline: Initial five year program -POLAR 8

Main Program Priority Areas:

- proof of performance
- trafficability assessments
- environmental assessments
- emergency preparedness exercises
- communications exercises

1992-1994 allow 300 days for operations each year

It is recommended that this period be allocated to contractually related proof of performance trials and initial trafficability assessments. It is a contractual requirement that the ship return to Victoria, British Columbia, at the end of this year for drydocking and warranty inspection. Coast Guard initiate and prescribe the missions.

Activities To Be Planned For:

Priority One: An expanded P.A.P.A. (Post Acceptance Proof of performance) trial series will be carried out in Canadian and International Waters of the Arctic. This will involve operations in M'Clure Strait, Viscount Melville Sound, and the Arctic Ocean.

Priority Two:

A) Mid-Winter demonstration transits of the North West Passage in both directions via both Prince of Wales Strait and M'Clure Strait, including an environmental assessment of voyage effects.

B) Circumnavigation of the Queen Elizabeth Islands Group with practical accessibility trials at the sites being evaluated under Coast Guard's current theoretical site evaluation, including environment assessment of voyage effects.

C) Phase I - Demonstration transit of Arctic Ocean from the Pacific via the Chukchi Sea with the objective of passing through and conducting appropriate research at the North Pole after which the transit would continue through into the Atlantic via the Greenland Sea.

This voyage could then be followed up by a series of port visits in interested nations of the European and Baltic areas, as may be deemed appropriate. The ship will be required to stop in the region to refuel in any event.

An appropriate scientificenvironmental research program will be developed for such a voyage involving routine stations for the conduct of research in the physical, meteorogolical and biological sciences.

Phase II - Return to Canadian operating areas could be accomplished three ways depending on the success of the initial voyage and the degree of associated interestpublicity.

A) Direct via open water south of Greenland;
B) North about Greenland via the Lincoln Sea or;
C) By a second trans-Polar voyage following an alternate route for scientific stations.

The purpose of such operations would be to:

- Demonstrate and prove the ship's full capability,
- Conduct scientific and environmental studies,
- Publicize Canada's present effort and position as an Arctic littoral state and Canada's capability with respect to its sovereignty position.

1994-1995 Allow 300 Days for Operations

It is recommended that the ship begin to assume a more normal posture during this year and assume standby readiness to provide normal icebreaking and other mandated services in the North West Passage. Coast Guard will initiate and prescribe these missions. A significant portion of available operational time during this period should be allocated to scientific and defence related missions which will be initiated and prescribed outside of Coast Guard.

1995-1996 Allow 300 Days for Operations

Operations should be planned for 300 operational days. Distribution of effort for this, down the planning horizon, will depend on the demand for ship's time between scientific, defence and transportation missions.

1996-1997 Allow 300 Days for Operations

As above, 300 days for operations.

NOTE: Allowing approximately 300 days per year for operations could see POLAR 8 being inactive during periods in July, August, or September when other Coast Guard icebreakers are active in the Arctic. Self maintenance and refits will be scheduled for this period, however, all normal operational staff and facilities on the ship will be maintained during these periods. It is worth noting that there is likely to be more time for scientific tasks available than in later years. It is anticipated that no significant increase in Arctic travel will have taken place by then, but as time goes by after that, it is likely to increase as more experience is gained from the POLAR 8's operations during the non-summer periods and as more Arctic class commercial ships become available.

QUESTIONS:

H. Zimmerman: The question is addressed to the Canadian colleagues regarding the extent of international cooperation: is there some science plan at the international level that you wish to propose?

COMMENTS:

M. Keen: The Department of Energy Mines and Resources and the Coast Guard are involved in the early planning stage of developing a coordinated science plan for the Polar-8.

C. Barnes: There has been in the last few months the development of a multi year marine science plan, involving all the marine agencies in the Federal government. It is not yet well organized but it is anticipated that the Polar 8 will have a major role in Arctic Ocean research plans.

M. Keen: We might wish to develop 20-30 year science plans in line with the life of the vessel but is this realistic ? All would agree that there is no lack of science to do in the Arctic Ocean but scientists don't normally plan much more then five years in advance with any degree of certainty.

QUESTIONS:

H. Zimmerman: Was the initial mission profile of the Canadian Coast guard as described by M. McCloy in order of priority?

These are all simultaneous activities

M. Peterson: What kind of escort pattern would you try to develop for a drill ship which itself would be mobile to some extent even when on a drill station?

As long as there is sufficient room for navigation, we must stay upstream of it if it is on station or ahead of it if it is underway.

VIII. OTHER ISSUES:

A - SITE SURVEYS

Dr. Joergen Miernert (Geologist, GEOMAR):

Investigations to date of importance for site surveys:

- ARK IV3
- CESAR
- FRAM I-IV
- LOREX

Possibilities for future site surveys:

- Snow Mobile surveying from sea ice or deployment of a drifting array around the drilling platform.
- Drones, used close to the margins.
- Submarines.

- We can reconstruct the last glacial changes in the Arctic ocean but are unable to reconstruct the pre-glacial history of the Arctic ocean.
- The Long Coring system being developed by the University of Rhode Island and the Atlantic Geoscience Centre must be tested in the Arctic environment.

- Refer to the Arctic Drilling Five Year draft plan (Appendix 8) which has been prepared as a plan to start discussions.

The scientific objectives are:

  - To reconstruct the pre-glacial Arctic deep sea paleoenvironment.
  - To study the initial climatic cooling, glaciation and sea ice cover history.
  - The high-amplitude late Cenozoic climatic and ice sheet oscillations.
  - The paleoceanographic and paleontologic response to climate change and depth change.
  - The structure, nature and development of major morphotectonic features.
  - The paleogeography and paleobathymetry of the Mesozoic and Cenozoic Arctic.

- The decision on the proposed sites depends on the ability to do pre site surveys and the type of survey system which will be used.
- One site has been proposed on the Yermak plateau on the Morris-Jesup rise to reconstruct the tectonic development and opening of the Fram Strait.
- Three sites are proposed to reconstruct the changes in circulation pattern of the Arctic Ocean and to compare the major basins in the Arctic, such as the Amundsen and the Makarov Basin, and also to reconstruct the development of the Alpha Ridge and the Chukchi Plateau.
- These are therefore only preliminary sites, we must together find specific sites which will cover our major scientific objectives.

B - POLITICAL CONCERNS:

Dr. L. R. Merklin:

Review of the recommendations from the Moscow meeting (Nov. 1987) of American and Soviets experts on Arctic investigations.

- Recommended to drill in the deep Arctic ocean by JOIDES RESOLUTION together with one or two USSR support icebreakers for ice safety.
- Priority should be given to the northern part of Greenland Sea in the North pole direction up to the ice safety limit.

- For geological and geophysical investigations (now underway through bilateral or international agreements) in the central Arctic, where the JOIDES RESOLUTION can't operate it is recommended to use a drifting icebreaker for one or two years at a time and should-could be repeated several times.

- The geological and geophysical transects from Canada should be made through North Pole to Siberia and to the Himalaya's up to the Indian ocean. The investigations can be supplied by aeroplanes, helicopters and vessels within boundaries of national sectors and economic zones.

- The special investigations should start on the Arctic Plateau (borderlands), Yermak and Chukchi plateaus where it would be useful for ODP deep sea drilling proposals. Investigations using submersibles could be one of these Special Investigations.

- Real Arctic geodynamics and seismicity can be determined only by using seismology networks on the Arctic beaches and islands, about 12- 15 stations (USSR, USA, Canada) connected for a 3 to 5 year period.

- Geological and geophysical drifting stations must be done with known techniques: side-scan sonars, reflection and refraction seismics, gravity, magnetic and heat flow measurements, heavy bottom penetrators (corers) and dredges, submersibles and towed apparatus such as TV and photo cameras, geochemical probes etc.

- These investigations must be coordinated with other geological and geophysical work as well as that from the Antarctic.

- We recommend to drill at first the ice sheets on the Arctic Islands instead of parts of Greenland.

- Dr. Merklin then showed a series of slides on his participation on the USSR expedition using nuclear icebreakers to first reach the North Pole with a surface ship.

IX. WHERE DO WE GO FROM HERE: DEVELOPING ORGANIZATIONAL STRUCTURE FOR N.C.A.P.

(A) Dr. Torre Vorren:

The Nansen Centennial Arctic program proposal:

- The Norwegian Academy of Science has planned a committee to formulate scientific research programs in the Arctic to commemorate Nansen's expedition in the Arctic nearly 100 years ago. The FRAM expedition is a bench mark in time which should inspire scientists from nations interested in Arctic research.

- The national committee is comprised of people from different disciplines and institutions.

- Thematic groups will be established: remote sensing, meteorology, glaciology, biology, oceanography, cosmic physics and marine geosciences.

- The overall plan for this committee is to propose a decade of research in the Arctic; the program is divided in two parts: 1. an ice drift with a vessel in the Eurasia Basin; 2. participating in the Arctic Ocean Drilling.

- This program I am proposing and suggest calling Nansen's Arctic Drilling Project (see Appendix 9) should have an executive committee of seven members, one each from Norway, Denmark, United States, Canada, U.S.S.R., and also Sweden and Germany which would formulate scientific policies and recommend objectives with respect to Arctic drilling. The science committee also comprised of seven members from the different nations will deal with research priorities for Arctic Ocean drilling, with scientific problems and with site survey studies. The technical committee composed of seven members will recommend, and evaluate the aspects of drilling platforms, related techniques, and identify new platforms to be developed.

- Although membership should be limited to countries with interest in Arctic research, it could remain open to others who can contribute to the program.

(B) Dr. Kristoffersen:

- Norway is actively considering field activities in the deep Arctic Ocean during the 1990's.

- Norway can contribute towards scientific drilling by improving on the ice site survey technology and by carrying out reconnaissance surveys for optimum drilling site definition.

- Locating optimum sites requires good MOBILITY.

Geological sampling: Design criteria for an active sediment corer which is now being actively developed as follows:
  - low equipment weigh
  - driving mechanism other than gravity alone
  - reduced friction between core pipe and sediment
  - telemeter information on penetration and deflection from the vertical to the surface
  - increased penetration

Over-ice towed snow streamer:

- length: 800 meters
- shot interval: 400 meters
- single channel seismic data reflection point interval of 25 meters
- speed of advance: 1 knot
- production: 15-20 kmday
- support: 500 kilogramsweek

Seismic reflection:

- drifting arrays
- arrays towed by submarines
- single channel sledge surveys with digital recording on a PC computer
- ice geophone streamers with recording on a PC computer

Sediment sampling:

- coring from drifting ice stations
- coring from ice breakers
- coring by aircraft supported mobile units

CONCLUDING COMMENTS ON THE NANSEN ARCTIC DRILLING COMMITTED PROPOSAL:

L. Johnson: This proposed NANSEN Arctic DRILLING committee should be scientific and not a protocol committee, a multi-facet approach is needed and data management and site surveys need to be addressed.

B. Molnia: How can we solve the problem of other groups or organizations having equally legitimate concerns on Arctic science? i.e. How do we communicate and coordinate our plans and or activities with them?

C. Barnes: A way to deal with such groups is to have associate or correspondence members who wish to be informed but do not necessarily wish to participate in our activities.

Y. Neprochnov: In the proposal it would be preferable to remove any political reference.

S. Blasco: We should expand the mandate of the Technology Committee in the proposal to cover the aspects of site surveys and of logistics.

P. Mudie: A potential problem could be the overlap between existing programs such as the Arctic Science Committee and the Arctic Panel for ODP.

D. Fuetterer: It would be better to have independent organizations with regional working groups.

H. Zimmerman: Would the Arctic Drilling community be better served by the formation of Arctic Drilling sub-committees in existing organizations? I feel sometimes that this proliferation of committees causes confusion and really impedes communication.

Y. Kristoffersen: We would like to know what is the focal point for Arctic research in each country or organization. The Norwegian Academy of Science could send a letter to the different organizations. It will be difficult to keep the Science and the Technology Committees apart, it is important to have interactions between both committees.

T. Pyle: Once the executive committee of the Arctic Drilling Committee is formed, it would be important to write to the scientific advisors of the Ocean Drilling Program outlining their interests and goals etc. and asking for assistance from the safety and other committees as has been discussed previously.

K. Manchester: In summary all I can say is if this proposed Arctic Drilling Committee is a good idea it will likely be successful in the future and if it is a poor idea there will be little interest or support shown for it and it will flounder. I personally believe it is a good idea, and I think it will be successful.

CONCLUSION:

(1) T. VORREN WILL WRITE TO EACH COUNTRY REPRESENTED HERE TO GET THE NAME OF THE PERSON WHO WILL REPRESENT THEM ON THE INTERIM EXECUTIVE COMMITTEE WHICH WILL MEET WITHIN A YEAR IN WASHINGTON. HE MUST BE GIVEN THE NAME OF THE PERSON TO WHOM HE SHOULD WRITE HERE AND NOW. THESE NAMES WILL BE GIVEN TO THE NORWEGIAN ACADEMY OF SCIENCE AS INTERIM REPRESENTATIVES UNDER THE ARCTIC DRILLING PROJECT.

(2) THIS INTERIM COMMITTEE WILL DISBAND AFTER THE WASHINGTON 1989 MEETING WITH THE ASSUMPTION THAT A PERMANENT COMMITTEE WILL TAKE OVER.

(3) THE ATLANTIC GEOSCIENCE CENTRE OF THE GEOLOGICAL SURVEY OF CANADA AT BEDFORD INSTITUTE OF OCEANOGRAPHY WILL ACT AS THE INTERIM SECRETARIAT FOR THE NEXT YEAR.

PART II: APPENDICES AND FIGURE CAPTIONS

LIST OF APPENDICES AND FIGURES

LIST OF APPENDICES (CONT'D)

Appendix 7. NOAA Study in preparation for exploration and scientific drilling of the Arctic Basin.

Appendix 8. Draft paper on Arctic Drilling Five Year Plan 1989 - 1994.

Appendix 9. Proposal for NAD - Nansen Arctic Ocean Drilling program.

Appendix 10. Ocean Drilling Program proposal for Arctic Ocean drilling.

APPENDIX 1

FROM T. CROWLEY AND C. NORTH, ABRUPT CLIMATE CHANGE AND EXTINCTION EVENTS IN EARTH HISTORY; 1988, SCIENCE, VOL. 240, P. 996-1002.

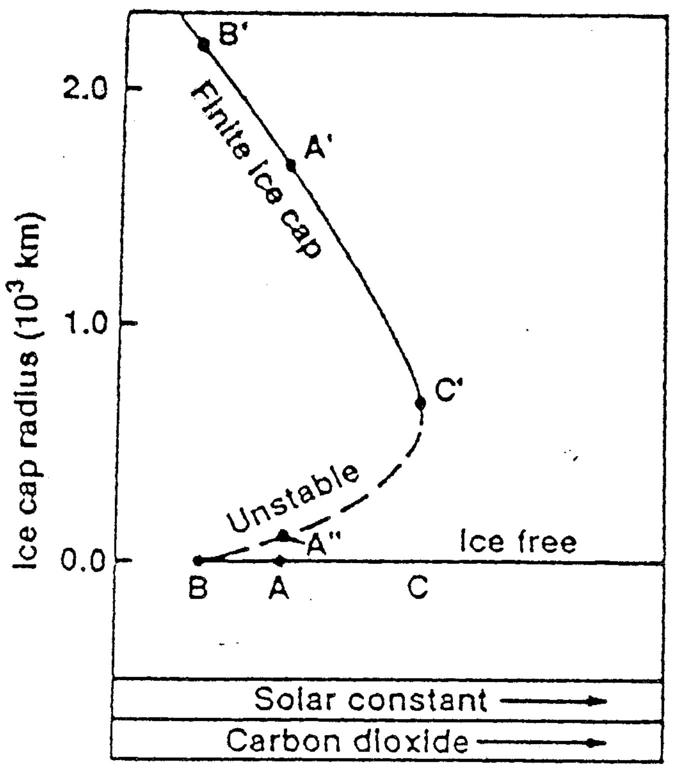


Fig. 1. Schematic of equilibrium solutions of ice feedback models for different levels of forcing. The dependent variable is the ice cap radius and the independent variable is the solar constant (or CO_2) increasing to the right. See text for additional discussion. [From (*18*); reproduced by permission of the Geological Society and *The Journal of the Geological Society (London)*]

ODEN II

Dimensions and Capacities

Length over all	108.0 m
Beam over reamer	29.4 m*
Beam midships	25.0 m
Depth to upper deck	12.0 m
Draft operation	7.0 - 8.5 m

* ODEN II is the widest icebreaker in the world; even wider than USSR nuclear icebreakers.

Displacement at d 8.0 m	11800 tonnes
Weight	8000 tonnes
Fuel capacity	4400 m^3
Ballast capacity	3500 m^3
Power to propellers	18.0 MW (24500 HP)

Performance

Icebreaking capability in level ice: 1.8 m at 3 knots

Turning radius in 0.8 m ice: without heel - 2.5 ship lengths
with 7° heel - 1 ship length

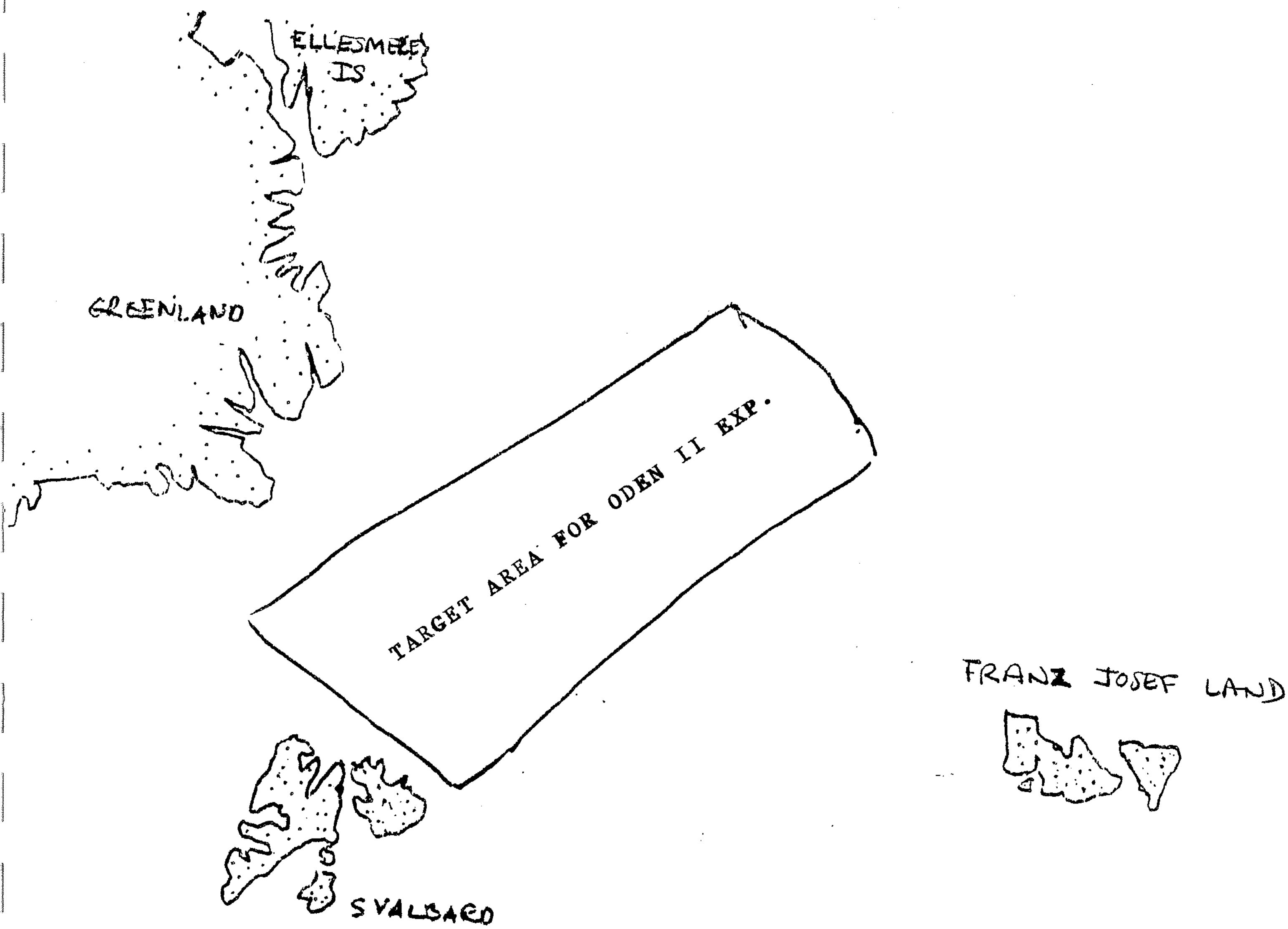
Speed in open water: 17 knots

Endurance: Icebreaking 0.9 m ice: 12000 nautical miles

Open water at 13 knots: 100 days or 30000 nautical miles

Deep-sea DPR installed

APPENDIX 3



TARGET AREA WILL BE BETTER
DEFINED AUTUMN '88

APPENDIX 4, TABLE 2: **1986 MONTREAL WORKSHOP**

Arctic Drilling Proposals

Eleven proposals have been received or considered so far. They are in three general categories as follows:

PROPOSALS	PRINCIPAL PROPONENTS
(A) Mesozoic-Cenozoic History, Paleoenvironmental Emphasis	
-- Arctic Fiords	J. England: U. of Alberta
-- Canadian Beaufort shelf/slope	P. Hill, S. Blasco: GSC/AGC
-- Canadian Beaufort shelf/slope	E. Burden: MUN
-- Banks Island shelf/slope	J.S. Vincent: GSC/TS
-- Alaskan Beaufort shelf/slope	J. Brigham-Grette: U. of Alberta
-- Arctic Basin	C. Pereira, S. Macko: MUN
(B) Mesozoic-Cenozoic Stratigraphy, Margin and Basin Evolution / TECTONIC MODELS	
-- Chukchi Cap, North Wind Ridge, Alaskan Beaufort slope	A. Grantz: USGS
-- N.W. Archipelago shelf	A. Embry, R. Stephenson: GSC/ISPG
-- Canadian Beaufort slopes	R. Young, V. Lyatsky: Home Oil
-- Western Canadian Beaufort	J. Dixon, J. Dietrich, S. Lane, D. McNeil: GSC/ISPG
(C) Site Survey Investigations	
-- Wide Angle Reflections	A. McKay: NSRF

David Roberts

APPENDIX 4, TABLE 3

BP Petroleum Development Limited

(a subsidiary of BP Exploration Company Limited)

(June 7, 1988)

OBJECTIVE 1: Opening history of the Arctic Ocean.
(Tectonic origin)

- timing, direction age, presence/absence of microcontinents old spreading centres.

Target areas: Canada Basin, Lomonosov Ridge, Alpha Cordillera Yermak Plateau, Chuckhi Ridge.

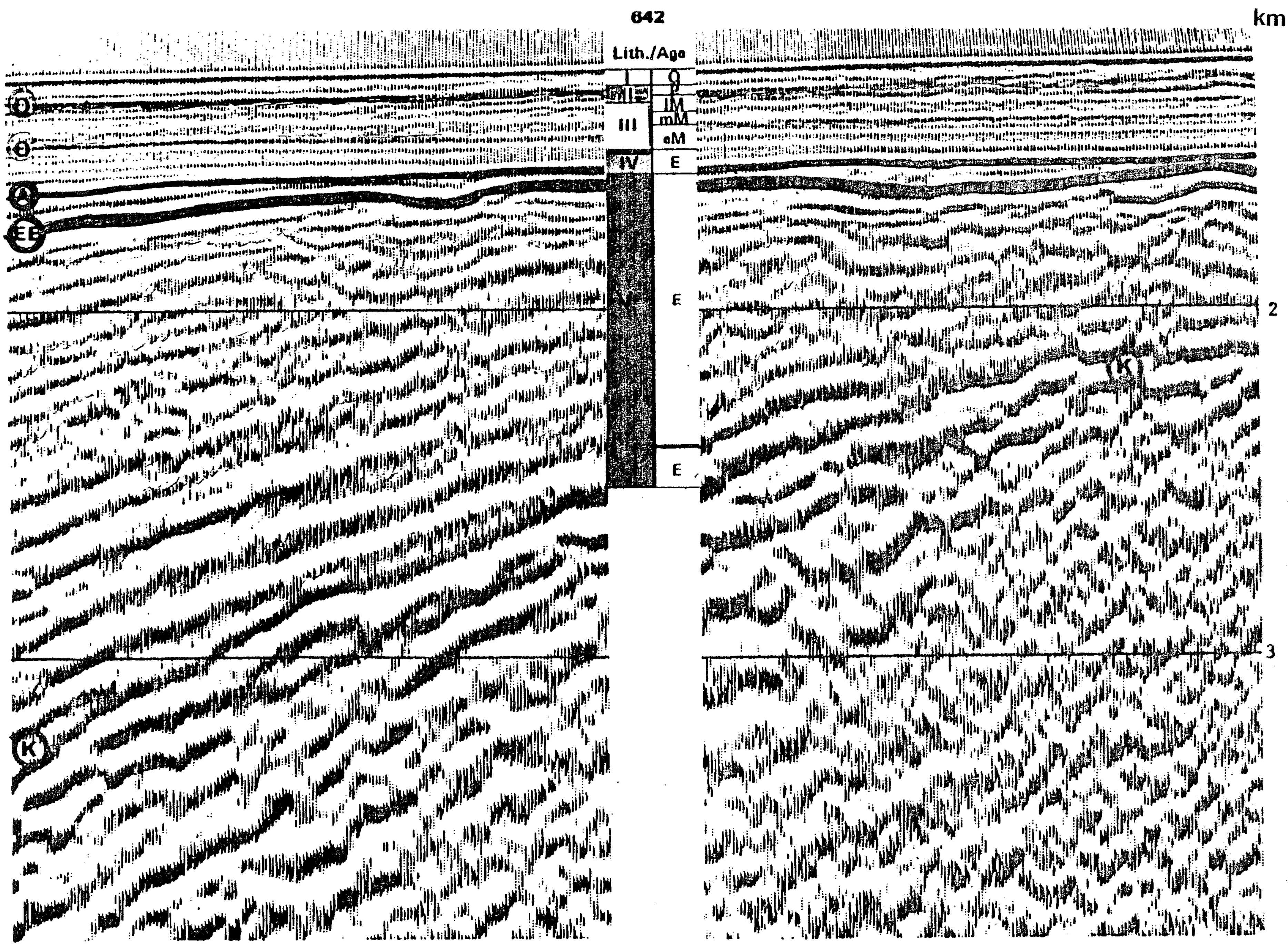
OBJECTIVE 2: Palaeoceanography of the Arctic Ocean:

Areas as above but also the Nansen Cordillera

- high latitude Mesozoic climate, palaeoceanography,
- Arctic climate evolution through the Tertiary.
- circulation exchange with the Atlantic/Pacific Oceans

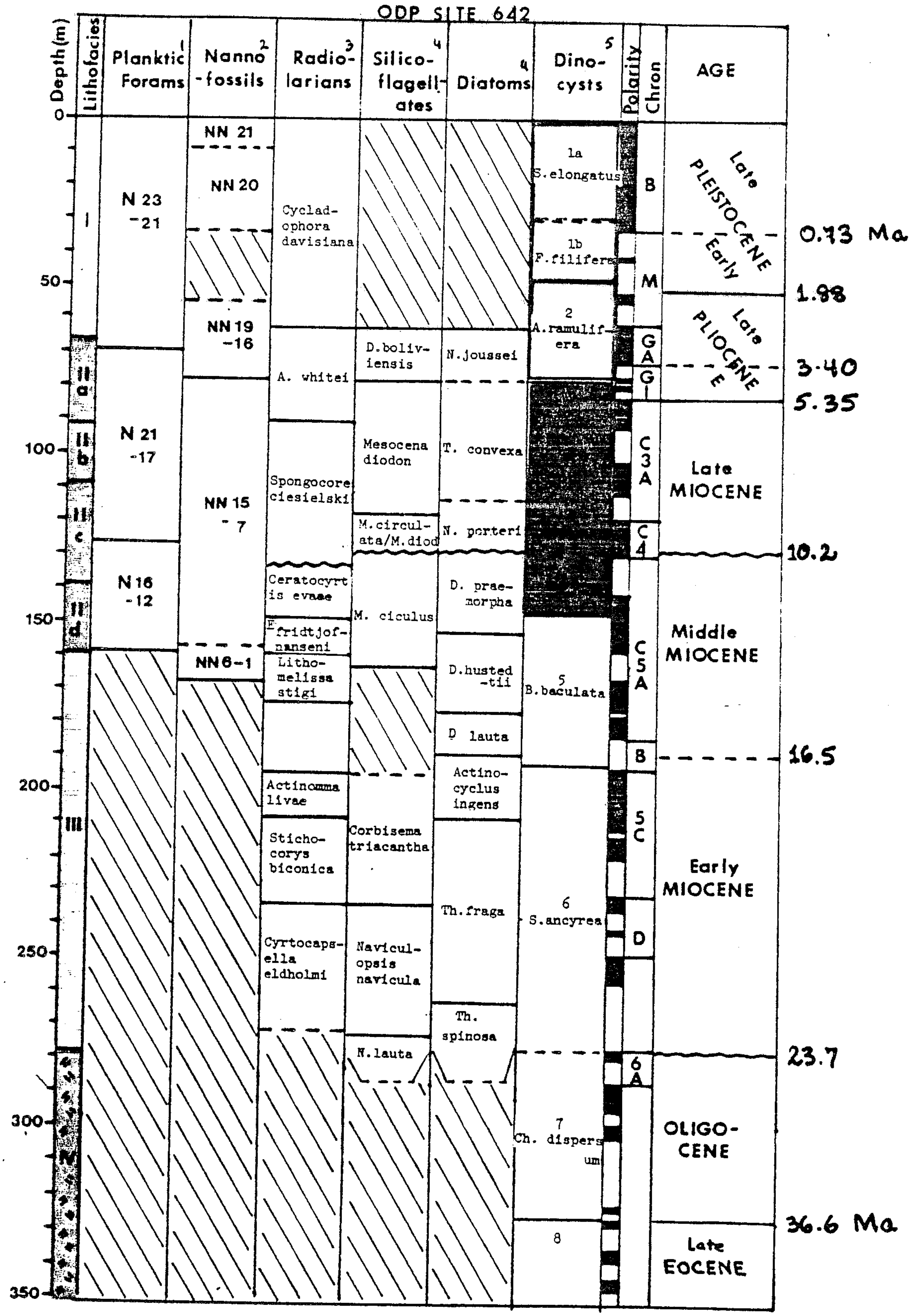
Cretaceous. Tertiary boundary event stratigraphy.

Anoxia of the Arctic during the Cretaceous.

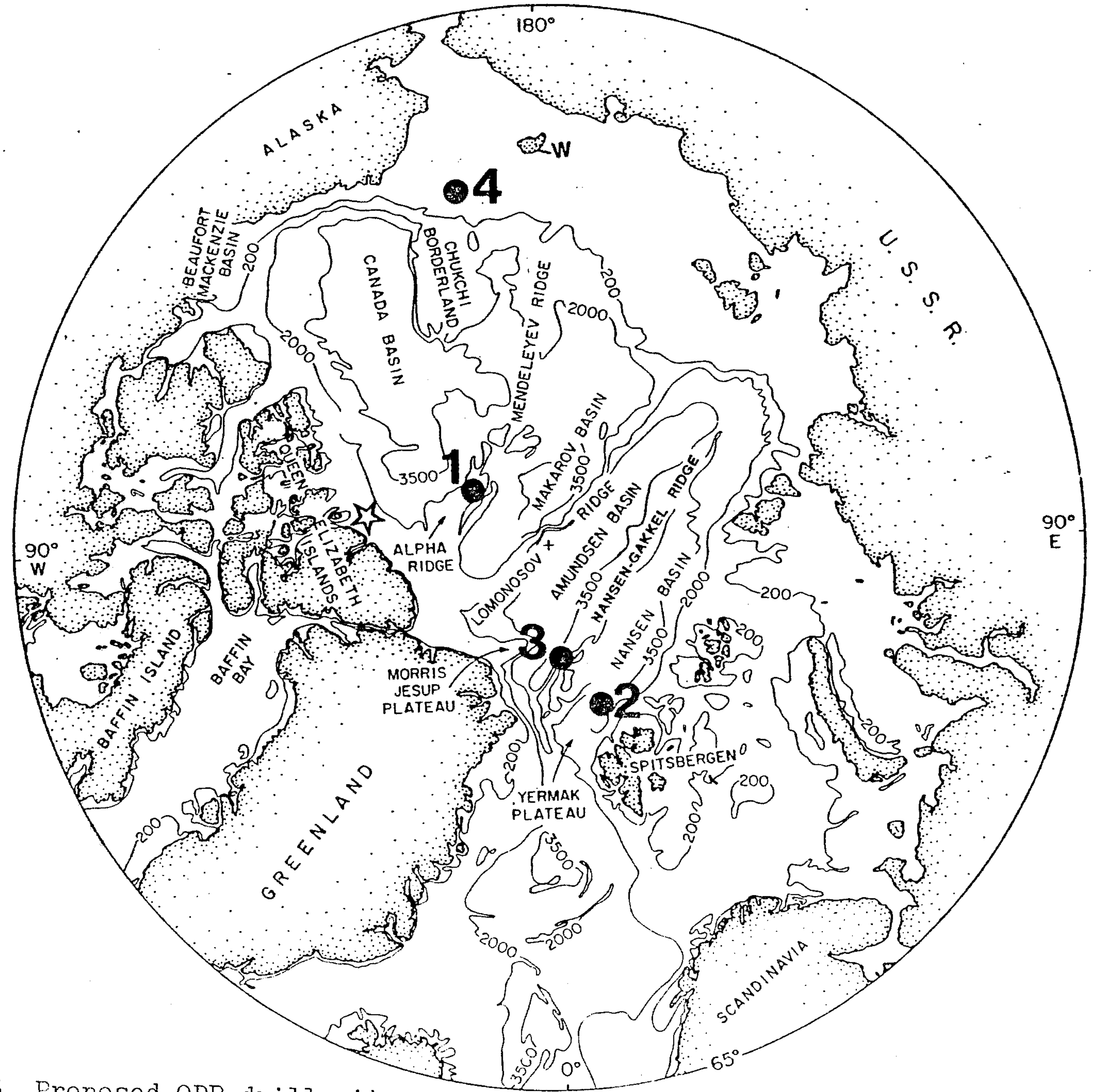


APPENDIX 4, FIG. 1. ODP Leg 104 Site 642 drilling Voering Plateau

APPENDIX 4, FIG. 2. ODP Leg 104 high latitude biostratigraphy



(1) Jansen (2) Donnaly (3) Bjorklund (4) Ciesielski (5) Mudie



APPENDIX 4, Fig. 3. Proposed ODP drill sites

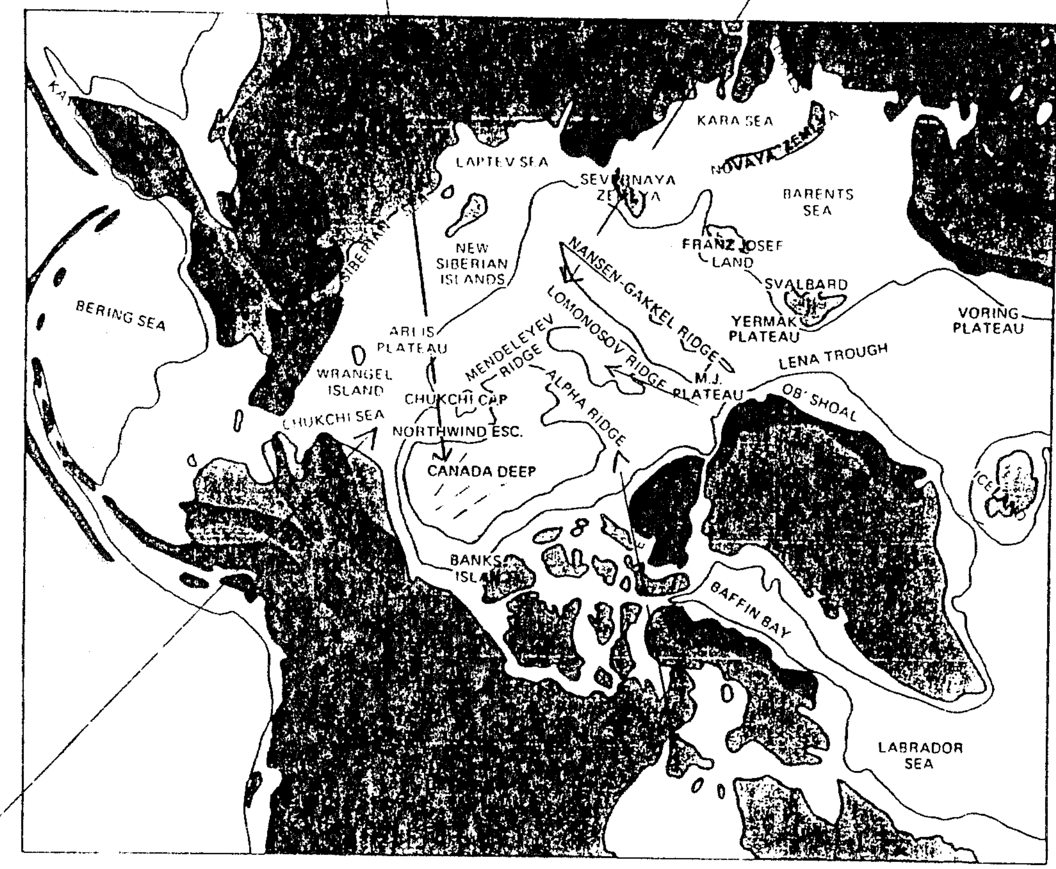
APPENDIX 4, FIGURE 4: Primary scientific questions addressed by Arthur Green, Exxon Research

Are the magnetic anomalies spreading anomalies? Which way (direction) did the Canada Deep open?

What is the oldest sediment in this thick sedimentary basin?

Is the Lomonosov Ridge really a continental fragment? If so:

- Was it an old foldbelt - of what age?
- Are there volcanics and intrusives on the ridge?



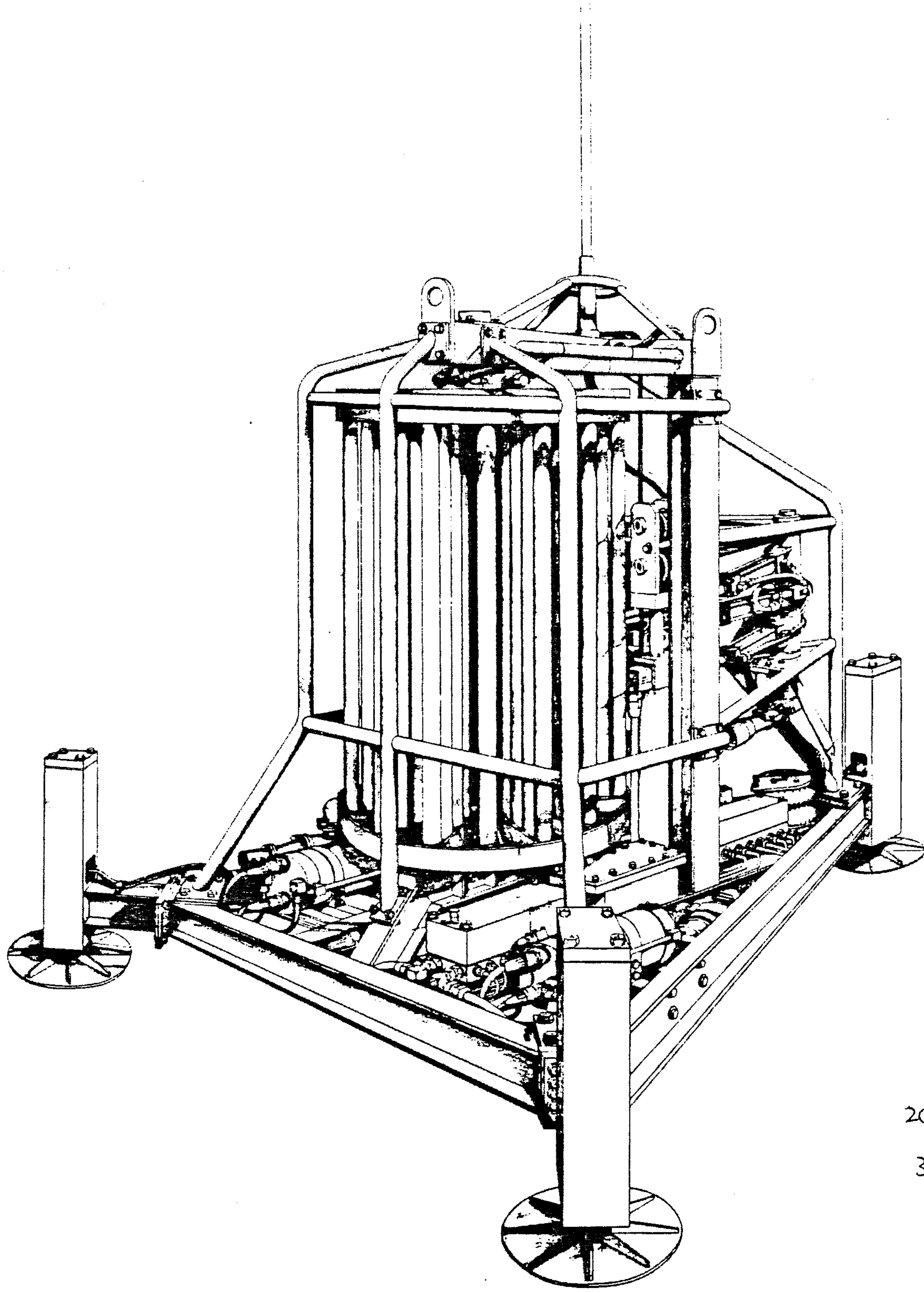
Age of basin?

What are the Chukchi Cap and Northwind Ridge? Are they related?

What is the origin of the Alpha Ridge?

- Rock types
- Volcanics - age of?
- Sediment - age & type
- Continental remnant?
- Compressional ridge?
- Hot spot trace?
- Etc?

SEAFLOOR CORING



20 Kw
3 x 4 m

WILLIAMSON AND ASSOCIATES, INC.
OCEANOGRAPHERS & OCEAN ENGINEERS
1219 WESTLAKE AVE. NORTH, SUITE 111
SEATTLE, WA. 98109
206·282·2396

POLAR 8 ICEBREAKER PROJECT

PRINCIPAL PARTICULARS

1.	LENGTH OVERALL	167.8 M
2.	LENGTH AT WATERLINE	150.0 M
3.	BEAM	36.0 M
4.	DEPTH	19.0 M
5.	DRAFT (MAX)	12.5 M
6.	DISPLACEMENT	38,000 TE
7.	COMPLEMENT	155 PERSONS
8.	SCIENTIFIC PERSONNEL	38 (MAX)

9. ACCOMMODATION - - - - - HOTEL TYPE ALLOCATION

10. POWER AND PROPULSION:

(A) PROPULSION - - - -TRIPLE SCREW DIESEL ELECTRIC

(B) PROPULSION MOTORS = 49,236 KW (66,000 HP)

(C) CENTRE NOZZLE AUGMENTATION = 17% POWER = 8,370 KW)

(D) TOTAL EFFECTIVE PROP POWER = 57,606 KW (77,220 SHP)

(E) TOTAL INSTALLED POWER = 62,000 KW

11. ENDURANCE:

55 DAYS (APPROX) FULL POWER OPERATION

POLAR 8 ICEBREAKER PROJECT

RESEARCH FACILITIES AVAILABLE ONBOARD

1. G.P. LABORATORY 70 M^2
2. ICE AND MET OFFICE
3. GRAVIMETER LABORATORY
4. FOUR (4) CONTAINER LABORATORIES. SPACE AND FACILITIES
5. WORKING DECK SPACE ON STERN AREA 300 M^2
6. TOWING WINCH, DOUBLE DRUM (SAMPLING &/OR TOWING)
7. STERN "A" FRAME, 20 TONNE CAPACITY
8. STARBOARD SIDE "A" FRAME 20 TONNE CAPACITY
9. REFRIGERATED LABORATORY (STORAGE) 30 M^3
10. MOONPOOL 2.4 M x 1.6 M
11. OCEANOGRAPHIC STOREROOM 35 M^2
12. SCIENTIFIC CLOCK SYSTEM (CESIUM)
13. SCIENTIFIC COMPUTER ROOM 28 M^2
14. TRANSDUCER SPACE 36 M^2
15. OCEANOGRAPHIC WINCH ROOM 40 M^2

MELVIN N. A. PETERSON
CHIEF SCIENTIST, NOAA

APPENDIX 7

A STUDY IN PREPARATION FOR EXPLORATION AND SCIENTIFIC DRILLING OF THE ARCTIC OCEAN BASIN

Draft dated 2-5-87

Introduction

The Deep Sea Drilling Project accomplished a reconnaissance scientific drilling of the major ocean basins and marginal seas of the world with the important exception of the Arctic Ocean. The Ocean Drilling Program continues to address specific scientific drilling in much the same style but, despite the fact that the new drilling vessel JOIDES Resolution (SEDCO/BP-471 registered name) has a modest ice transit classification, it would not be competent to drill in any areas of Arctic Ocean basin except the most open parts of the marginal ice zone during the favorable season. Similarly, geophysical exploration of the Arctic Ocean has been largely restricted to areas of seasonally open waters.

Many geologists would regard the drilling and coring of the Arctic Ocean basin, with associated geophysics, in about the style of the Deep Sea Drilling Project with holes typically up to hundreds of meters of penetration, as being of very great importance.

The purpose of this proposal is to refine, by study, the proposition that the Arctic basin can be studied by the drift and drill approach. A suitable drilling platform would be towed and inserted into the icepack north of Bering Strait during the late summer. It would be allowed to freeze in and to engage the transpolar drift, to exit Fram Strait several years later. (Figure 1) Drilling and coring and other Arctic science would be accomplished enroute. An alternative strategy of attempting to locate such a platform where it could drift over specifically selected drilling targets should also be evaluated. In either situation, the drift and drill approach must be considered. The main thrust of this proposed work, however, is to examine the transpolar drift model.

The long-term mean motion of sea ice in the Arctic Ocean (Colony and Thorndike - 1984) is well known, so an initial location could be selected that would have good probability of drifting so as to afford valuable coverage of the arctic basin geology via the transpolar drift. Based on documented drifts, a single transit might reasonably be expected to pass over the westernmost Canada Basin, the Mendeleyev Ridge, the Makarov Basin, the Lomonosov Ridge, the Amundsen Basin, the Arctic Mid-Ocean Ridge and possibly the western extremity of the Nansen Basin. This encompassing list of the major known features of the basin results from the mean direction of ice drift being across the trends of the major features.

Drilling would be accomplished during drifting. Holes could only penetrate as far as the rate of drift would permit without exceeding allowable deviations of the drill pipe. Considering the slow and relatively steady motions involved, satellite navigation should be sufficiently precise to fully determine location and rate of drift for such purposes. The Global Positioning System will be superb for this application; inertial navigation might also be used. Movement of the icepack is somewhat irregular (Colony and Thorndike - 1985), and this movement pauses or slows or loops around on occasion, at which time deeper penetrations could be achieved than during normal drift. Stratigraphic information from more than one hole, each sequentially drilled to the maximum depth of a prior hole and then cored to greater depth, could be combined when the rate of drift does not permit full desired penetration in a single hole. Stratigraphic penetrations of hundreds of meters are clearly feasible in soft or semiconsolidated sediments. Hydraulic piston coring of surface cores could be routinely accomplished. The drill pipe would only need to be retrieved enough to clear the bottom for just drifting at the expected rates; maximum water depths of 14,500 feet are modest and, with no significant vessel movement other than the drift, fatigue life of the drill string will be long. Short-term predictability of drift would be advantageous, not only in starting and stopping drilling, but also to allow other programs to operate when conditions will not be suitable for drilling.

As an initial attempt to examine the scientific effectiveness of drilling in the Deep Sea Drilling Project style, while making the icebound transit of the transpolar drift, data from the Arctic Data Buoy Program (Untersteiner and Thorndike - 1982), using only daily data from the ice movement buoys from the single year 1980, were examined. Roughly 25% of the buoy-days produced net drifts of 0-2 nautical miles per day, which rates of drift can be associated with significant penetrations. For comparison with the Deep Sea Drilling Project, approximately half of Glomar Challenger's total time in over 15 years was in operating on site. The remainder was in port, cruising between sites, and breakdown and weather down-time. About half of the on-site operating time of Challenger included setting the dynamic positioning sound beacons, running drill pipe, all re-entry activities and borehole logging. In the case of the ice-drift model, none of these activities need be counted as part of the time available for drilling and coring; for example, the drill pipe would not necessarily be retrieved between drillings, re-entry would not be practicable, and logging, although desirable, does not seem feasible or economic. Thus a rough comparability can be established, in terms of available proportion of time for drilling and coring, between the Deep Sea Drilling Project - particularly its first 5-6 years - and the visualized arctic drift model, based on the whole-day drift data from 1980. In addition, based on the same sampling of ice-drift data, less than 3% of the buoy-days yielded drift rates during which it would be probably wise to not have a full drill string deployed and drifting. The remaining time could be devoted to shallow holes or surface coring, or to other scientific activities.

Clearly, penetrations and coring, with full stratigraphic coverage, can be achieved to depths of hundreds of meters in soft and semiconsolidated sediments, during the periods of reduced drift rate. Again, for comparison of effectiveness, more than 80% of the Deep Sea Drilling Project's 1092 holes were less than 500 meters and only 3% exceeded 1,000 meters.

The main thoroughfare of the transpolar drift (Figure 1) presents an impressive access to many of the major features of the Arctic basin, but by no means does it offer access to a large proportion of the Arctic Ocean's area or all of its features. Even within the main thoroughfare, it will not be possible to control the detailed or general movement. The strength of the proposition lies in the access that it does give; a series of holes, including as many shallow cores as desired, and a substantial number to depths of hundreds of meters of stratigraphic recovery, would be a remarkable contribution to our knowledge of the arctic and its global implications. Moreover, because of the impossibility of precise site selection and occupancy, a geophysical program will have to be designed to provide the geophysical information for the drilling, but also with the plan that significant sites, as they develop from the drilling, can become benchmarks in post-drilling geophysics that will knit the understanding together. This approach is not alien to prior experience with the Deep Sea Drilling Project, particularly for its earliest years, from which important sites, e.g. site 105, did become just such benchmarks for post-drilling geophysical studies. The conceptual development of an attendant geophysical program is also part of this proposal.

For the drift and drill concept, icebreaker support would not necessarily be required except probably for initial insertion into the icepack and also to meet the platform and take it in tow as it exits the Fram Strait area, and possibly also - most likely late summer of the year following insertion - to adjust the drift trajectory to assure proper engagement of the transpolar drift.

Present circumstance within the world oil industry, with many drilling platforms idle or being retired, suggests that a cost-effective approach to such a drilling problem could exist. As conditions are, a suitable drilling platform could probably be available at extreme discount. As an example, one particularly attractive possibility seems available; this is the "Glomar Beaufort Sea I", the Concrete Island Drilling System (CIDS). It is currently, and for the foreseeable future, idle and quite literally "on the shelf" of the Beaufort Sea north of Alaska. It is designed to float, as well as be ballasted down in shallow water for its normal oil drilling mode. Its main ice-resistant structural member is a giant, honeycombed concrete brick, designed to withstand both compressive forces of ice and also shearing loads when the unit is on the bottom. It is fully engineered to withstand the arctic environment; steam-heated derrick and rig floor, fuel tanks warmed with circulating hot ethylene glycol, etc. It is currently configured to be totally self-sufficient in fuel, water and consumables, in the full oil drilling mode, for almost a year. There is little doubt that it could be made similarly self-sufficient, in terms of fuel, water and major equipment and supplies, for the complete drift, at the visualized levels of activity. It is classified by the American Bureau of Shipping as an A-1 Caisson drilling unit, and is completely certified by the United States Coast Guard.

Within this whole context, certain specific studies need to be made, to refine and validate the entire concept and to properly present it for evaluation. These studies, which present the actual proposed work in this proposal, have been restricted to the fundamental "make or break" issues and certain essential conceptual design matters. Opportunities for improving effectiveness, such as the design of a longer Hydraulic Piston Corer to enhance surface coring, or the manipulation of the drill pipe ahead of the expected drift or adjusting the catenary of the drill string, to achieve longer drilling times, would not be engaged until these studies demonstrate the fundamental strength of the proposition within essentially existing capability.

The surface presence of a major platform could also afford many opportunities for a wide range of arctic research. A comprehensive outline of many possible programs is assembled in a report by the Polar Research Board of the National Academy of Sciences, 1976.

A major platform could make a contribution to the logistics of work in the central arctic, rather than only place demands on the logistics infrastructure. The experience gained from the visualized arctic work would be valuable in establishing a more permanent surface presence in the arctic.

PROPOSED WORK

I. Analysis of ice motion.

Objective - To establish a statistical data base of ice movement, to analyze the data base to determine a suitable histogram of available drilling days, and to evaluate the prospects for a short-term predictive capability for ice movements.

Discussion

A) Historical statistics.

The motion of the ice pack will totally determine both the long-term trajectory and the short-term rates and directions of a drilling platform locked in the ice.

The long-term trajectory will determine the major geologic features over which the vessel will pass. Considerable effort has already gone into studying the long-term mean flow of the ice, and into evaluating probabilities of rate and direction of the long-term drift. This knowledge is important in selecting the initial point of insertion into the ice pack in order to have the highest probability of engaging the transpolar drift, and in evaluating any developing need to adjust the trajectory. For the purposes of the visualized program and for this proposed work, this historical aspect is considered complete.

The short-term rates and directions of the ice pack have been far less examined. It is this short-term time scale, over a period of hours to several days, that will have the greatest influence on the drilling operations. The essential issue is to evaluate, from historical information taken along the expected drift track, how frequently the ice pack drift stalls or slows sufficiently to afford drilling opportunities. It would also be desirable to know what proportion of time drift is too rapid to have the drill string deployed, either for readiness to drill or for hydraulic piston coring.

General impressions certainly confirm that the slower rates of drift afford drilling opportunities. The purpose of this proposed work is to confirm that this is so, and to provide a basis to evaluate the overall probable effectiveness of the visualized program in drilling.

The data to be used are from the Arctic Data Buoy Program at the Polar Science Centre, Applied Physics Laboratory, University of Washington. Final data sets are archived at World Data Center A - Glaciology in Boulder, Colorado. Analysis of the historic data is intended to give statistical information concerning what may be expected in future drift.

The data on ice buoy location is a daily time series, as archived at Boulder, and individual satellite pass and three-hour time series, still retained at Seattle. This data applies for each of a number of buoys, some of which will be more significant than others, because they were deployed in the vicinity of the main thoroughfare of the transpolar drift.

Initially, a simple extraction, listing the great circle distance between 24-hour positions, can be created, including direction of net 24-hour drift. Inspection will show how many instances net drift rates do not exceed values associated with particular modes of drilling and coring. Also, inspection of the original data retained at Seattle, for periods identified as drilling opportunities, might offer some insight as to whether or not significant excursions might be buried inside daily net short drifts. Information from other arctic operations can also be examined.

B) Evaluation of short-term predictive capability.

The next step, which is longer term and more difficult, should be to develop an element of predictability of short-term ice drift, again with emphasis along the trajectory of the transpolar drift. Its purpose would be to anticipate times of suitable drift rate, including onset, duration and cessation. An ancillary purpose would be to allow more effective use of the platform for other studies, some of which may be operationally incompatible with drilling and coring or even having the drill string deployed; prediction of conditions that will not be suitable for drilling activities could assure more time for such other programs.

The more lead time in prediction, the better, particularly regarding the predicted onset of conditions favorable to significant drilling. Even one hour's lead time, and clearly several hours, would be of great value. This is equally true in prediction of renewal of drift and need to pull out of the hole. The predictive capability should be viewed as program enhancement and not as replacing accurate knowledge of drift of the drilling platform during operations.

The work here proposed is restricted to an evaluation of the prospects for having such a predictive capability. The study would be based in historical ice buoy data and associated meteorological data.

Such a study should have two elements, an historical approach and a real-time practice approach.

1) Historical.

Identify, from the study of historical statistics, desirable looking intervals that, in retrospect, would have been considered drilling opportunities for particular locations, and also for particular modes of drilling operations.

a) Reconstruct the wind patterns based on surface wind data, leading up to and prevailing during the drilling opportunity, for the area of the buoy being considered; also, reconstruct those associated with the termination of the drilling opportunity. Reconstruct, if necessary, an after-the-fact prediction of the developing wind and weather patterns, from the atmospheric data that would have been available.

b) Create an after-the-fact prediction of ice movement. For the more recent past, such reconstruction may not be necessary; Fleet Numerical Oceanography Center at Monterey, California has been creating daily ice forecasts, based on several models.

c) Compare predictions to actual ice movements.

d) Examine movement of nearby ice drift buoys and surface wind sensors to determine coherence of movement patterns, response to approaching and changing wind conditions, extent of transmission of movement by the ice pack itself, and characteristic delay times of response to various changes in conditions.

e) Evaluate and develop a strategy that will best serve the programmatic needs.

2) Real-time observation and practice prediction.

The purpose would be to determine the effectiveness of the prediction strategy adopted.

a) Pick several ice buoys along the transpolar drift to represent several locations of the drilling platform.

b) Using atmospheric data, including known winds, predict winds and then ice drift direction and rate.

c) Similarly, examine movement of nearby ice drift buoys for added elements of anticipation.

d) Compare these real-time predictions with actual movements of the ice buoys selected to represent the drilling platform.

It seems probable that the short-term predictive information and capability will naturally compartmentalize into two categories with differing time scales, both of significance to the drilling and coring.

The first, having a time scale of a day to several days, will be from derived information, as the forecasting of developing weather patterns and wind fields from meteorological data. This is easily visualized as a service function to the drilling platform, being performed by one of the established centers on shore.

The second, having a time scale of an hour to several hours, will be from directly measured approaching changes in surface wind and ice pack movement, heralding the specific arrival of the weather patterns, with measurements being made in the large vicinity of the drilling platform. Measured approaching wind and ice drift conditions may well be so specific and significant, for the immediate operational schedule, that a local network of telemetering observation stations, received and evaluated directly on the drilling platform, could well be an important requirement of the operational drilling and drifting program.

C) Ice analysis coordination.

This ice analysis work is visualized as being accomplished in close cooperation with organizations already specializing in specific aspects, but being focused and coordinated by the proposed activity to bear on the subject of the drifting platform and associated drilling activities. As mentioned above, the Arctic Data Buoy Program at the Polar Science Centre, Applied Physics Laboratory, University of Washington, and the Fleet Numerical Oceanography Center, Monterey, California, and the World Data Center A - Glaciology in Boulder, Colorado, are obvious examples of the organizations that should be involved. Estimates include costs for anticipated add-on activities within such organizations. No added specialized or directed field work is entertained in this work, although it is possible that some scheduled current field work might be modified or tailored to be responsive to the specific needs addressed in these considerations.

Statement of Work

No commercial study is visualized. Organize relationships and provide for payment of certain costs in the accessing, extraction, utilization, and study of data.

II. Evaluation of potential logistics contribution to be expected from a major platform.

Objective - To provide a master program planning schedule and associated program budgetary costs, and to conduct a top level hazards analysis and develop appropriate remedies.

Discussion

Having a major platform, including its drilling capabilities and requirements, but also having important excess capability in terms of living accommodations, storage, helicopter support, aviation fuel, repair facilities and loading of major equipment, offers an important potential contribution to the whole logistic support infrastructure for arctic work. This is in important distinction to activities that require continued and active support for all consumables, and thus only place demands on the logistics infrastructure.

In considering a major platform, the purpose of this study will be to entertain the very real possibility that such a platform could be completely self-sufficient for a period approaching four years, in terms of all major supplies and consumables, including fuel for drilling, living, aviation and vehicular support, drilling and coring equipment and expendables, stable foods, lubricants, essential spare parts and components, housekeeping and shipkeeping needs, and all other foreseeable but nonperishable needs.

Ideally, this approach will come close to reducing the continuing logistic support to requirements for incoming fresh food, fresh people and fresh medicinals, and returning people, samples and data. The one major exception to this ideal should be the new or improved scientific program; evaluation of the reasonable needs and provision for this absolutely required flexibility in a scientific program is an important part of careful planning.

The work proposed will evaluate the major needs and categories of needs, and view various solutions. It will emphasize consideration of those elements having load determining weights and volumes, and specific storage requirements. The work will not produce any detailed logistic or scientific plan, but rather it will provide the basis for more careful planning in these regards, after the big needs and opportunities associated with a major platform have been examined and placed in safe and acceptable solution(s).

Cost estimates of this task are considered within several sub-tasks. The overall objectives are to project needs, to bracket capability, to ensure feasibility and safety, and to estimate costs. Supply requirements will be initially engaged by consideration of a 1400-day voyage. Load-determining weights and volumes, major cost items and logistic support equipment will be given primary attention. These requirements will be based in a generalized operational scenario, including a reasonable manning model for operational needs and the scientific drilling and geophysical programs. Safety requirements will address those major hazards that could obviously have major programmatic implications, and potential solutions will be prepared. Issues such as operational and aviation fuel storage and transfer, ice and structure interaction, ice defense, general fire safety, personnel trauma, treatment and evacuation, including aspects peculiar to exposure and very cold weather, will be addressed. Layouts and arrangements will be considered, based on major categories of requirements, and consider various strategies, leading to best capability and safety. Naval architecture considerations will review broad elements of loads and stability, damaged stability, ballasting, restoring moments relative to strength of ice, and other subjects relative to a floating structure in a partly solid medium. For projected operational cost estimating, a master operational scenario will be roughly created. Overall logistic opportunities and capabilities will be evaluated relative to such a model, as a baseline.

Statement of Work

The following will serve as a guide in the preparation of Statement of Work for commercial study of this task:

1. Prepare quantified lists of major supplies, spares, drilling consumables, extra equipment, manning and other categories of special operational logistics that will significantly affect weight, space, and/or cost. Provide appropriate assumptions, rationale, and calculations as documentation.

2. Prepare a top level critical hazards study to address any potential or perceived operational hazards, the potential extent and impact of the hazard, and a generalized solution or plan to eliminate, mitigate or cope with the hazard. This task will address only those hazards with potentially severe impact on the safety of the personnel, the vessel, or the environment. Any required hardware additions with significant cost impacts will be quantitatively described.

3. Provide general arrangement-type drawings of the various spaces, volumes, machinery, and storage areas for the materials defined in subtask 1 of this task; with specific consideration of proximity, access, phased needs, long duration and arctic conditions.

4. Utilizing the weight inputs from subtasks 1, 2 and 3, review and report on the draft, intact stability, damaged stability, and ballast requirements for a caisson-type vessel.

5. Working with the program management team, generate a program work breakdown structure (WBS) that will identify and account for all major cost elements of the drift program, including both capital and expense items. Generate a master program schedule and provide time-phased cost estimates to complete an overall program expenditure budget. Furnish documentation of all assumptions and calculations in an itemized format.

III. Design of a smooth and flexible bottomhole drilling assembly, and analysis of the drill string for the visualized mode of operations.

Objective - To confirm the technical feasibility, to provide conceptual designs, and to estimate costs for the "drilling while drifting" mode of taking seabed cores; stresses and deflections of the bottom hole assembly and pipe will be analyzed and topside pipe and core barrel handling will be studied.

Discussion

The bottomhole assembly is that portion of the drill string at the very bottom end, below the long length of standard diameter drill pipe. It includes a) heavy wall drill pipe and drill collars, which provide weight to keep the drill pipe in tension and apply pressure to the bit, b) bumper subs, which are splined joints that will transfer torque but telescope to allow the ship and drill pipe to heave up and down and still keep uniform pressure on the drill bit, c) the outer core barrel in which the retrievable inner core barrel seats, and d) the drill bit. The assembly would typically weigh 40,000 lbs. in sea water.

In arctic drilling from within the ice pack, heave will be virtually nonexistent; thus, a major reason for using bumper subs will not exist. The bumper subs were historically one of the main weak points in the typical bottomhole assembly.

Another characteristic weak point was at threaded joints, particularly at joints that corresponded to abrupt changes in cross section strength and flexibility. Additionally, failure could occur in the regular drill pipe, just above the bottomhole assembly, again at a point of major change in strength and stiffness.

The bottomhole drilling assemblies, of the Deep Sea Drilling Project and currently the Ocean Drilling Program, which were assembled largely from available components made to American Petroleum Institute standards for oil field work, come encouragingly close in desired capability. Other than adopting, fairly early in the Deep Sea Drilling Project, a structurally more balanced pin and box (male and female screwed connection) for the drill collar threaded joints to be more suitable when standing freely and unsupported by the drill hole, no particular attention was paid to lateral forces.

During the drilling and taking of seabed cores while the vessel is drifting with the ice pack, the drill pipe tends to be laterally dragged from the hole. Sufficient weight must be provided at the extreme end of the pipe to overcome sidewall friction and ensure that the pipe will continue to proceed into the hole as more and more pipe is payed out. The makeup of the pipe at the extreme end of the string, the bottom hole assembly (BHA), must possess the proper combination of weight, strength, and flexibility to be able to withstand the resulting stresses.

On a number of occasions during the 15-year operational life of the Deep Sea Drilling Project and the Glomar Challenger, the drill string was simply dragged out of the hole, as the result of some malfunction of the dynamic positioning system or being pushed off station by heavy weather. On a number of these occasions, the drill string suffered no immediately apparent damage. When damage did occur, the damage was always sustained in the vulnerable components, in the threaded joints, or in the drill pipe immediately above the assembly.

These circumstances suggest that modest design improvements could significantly increase the chances for the drill string to survive being dragged out of the drill hole. The advantages inherent in such improvement are easily visualized in the context of the drift and drill approach.

The objective of the redesign of the BHA would be to eliminate these weak points. In concept, the final design will embody a full smooth taper, may eliminate some threaded connections and assure fully balanced connections where they are retained, and also consider introducing flexibility where needed. External roughnesses and shoulders would be minimized. The smooth taper, in shape and stiffness, would carry through to the drill pipe itself. The radius of acceptable curvature, while coring, must be such that the retrievable inner core barrel can pass, although a flexible inner barrel could be considered. Buoyancy for the drill pipe, clear of planned penetrations, might be considered to adjust the catenary of the suspended drill string while constrained at its lower and upper ends, and concentration of mass as near the bottom end as possible would seem advantageous. Proper materials, heat treat and inspection requirements are an intrinsic part of design.

Although not a part of this proposed work, construction of a full-size BHA and realistic field testing should be considered integral with the design, and would be proposed following creation of the acceptable design concept(s).

Testing is visualized with increasing degrees of realism. Certain aspects of integrity and continuity could be tested in air, but would omit the buoyancy of water. The most realistic test will be in actual drilling conditions duplicating the Arctic drift. Such tests will both test the configuration with regard to expected conditions, and also help define acceptable limits of operational conditions and activities.

It is envisioned that the most straightforward testing will be from a dynamically positioned drill ship, ideally the Ocean Drilling Program drill ship. Under these conditions, programmed rates of offset with the dynamic positioning can duplicate conditions of ice pack drift, and with the excellent heave compensation available the tests will very nearly approximate the heave-free conditions while frozen into the ice pack. Testing could be accomplished almost anywhere in the open ocean in comparable water depths and with similar common sediments. Even the water temperatures in the deeper waters will be very similar, the Arctic Ocean being only several degrees colder, but effectively the same for matters like brittleness and behavior of lubricants.

The proposed study will also include analysis of the whole drill string, including its support and constraint at the drilling platform. The Deep Sea Drilling Project undertook several drill string analyses of increasing sophistication and increasing attention to dynamic loading. However, the combined maximum water depth plus expected penetration in the Arctic Ocean is only about two-thirds the maximum length of drill string used by Glomar Challenger. Hence, this study will emphasize the lateral forces from drift and apparent current, reverse bending from rotation while curved, sidewall friction, and pullout loads rather than the effects of dynamic and static gravitational loading.

The conceptual design work and analyses would be accomplished under commercial subcontract with a group or firm knowledgeable of drilling and coring and familiar with the style of work accomplished by the Deep Sea Drilling Project and the Ocean Drilling Program. Cooperative involvement of the engineering and operations groups of the Ocean Drilling Program would be desirable for possible mutual benefit in knowledge and to facilitate operational testing at a future time.

Cost estimates are based on utilizing the most up-to-date technology and standardized rig and downhole equipment to accommodate the unique "drilling while drifting" mode of operation. The objective of the task is to develop a realistic and feasible solution that will enable rewarding coring activities to take place during a reasonable proportion of days during the drift. If this objective can be established, then the entire drilling program is feasible; any subsequent improvements in design or operation would only serve to make the program more efficient.

It will be necessary to develop an analytical model of the drill string, so that deflected shape, dynamic characteristics and resulting stresses and fatigue can be analyzed. It will be necessary to ensure adequate weight at the end of the drill string while maintaining flexibility, as well as avoid abrupt changes in section modulus.

Topside pipe handling for S-135 steel pipe, and rotation equipment will be reviewed. Special attention will be given to core barrel handling, because of the large time-dividends potentially achievable.

Deliverables will include conceptual designs and equipment selection, as well as cost estimates based in current quotations. Also included will be an evaluation of programmatic effectiveness, as related to these specific considerations of drilling and coring. Specifically excluded is any construction or physical testing, or radically innovative design concepts. The latter may receive some intellectual attention, but are not part of this proposed task.

Statement of Work

The following will serve as a guide in the preparation of a Statement of Work for commercial study of this task:

1. Prepare an engineering report addressing the salient items of the above task discussion.

2. Construct a computerized math model of the drill string in sufficient detail to study the deflected shape, dynamic characteristics, and stresses in the pipe and components. Detailed computer analyses of individual components such as threaded joints and connectors will not be a part of this study.

3. Analyze various BHA/drill string makeups and operational scenarios to confirm safe stress levels.

4. Design an integrated bottomhole assembly and drill string, utilizing the inputs of various suppliers, consultants and experts, and confirmed by suitable analyses.

5. Review the topside pipe handling system for working with the S-135 pipe string, the installation of a top drive or power swivel, and the handling of core barrels. Provide suitable conceptual layout drawings, engineering discussions, operational time-line analyses, and preliminary structural analyses as required to substantiate recommended modifications.

6. Provide discussion and cost estimate of the follow-on engineering and testing necessary to confirm the conceptual work of this task.

IV. Create design concept for a water intake for drilling circulation.

Objective - To provide a conceptual design and estimated cost for a variable depth sea suction.

Discussion

During the summer melt season, water of low salinity can accumulate beneath the ice pack because of the melting of sea ice from which the salt has been previously excluded, the brines having drained during earlier freezing periods or been flushed during earlier meltings. This layer of buoyant, lower salinity melt-water can collect just beneath the ice cover and if taken into the pump suction, might freeze in the drill pipe or hole when pumped to depth, where temperatures may be as low as -1.5° C.

To avoid this problem, a water intake should be designed to receive water from beneath the lower salinity layer. In the most simple concept, this would be an extendable pipe or hose hanging beneath the hull to suitable depth. Such a device would only be needed, for the reasons stated above, during times when the ice is melting; however, it might also be of value in avoiding ice-clogging of hull-mounted intakes and in avoiding carrying pieces of ice through the circulating pumps.

The proper design of such an intake will require evaluation of several factors:

A. Required maximum depth to assure receiving water of sufficient salinity to avoid freezing at depth. A degree of variability of the intake depth should be a requirement of the design.

B. A suitable combination of rigidity and flexibility that will avoid collapsing with pump suction, will yield with an ice impact and yet remain essentially vertical even when drifting at approximately one knot; the proper routing and deployment technique.

C. Need for an in-line reservoir to receive water from the intake by means of a separate intake pump, to secondarily feed directly to the drilling circulation system. Such a reservoir could serve as an ice crystal separator or as a warming stage, particularly if water on the verge of supercooled is to be pumped.

D. Need for, and devise as necessary, a temperature and salinity monitor for intake water.

The broad conceptual thinking would not be specific to any single drilling vessel or platform. Any specific design concept would be with regard to a class of possible platforms, e.g. single hull vessel, mobile caisson platform, etc. The work would be accomplished by commercial subcontract with a group or firm knowledgeable of drilling platforms and arctic operations, in response to a statement of work that sets forth basic environmental knowledge and concerns. Adaptation of commercially available components would be required wherever reasonable.

Cost estimates are based on carrying the study only to deliverables that include working conceptual design drawings, preliminary structural analysis, a discussion of options and rationale, and rough cost estimates. Environmental parameters and specifications will be developed inhouse.

Statement of Work

The following will serve as a guide in the preparation of a Statement of Work for commercial study of this task:

1. Prepare an engineering report addressing the above items A through D.

2. Prepare conceptual design drawings of the required intake and handling system sufficient to estimate R.O.M. costs.

3. Provide preliminary structural analysis to confirm conceptual sizing and costs.

4. Generate cost estimate.

V. Design concept for an attendant geophysical program.

Objective - To provide the conceptual design of a meaningful real-time geophysical program that will predict seabed conditions to be encountered and ensure safety of the drilling program.

Discussion

An attendant geophysical program will be an essential and integral part of the drilling program. It will serve the same purpose as the now classical site survey, to the drilling. In effect, the site survey program must go along with the drift of the drilling platform, because the details of the drift cannot be predicted long in advance.

The purpose of this study will be to create a design for such a geophysical program. Such a program should provide the necessary operational information, such as anticipated thickness of sediment layers, structural attitude, and physiographic province and general sedimentary style to be anticipated. It should provide information bearing on safety of drilling with regard to possible entrapment of hydrocarbons, such as structural closure, faulting, possible evidence of depth to the base of any hydrates of natural gas, and unconformities and structures at depth. It should provide the information, along with the drilling, for the scientific interpretation of the structural, sedimentologic, and tectonic history of the region. It might also take advantage of special circumstances, such as the relatively rigid ice cover, that might make certain observations uniquely feasible.

Because the drift can go in any direction, although having a long-term probable direction, the program should be capable of providing information significant to the drilling, sufficiently in advance to allow for its first interpretation on the drilling platform, no matter what the short-term direction of drift may be.

To suggest, for the purposes of this proposal, the general feasibility of such a program, it is possible to outline some salient features that such a program might entail.

* An array of hydrophones or sonobuoys, linked to the ship by hard wire or radio, and deployed through the ice, would symmetrically surround the drilling platform. The effective radial distance from the drilling platform would be the equivalent of about one to several days common drift distance. A common sound source, probably an air gun, would be employed. Drift rates are slow, so even at a very slow pulse repetition rate, sectors of the array could be sequentially or simultaneously recorded, giving a set of continuous recordings, each with its directionality. The pulse repetition rate could be linked to drift rate or distance traversed. Although direction of drift can change, the ice pack does not rotate significantly, thus the directionality of the array should remain relatively stable for long

periods. Range between sensors could be internally calibrated as needed. The array could be established, maintained and repaired with vehicular or helicopter support. The multiplicity of the array offers some redundancy, in case of partial failure.

* Opposite ends of the array or purposeful extensions, or even a satellite array, beyond that needed for the site survey function, could give substantial aperture for deep penetration reflection or refraction study.

* A hull-mounted sub-bottom profiler would give information directly beneath the drilling platform, particularly in the detail of the upper 100-200 meters of sediment.

* Geophysical work could be linked to the drilling program only by the potential logistic support from the platform, such as refraction lines across major geological features within reach of the drift track.

The study would involve the assembly of and working with a group of persons knowledgeable in the operational, safety and geophysical needs of scientific ocean drilling, seismic profiling, in seismic equipment, in sonobuoy capabilities and potentials, in special purpose and regional geophysical needs, in the characteristics of the arctic ice pack, in deploying instruments through the ice pack, and in logistic support for work on the ice.

With this group, a feasible, operationally sound and scientifically rewarding geophysical program would be designed. Initial needs, durability, and continuing maintenance, repair and replacement needs would be estimated, and the program would be placed in the context of levels of logistic support reasonably available from a drilling platform. Environmental and other operational concerns will be taken into consideration.

It is important to make an initial evaluation of the demands of the essential and the desirable geophysical work, because the geophysical effort is important, but also open-ended. When added to the specific platform and drilling needs and immediately associated scientific requirements, in personnel, storage, and logistic effort, the information will help provide a real basis to evaluate potential platforms in terms of the total scientific drilling program and also in terms of available capability for other important scientific arctic work.

Statement of Work

Organize advisory group specific to the visualized arctic geophysical program, planning it to be complementary to advisory groups already in operation. Support and conduct meeting(s), prepare report on program, evaluate and interface with other aspects of planning as set forth in this proposal.

References

Colony, R. and Thorndike, A.S., 1984. An Estimate of the Mean Field of Arctic Sea Ice Motion. Journal of Geophysical Research, 89:10,623-10,629, Nov. 1984.

Colony, R. and Thorndike, A.S., 1985. Sea Ice Motion as a Drunkard's Walk. Journal of Geophysical Research, 90:965-974, Jan. 1985.

Untersteiner, N. and Thorndike, A.S., 1982. Arctic Data Buoy Program. Polar Record, 21:127-135.

Polar Research Board, 1976. Scientific Plan for the proposed Nansen Drift Station.

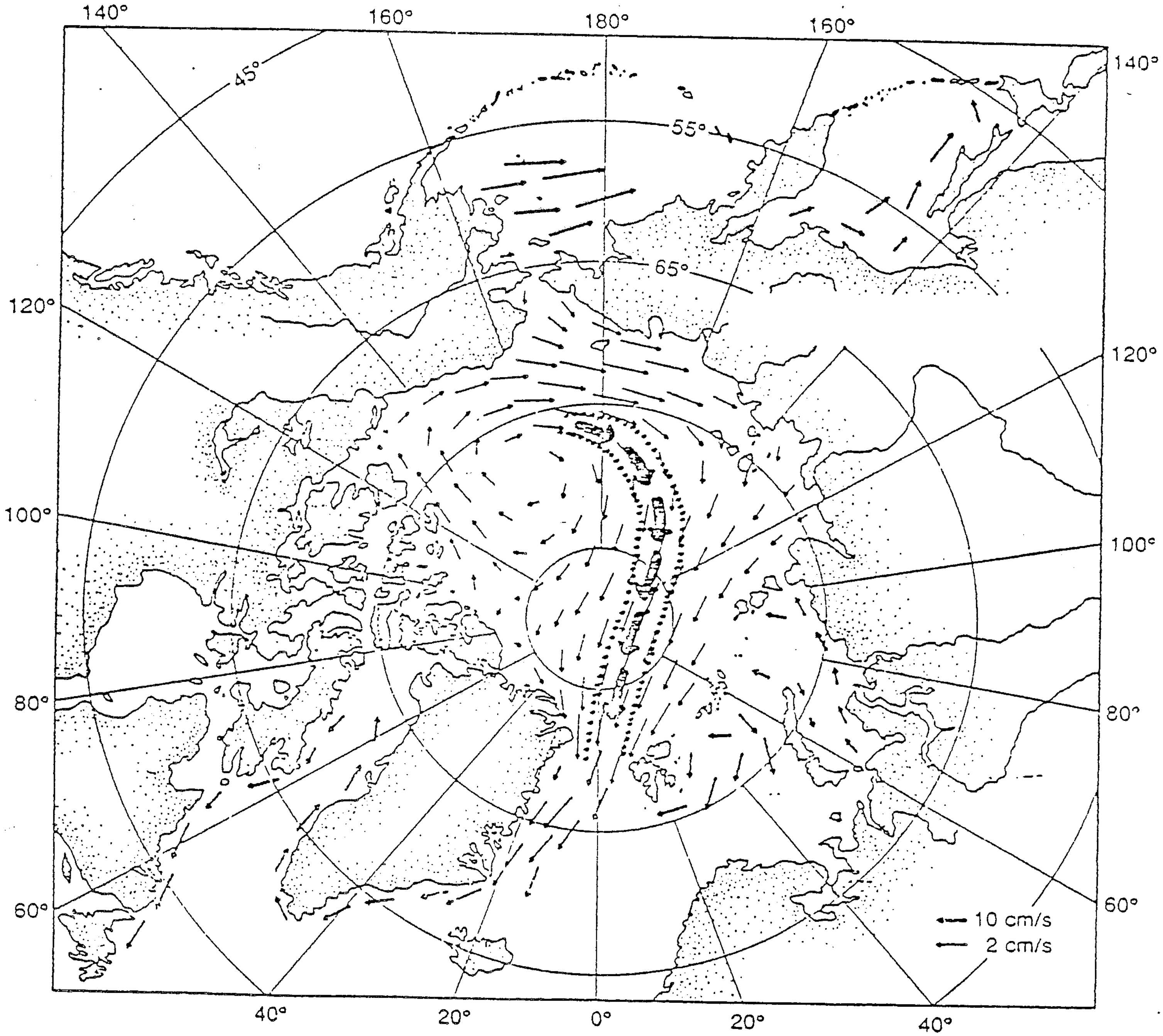
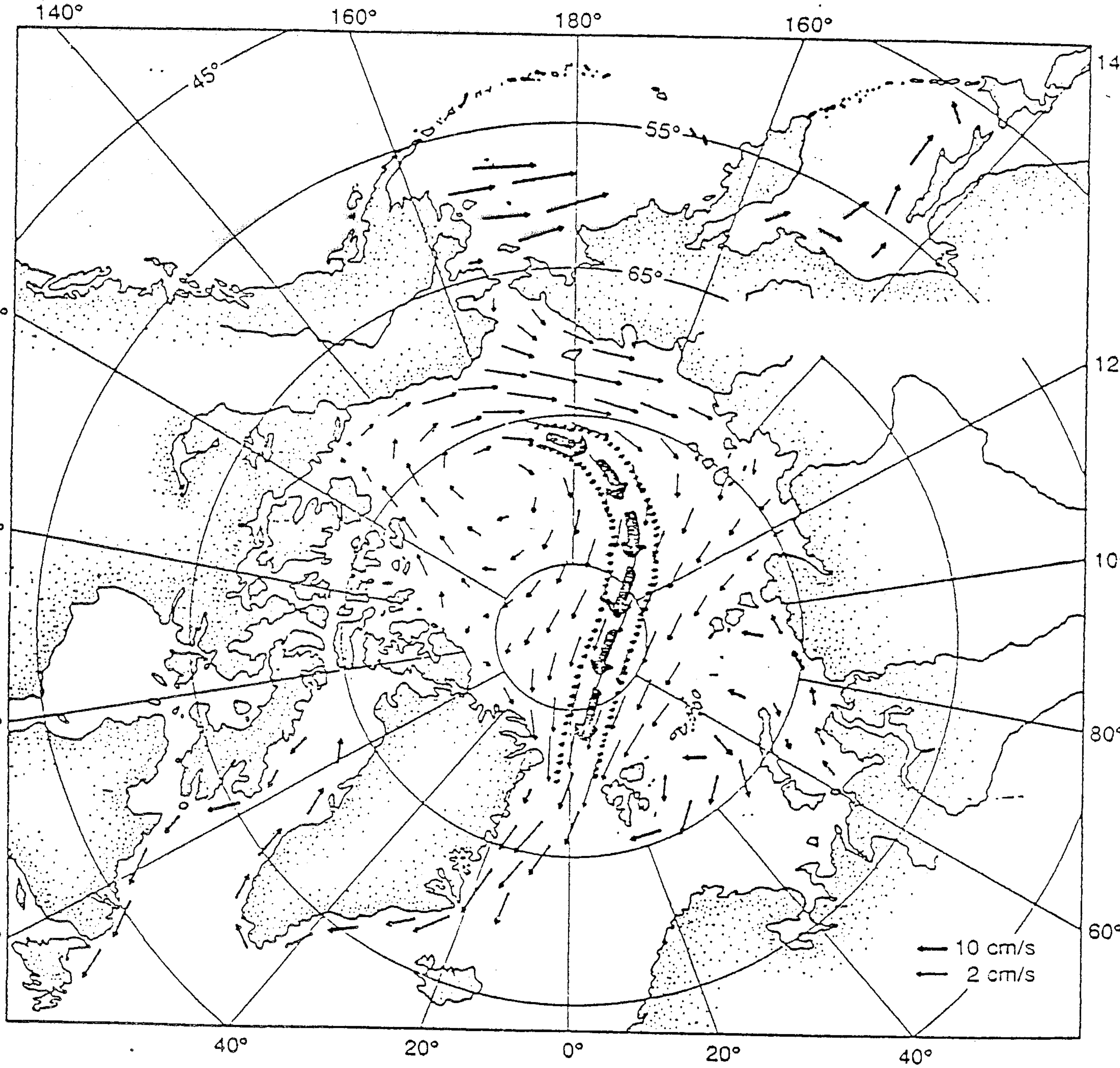


FIGURE 1.
Long-term mean motion of sea ice as analyzed from direct observations. Note the scale change from the Central Basin to the marginal seas. The overlay delineates the 1000-meter depth contour, the average minimum ice extent, and the average maximum ice extent. (Untersteiner - personal communication).



Long-term mean motion of sea ice as analyzed from direct observations. Note the scale change from the Central Basin to the marginal seas. The overlay delineates the 1000-meter depth contour, the average minimum ice extent, and the average maximum ice extent.

INITIAL EVALUATION - DRIFT RATES OF ICEPACK

* MAXIMUM WATER DEPTH ~4.5 KM. ~ 14,500 FT.
* DEPTH RANGE OF MAIN DRILLING ACTIVIES 5,000-14,500 FT.
* DRILL STRING LENGTHS 5,000 - 15,000$^+$ FT.
* BASED ON GLOMAR CHALLENGER OPERATIONAL EXPERIENCE
* FOR SIMPLICITY:

CONSIDER 5000 FT 10,000 FT 15,000 FT.

DRILLING & CORING TIMES *

	5000 FT. (~1.5 KM.)		10,000 FT. (~ 3.0 KM.)	15,000 FT. (~ 4.5 KM.)
CORING CYCLE W/O ROTATING TIME	45 MIN.		60 MIN.	80 MIN.
FOR DEPTHS OF PENETRATION:				
100 METERS	11 HRS.	10 x 60 MIN = 10 HRS. + 2 HRS. =	12 HRS.	15 HRS.
200 METERS	22 HRS.	20 x 60 = 20 HRS. + 4 HRS. =	24 HRS.	30 HRS.
300 METERS	33 HRS.	(etc.) 6 HRS.	36 HRS.	45 HRS.
400 METERS	44 HRS.	8 HRS.	48 HRS.	60 HRS.

* ASSUME DRILL STRING READY TO SPUD
CONTINUOUS CORING IN SINGLE HOLE

STATIONKEEPING TOLERANCES AND DRIFT

1. ORIGINAL G/C SPECIFICATIONS 5% OF WATER DEPTH
   ALSO CONSIDER 10% OF WATER DEPTH

FOR 10,000 FT. W.D.	5% = 500 FT.	10% : 1,000 FT
TO DRIFT IN 12 HRS.	0.16 N.M./DAY	0.32 N.M./DAY
" 24 HRS	0.08 N.M./DAY	0.16 N.M./DAY

FOR 15,000 FT W.D.	5% = 500 FT	10% : 1,500 FT
TO DRIFT IN 12 HRS	0.25 N.M./DAY	0.5 N.M./DAY
" 24 HRS	0.125 N.M./DAY	0.25 N.M./DAY

CONCLUSION :

UP TO 0.5 NAUTICAL MILE PER DAY IS THE DOMAIN OF SIGNIFICANT, CONTINUOUSLY CORED HOLES

NOTE :

DEEPER WATER MAKES EASIER AT SAME DRIFT RATES

TOLERANCES & DRIFT

EXAMPLE AT 10,000 FT. W.D.

1 N.M./DAY (250 FT./HR.) 5% (500 FT.) → 2 HRS. 10% (1000 FT.) → 4 HRS.

2 N.M./DAY (500 FT./HR.) 5% (500 FT.) → 1 HR. 10% (1000 FT.) → 2 HRS.

AT 1 N.M./DAY, STILL CONTINUOUS CORING TO ~ 30-40 METERS
BUT AT 2 N.M./DAY, ONLY TIME FOR ~ 20 METERS

CONCLUSION:

1 NAUTICAL MILE/DAY IS MAXIMUM DRIFT RATE FOR REALISTIC SINGLE HOLES WITH CONTINUOUS CORING.

EVALUATION OF EXPERIENCE IN BIT MOTION

(RELATIVE TO EXPECTED DRIFT RATES AND SPUDDING)

DATA FROM GLOMAR CHALLENGER'S RE-ENTRY TRIALS 1970

* TYPICAL DRIFT FROM DYNAMIC POSITIONING OSCILLATIONS & HUNTING

50 - 200 FT / 10 MINUTES

7,200 FT./DAY	28,800 FT./DAY
1.2 N.M./DAY	4.8 N.M./DAY
.08 FT./SECOND	.33 FT./SECOND

* FIGURE "8" PATTERN TYPICAL

* DURING SEA STATE 5, DURING OPERATIONAL RE-ENTRY TRIALS MAXIMUN BIT MOTION ESTIMATED AT 1 FT./SECOND, AT FIGURE "8" CROSSINGS

1. FT/SECOND
86,400 FT/DAY
14.4 N.M./DAY

CONCLUSION: TYPICAL RATES OF DRIFT FOR THE BIT, ONLY FROM NORMAL DYNAMIC POSITIONING, WERE CONSIDERED. AT NO TIME, DURING NORMAL DYMAMIC POSITIONG, WOULD SPUDDING HAVE BEEN CONSIDERED ANYTHING BUT ROUTINELY POSSIBLE.

NO CONCLUSION: REGARDING FULLY DEVELOPED INCLINATION FROM DRAG ON PIPE

MAXIMUM DRIFT RATE TO STREAM PIPE

1. GLOMAR CHALLENGER OPERATED IN UPTO 3-4 KTS. CURRENTS
   SURFACE CURRENTS - ONLY UPPER SEVERAL HUNDRED METERS
   ARBITRARILY DEGRADE BY FACTOR OF 10

   YIELDS 0.3 - 0.4 KTS. EQUIVALENT IN FULL WATER COLUMN

   0.3 KTS = 7.2 N.M./DAY
   0.4 KTS = 9.6 N.M./DAY

2. G/C - DSPP POLICY - MOVE SHIP WITH PIPE STREAMING:
   NOT TO EXCEED 1 KT.

   1.0 KT = 24 N.M./DAY

3. CALCULATION BASED ON 10° ANGLE OF GUIDE HORN - 2.67 FT./SEC
   (KENNECOT EXPLORATION, INC.)

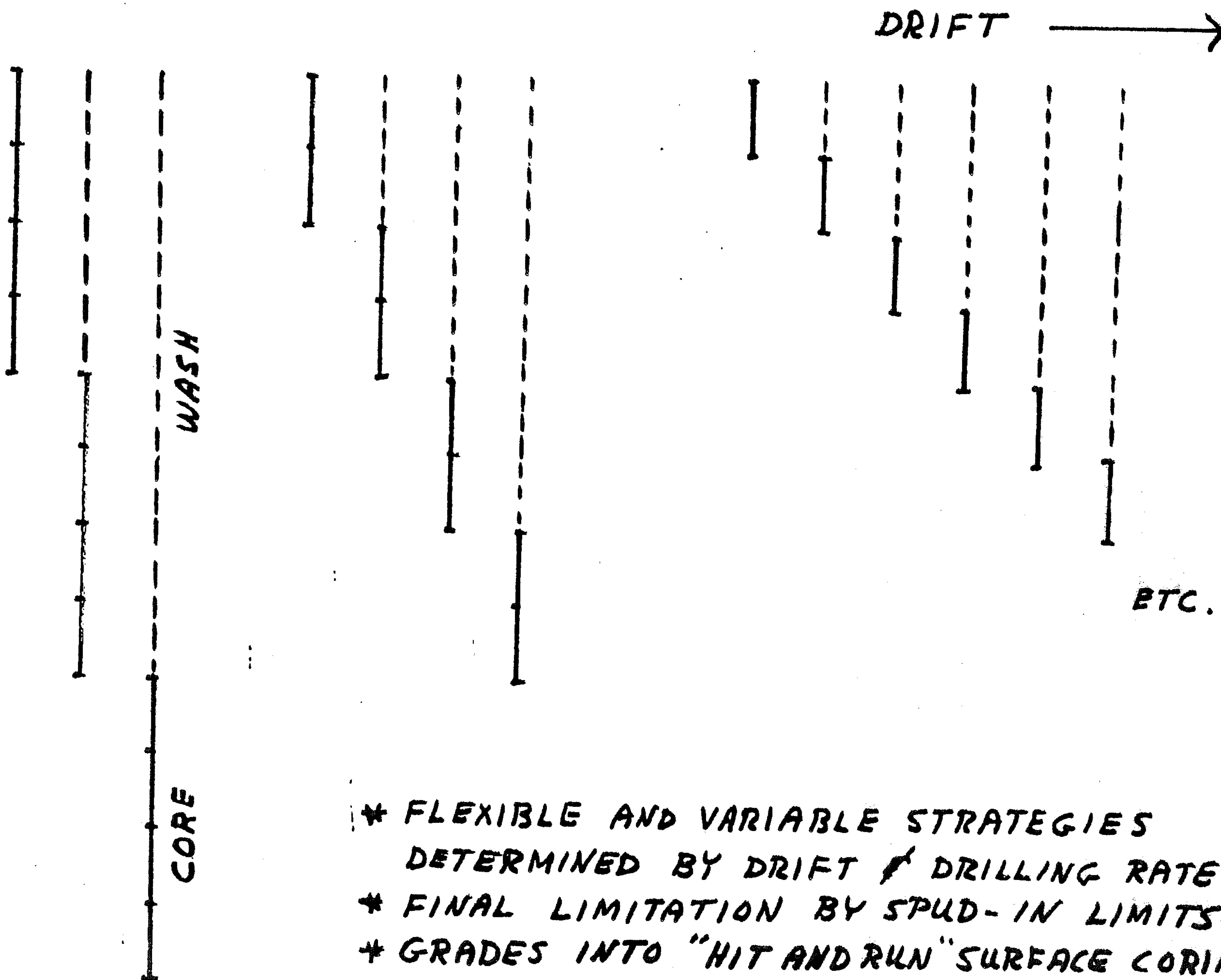
   1.58 KTS. = 37.9 N.M./DAY

   (NOT CONSERVATIVE - NO ALLOWANCE FOR ROLL AND PITCH - BUT PERHAPS APPROPRIATE TO SHIP LOCKED IN ICE)

ADOPT: 10 N.M./DAY

CONSERVATIVE - NEAR LOWEST OF CALCULATIONS

MULTIPLE - HOLE PROGRESSIVE - PENETRATION



- * FLEXIBLE AND VARIABLE STRATEGIES DETERMINED BY DRIFT & DRILLING RATES
- * FINAL LIMITATION BY SPUD - IN LIMITS
- * GRADES INTO "HIT AND RUN" SURFACE CORING
- * CAN CORE FROM BOTTOM - UP IF SAFE

STRATEGIES FOR SINGLE-SHOT CORING

(NEAR LIMIT OF DRIFT-RATE FOR PENETRATIONS MORE THAN SURFACE CORE)

QUESTION: WHAT CAN YOU DO IN 30 MINUTES?

EQUIVALENT TO:
- 4 N.M./DAY = 1000 FT/HR
- 500 FT./30 MINUTES
- 5% OF 10,000 FT.

RUN ROTARY CORE BARREL AND BE READY TO SPUD

SPUD AND WASH IN APPROXIMATELY	60 FT	2 MIN
CONNECT SECOND DOUBLE		5 MIN
WASH IN	60 FT	2 MIN
CONNECT NEXT DOUBLE		5 MIN
WASH IN 30 FT	30 FT	1 MIN
REDUCE CIRCULATION AND CORE	30 FT	2 MIN
DISCONNECT AND PULL THREE DOUBLES		13 MIN
		30 MIN ELAPSED TIME WHILE VULNERABLE

THEN: MAKE WIRE LINE TRIP TO RETRIEVE CORE WHILE DRIFTING

NOTE: MIGHT IMPROVE SITUATION WITHOUT TOP DRIVE

CONCLUSION: CONSIDER 5 NAUTICAL MILES PER DAY AS FASTEST DRIFT RATE FOR OTHER THAN "HIT AND RUN" SURFACE CORE

AGAIN - FINAL LIMITATION BY SPUD IN LIMITS

"HIT AND RUN" HYDRAULIC PISTON CORES

RUN HPC BARREL ON WIRE LINE

PREPARE TO FIRE HPC

FIRE HPC

IMMEDIATLY LIFT OFF MUDLINE AND
RETRIEVE CORE BARREL - PULL OUT

} ELAPSED TIME WITH HPC IN MUD 1-2 MINUTES

THEN: WIRE LINE RETRIEVAL OF CORE BARREL
WHILE DRIFTING

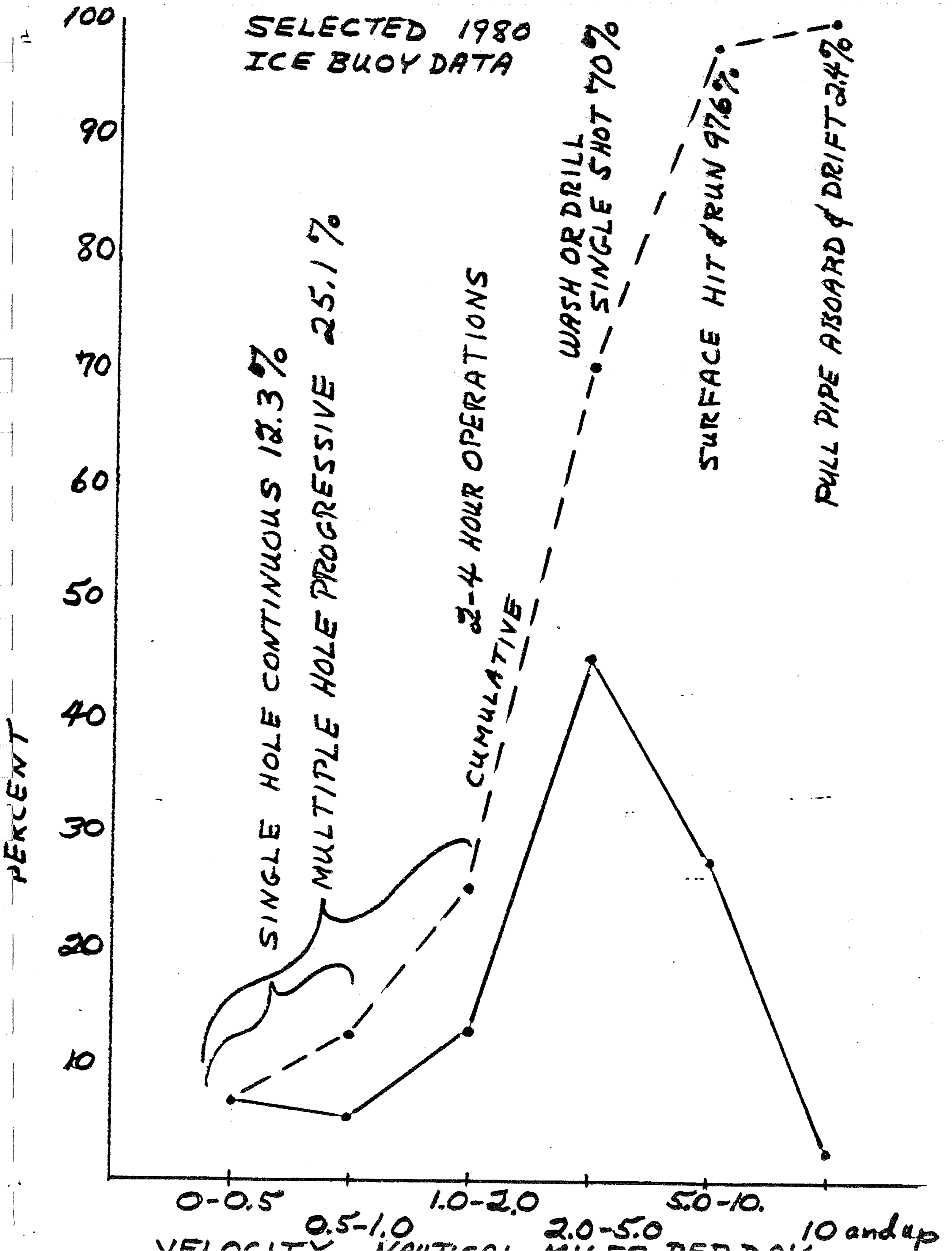
ASSOCIATION OF DRIFT RATES WITH DRILLING & CORING STYLES

NAUTICAL MILES PER DAY	STYLE
0 - 0.5	SINGLE HOLE CONIINUOUS
0.5 - 1.0	MULTIPLE HOLE PROGRESSIVE
1.0 - 2.0	2-4 HOUR OPERATIONS (2-4 CORES)
2.0 - 5.0	WASH OR DRILL TO DEPTH, SINGLE SHOT & PULL
5.0 - 10.0	SURFACE CORE "HIT & RUN" OR DRIFT WITH PIPE
10 and up	PULL PIPE AND DRIFT W/O PIPE DEPLOYED

19[illegible]0 [illegible] Buoy Data

Buoy #	1941		1908		1929		1913		1930		1931		1923		1936		Totals	
Months Reported	8		9		7		1		8		2		1½		8			
Velocity n.m./day ↓	← Bering												Fram →					
	%	#1	%	#	%	#	%	#	%	#	%	#	%	#	%	#	n Days	%
0 - 0.5	8	18	18	46	4	7	⊖	⊖	3	8	⊖	⊖	⊖	⊖	4	8	87	6.9
0.5 - 1.0	7	16	6	16	3	5	15	4	3	7	9	6	3	1	5	12	67	5.4
1.0 - 2.0	11	27	9	24	10	16	8	2	13	31	15	10	13	5	20	45	160	12.8
2.0 - 5.0	40	96	35	90	46	73	42	11	52	124	49	33	53	21	51	115	563	45.0
5.0 - 10.0	33	78	27	70	33	52	31	8	27	64	24	16	30	12	20	44	344	27.5
10.0 - up	1	3	4	10	4	6	4	1	2	5	4	3	3	1	0.4	1	30	2.4
total days		238		256		159		26		239		68		40		225	1251	100.0

= Days Reported
% = % of Days


SELECTED 1980
ICE BUOY DATA
100
90
80
70
60
50
40
30
20
10
PERCENT
SINGLE HOLE CONTINUOUS 12.3%
MULTIPLE HOLE PROGRESSIVE 25.1%
2-4 HOUR OPERATIONS
CUMULATIVE
WASH OR DRILL
SINGLE SHOT 70%
SURFACE HIT & RUN 97.6%
PULL PIPE ABOARD & DRIFT 2.4%
0-0.5
0.5-1.0
1.0-2.0
2.0-5.0
5.0-10.
10 and up

NEEDED STUDIES

1. DRILL WATER INTAKE
2. IMPROVED BOTTOM-HOLE ASSEMBLY
3. ANALYSIS OF ICE MOTION
4. LOGISTIC DEMANDS AND CONTRIBUTIONS
5. GEOPHYSICAL PROGRAM

6. LONGER CORES
    - ROTARY
    - HYDRAULIC PISTON CORER
7. SHORTEN CORING CYCLE TIME

APPENDIX 8

ARCTIC DRILLING

FIVE YEAR PLAN

1989 - 1994

DRAFT 14 JUNE

TABLE OF CONTENTS

OVERVIEW

Background

Scientific drilling of the ocean floor began in 1968 with the Deep Sea Drilling Project, using the drill ship Glomar Challenger. In 1985, a second generation of ocean drilling began with Ocean Drilling Program and the JOIDES Resolution. Until now, sea ice has prevented drilling in the Arctic Ocean. An assessment of presently available technology indicates that it is feasible to commence scientific drilling in the Arctic.

Strategy

The primary goals of Arctic drilling are to understand (1) the climatic evolution in the Arctic which has had global effects on the responses and dynamics of the world's ocean and atmosphere, and on the biosphere and (2) to determine the nature and evolution of the Arctic margins and major structural features for resource evaluation and for global reconstructions. Other marine disciplines are urged to take advantage of available platform(s).

Program Implementation

Interested nations have formed an ad-hoc group of scientists who in the next few months expect to organize a steering committee with sub-committees for technology and science. Active nations are Norway, West Germany, Sweden, Denmark, Canada and the U.S.

Initially a systematic program will commence to compile existing data, followed by filling data gaps by conducting comprehensive airborne, shipborne, and ice station geophysical and geological surveys including the collection of piston cores, and shallow corings (core lengths of 200 m or less from single entry holes). The program will be international with participation open to all interested nations.

Expected results:

1. Characterization of pre-glacial Arctic deep-sea paleo-environments.
2. Timing and characteristics of initial climatic cooling and glaciation.
3. Timing, magnitude and periodicity of high-amplitude late Cenozoic climatic oscillations and resultant ice sheets.

4. Paleoceanographic and paleontologic (both flora and fauna) response to climatic change, warm-cold oscillations and changes in the depth and width of corridors linking Arctic and global oceans.
5. Structure and nature of Alpha Ridge, Chukchi Plateau, Lomonosov Ridge, Yermak Plateau, Morris Jesup Plateau and Nares strait lineament.
6. Structure and development of Arctic continental margins.
7. Paleogeography and paleobathymetry of the Mesozoic and Cenozoic Arctic.

Approach

In order to address the scientific issues long cores (at least 200-300 m in length) are required. The problems of Arctic drilling and the attendant site surveys are non-trivial and will pose a significant challenge. There are however, certain options.

1. Utilize and ice island such as Hobson's Choice or multi-year floating sea ice suitably thickened and smoothed as a platform.
2. Utilize an existing drilling ship either frozen into the ice pack to drift passively or use icebreakers to reposition and drill specific targets.
3. Use JOIDES RESOLUTION for selected Beaufort and Greenland Sea sites with ice breaker support.
4. Utilize a research vessel with icebreaking and shallow drilling capability to sample selected sites.
5. Initially utilize a gattling gun core approach to obtain samples up to 50 m long.

Site selection will pose a problem; however, they are necessary prior to any drilling. One approach would be to use a sea ice camp to obtain seismic reflection data in the vicinity of previous geophysical surveys namely T-3, LOREX and/or CESAR. Alternatively if a drifting platform is utilized, site surveys could be accomplished ahead of the drift.

The establishment of a permanently manned scientific station from which the drilling operations can be carried out, will doubtless also attract many other types of investigations from other disciplines which will profit from the logistics of the drilling operations. One might anticipate "piggy-back" programs such a Arctic marine biology dynamics, physical and chemical oceanography, aural studies and glaciology, ice and ship engineering.

Conclusion

It is proposed to commemorate the famous Norwegian F. Nansen's FRAM drift which was conducted during 1893-1896.

Innovative thinking and F. Nansen's courageous personal effort led to the construction of the famous polar research vessel FRAM. It is our proposal that Arctic deep-sea drilling would be carried out in celebration and honor of the centennial of this singular event. Thus, the program would be known as Nansen Centennial Arctic Program (NCAP). The program will would commence in the year 1993-1996 and will represent a daring, international and interdisciplinary effort to carry out research in the Arctic truly worthy of the great F. Nansen.

Arctic Drilling Endorsement

Arctic Geology/Geophysics sub-committee of ICL
Marine Geology commission of IUGS
Canadian ODP committee
Norwegian Academy of Science
Germany: German Research Foundation (DFG) and Federal Ministry of Science and Technology (FMS&T)
Interagency Arctic Policy Committee (USA) Arctic 5 Year Plan
Second Conference of Scientific Ocean Drilling (COSOD)
Arctic Component of IGBP - DRAFT

INTRODUCTION

1.1 Importance of the Arctic

Knowledge of the Arctic Ocean is important for more than just solving regional problems in that it is linked to the evolution of the adjacent oceanic basins as well as adjacent continents. An understanding of past and present plate movements in the Arctic will be required before a complete model of late Mesozoic and Cenozoic northern hemisphere plate motions can be achieved. These motions and the structure, paleontology, and paleoenvironment of the Phanerozoic sedimentary rock sequences of the circum-polar regions and its continental shelves are highly relevant to the exploration for hydrocarbons.

Today's polar oceans represent unique environments because of their cold hydrospheres and because of the ice caps on adjacent land masses. These environments are the result of a long-term climate change since the end of the Mesozoic and short-term, recurring climate shifts between late Cenozoic glacials and interglacials.

Studies of the marine depositional environments and sediments of the polar oceans which record this evolution, have provided very important but fragmentary data to describe the onset of the cold polar climate since Neogene time and the response of faunas and flora to the cold temperatures. Virtually nothing is known of the transition period.

The evolution of the cold hydrospheres have also had a tremendous impact on the hydrography of the world's oceans because as the surface waters of the polar oceans cool, they sink and flow equatorward to fill all major deep-sea basins. The climatic evolution in the polar regions is therefore global in it's impact, for both the responses and dynamics of the world's ocean and atmosphere as well as for the biosphere. To trace this evolution from its probable onset in the late Mesozoic to the present is a first order geoscientific problem which can only be solved by studying the history of the polar oceans. The sediment record of the southern oceans is quite well known from long piston cores and drill samples from the DSDP. The Arctic however is much less well known.

1.2 Paleo-Oceanography

High latitue polar regions of the Earth have experienced cold, cool and temperate paleoclimates in the course of their geological history, but they have probably always been colder than low latitude continents and oceans. Extreme climates which led to the development of extensive frozen regions at high latitudes can, however, only be documented for a few, relatively short intervals of the Earth's history which apparently have been separated by long time spans with little or no ice. The youngest one of these developments, the Cenozoic evolution of glacial-type climates during the past 30-40 Ma, was different from the preceding ones. Climatically isolated land areas and ocean basins were hemispheres which experienced repeatedly the effects of glaciations. For all scenarios of glacial-type climates older than the Cenozoic, we have only been able to document unipolar glaciation because the opposite high latitude area was situated in wide deep ocean basins, probably kept relatively ice-free because of the advection of warmer surface waters from lower latitudes.

Despite the apparent similarity of Quaternary high latitude paleoclimates, the development of glacial-type paleoceanographies of the northern and southern polar ocean have revealed important differences. Our understanding of Cenozoic southern hemisphere paleoclimates and paleoceanography is much more advanced than it is for the northern hemisphere, It is particularly intriguing that the presently available data suggest that the southern hemisphere may have become cold more than 30 my earlier than its northern counterpart.

There are numerous reasons why it has been so much more difficult to achieve progress in studying the Late Mesozoic and Cenozoic history of the northern polar oceans. The prominent major obstacles have been 1) the difficulty in obtaining deep-sea sediment cores which could be dated easily and efficiently by means of presently available stratigraphic methods and dating techniques, and 2) the lack of sufficient sample material documenting the early (i.e. pre-Pliocene) development of cold surface waters in the Arctic Ocean. In Fig.1 we have complied evidence from all presently available deep-sea sediment cores form the Arctic Ocean, and it is immediately clear that this attempt to synthesize properties and changes of the Late Mesozoic and Cenozoic depositional environments of the northern polar oceans is highly fragmentary.

1.3 Geology/Geophysics

Knowledge of geology and geophysics in the Arctic Ocean is important for more than just solving regional problems. The origin of the Arctic Basin is linked to the evolution of adjacent ocean basins and continents. Geologists need to understand past and present plate movements in the Arctic before they can make a complete model of plate motions and paleogeography in the Northern

Hemisphere in late Mesozoic and Cenozic times. Understanding those motions and the structure, paleontology and paleoenvironment of Phanerozoic sedimentary rock sequences in the circum-polar lands and continental shelves is important in exploring for hydrocarbons.

1.4 Present Knowledge

1.4.1 Paleo-enviroment Mesozoic and Paleogene Arctic Ocean sediment cores, consisting of Campanian black muds and uppermost Cretaceous and Paleogene siliceous oozes, document a relatively warm, northern polar ocean basin. It is not clear if the entire Arctic Ocean was an area of high organic productivity or only parts of the western Alpha Ridge.

All upper Cenozoic Arctic Ocean deep-sea sediment cores document a seasonal or perennial sea ice cover which occasionally received large amounts of ice-rafted coarse terrigenous sediment components from the adjacent continents. Sedimentation rates in the Eastern Arctic are on the order of 1-3 cm/Ka Rates of 1-3 mm/ka are found in the central Arctic.

1.4.2 Marine Geophysics

The Cenozoic history of the Eurasian Basin is well understood because it involves the Euasian and North American plates and is therefore constrained by data from more southerly regions and contains a readily decipherable magnetic pattern from the active mid-ocean ridge. Reconstruction of the older portion of the Arctic Ocean is more difficult. However, information collected on ice station CESAR in 1983, interpreted in conjunction with regional geologic and geophysical date, provides a practical insight into its oceanic affinities and age. A dredged outcrop of the Alpha ridge, consisted of weathered fragmental alkaline volcanic rocks. Refraction data reveal a thick crust nearly 40 km and a high velocity lower crust on his ridge. It is hypothesized that Alpha Ridge therefore represents a late Cretaceous oceanic plateau. A more recent analogue is the Iceland-Faeroe Ridge. The magnetic information have been shown to be consistent with this interpretation of oceanic crust. The Amerasia Basin is closed by rotation the Arctic-Alaska plate against NA during the Cretaceous. This reconstruction, its timing and its position are consistent with the geology of the Canadian Arctic Islands and Alaska.

1.5 Scientific Questions

1.5.1 Paleo-oceanography

As is evident, one of the first order unsolved questions in earth sciences is the paleo-oceanographic and paleoclimatic evolution of the northern polar deep-sea basins. As noted, some progress has been achieved over the past 20 years from ice stations and ice reinforced research vessels in obtaining numerous relatively short, sediment cores. These samples document a relatively warm Arctic Ocean influenced by intensive floral changes and a seasonally or perennially ice-covered glacial type Arctic Ocean for the latest Cenozoic (3 to 5 Ma). No data exists for the intervening interval. It is presently believed that, in the course of the development of Cenozic glacial type conditions, the southern hemisphere had already cooled 25-35 Ma while northern hemisphere glacial type environments can only be documented for the youngest geologic past. We do not know how and when the Arctic Ocean ice cover developed, or how it behaved in response to late Cenozoic glacial-interglacial climatic fluctuation. Biostratigraphic type sections are required for both the eastern and western Arctic. There are indications of significant differences in rates of sedimentation, and possibly different times for the onset of climatic deterioration. Alpha and Lomonosov Ridges in the past were a greater barrier to free circulation; however their effects and rate of subsidence are unknown.

The following are the first order of paleoclimatic scientific questions that must be addressed in both the eastern and western Arctic.

1) Characterization of the pre-glacial Arctic deep-sea paleo-environment;
2) Timing and characteristics of initial climatic cooling and glaciation;
3) Timing, magnitude and periodicity of high amplitude late Cenozoic climatic oscillations and resultant ice sheets: both continental and marine;

4) Paleo-oceanographic and paleontologic (both fauna and flora) responses to climatic change, warm-cold oscillations and changes in the depth and width of ocean corridors linking Arctic and Global oceans.

In addition to paleoclimatic and stratigraphic issues there are significant structural and tectonic Arctic issues.

1:5.2 Geology/Geophysics

Drill samples from Alpha Ridge are required to determine if it is really an alkaline basaltic structure as suggested by one sample obtained during CESAR and to date the basement rocks. Are the alkali basalts dredged from Alpha Ridge typical? What is the composition of Mendeleev Ridge which has a much weaker magnetic signature? The Lomonosov Ridge rocks are assumed to be a rifted sliver of the Barents/Kara sea margin but there is no direct proof. It is unknown if it is composed of rocks which are Caledonidian, Hercynian or some other origin, Chukchi Plateau and associated borderland highs are totally unknown as to whether they are continental or oceanic. This is a critical feature in any reconstruction. Morris Jesup Rise and Yermak Plateau have never been sampled, but at least in the case of Yermak Plateau, they are assumed to be partially stretched continental crust and part oceanic basalt resulting from hot spot activity. The Lincoln Sea is totally unknown, but it is a key area where the Lomonosov and Alpha Ridges meet the continents in an unknown way, and where the Nares Strait joins the Arctic.

This latter junction bears directly on the controversy of whether Nares Strait is a transfor along which Greenland slid as Baffin Bay opened, and on the evolution of ocean corridors linking the North Atlantic and Arctic biogeographical provinces. Parts of the continental margins of east Greenland and Svalbard are both suspected rifted and sheared margins, with structural targets that should be drilled to define the timing and evolution of the margins

2.0 APPROACH

Bedford Institute of Oceanography hosted a 3-day workshop December 1986 to decide what drilling technologies are required to obtain samples form the shelves, margins, basins and ridges of the Arctic Ocean. The workshop objectives were to assess existing drilling technologies developed for commercial operations in the Arctic, to determine how those technologies could be used to meet scientific objectives, and to define technological advances needed to achieve scientific objectives.

Arctic Continental Margin

A complex program of Arctic drilling particularly for the complex and difficult but economically significant continental margins, must be embedded in a coherent overall program of Arctic Ocean marine geology and geophysics. As a first step in a comprehensive approach to leading to drilling, a program of systematic compilation of existing data needs to be developed in order to clearly define scientific questions. This should include, where required, additional coverage by airborne, shipborne and over-ice geologic and geophysical surveys and the retrieval of bottom samples with gravity and piston corers and other appropriate coring techniques.

In order for drilling to be most effective, appropriate sites must be identified and surveyed. Every effort should be made to minimize data collection through the use of all suitable aircraft, ships and over-ice opportunities to survey potential drilling sites. A data bank of potential sites and related geophysical database, a comprehensive program of drilling should be established.

Subsequent to the aquisition of sufficient high Arctic operating experiences with emphasis in continental margins, and the acquisition of a sufficient geophysical database, a comprehensive program of drilling should be considered for those problems that are addressable only by the deep drill.

Arctic Ocean Basin

For some aspects of the Arctic Ocean Basin work many of the information needs will be parallel those of the continental margin. Unique opportunities exist, however, for the Arctic Ocean Basin, that are afforded by the deep water, and hence the smaller ratio of drift distances to water depths, for the characteristic systematic ice drifts. This favorable advantage finds particular merit in the possibility of serious drilling and coring from a substantial drilling platform drifting with the transpolar drift, and frozen in the drifting ice. Such a major platform offers many advantages in the realms of load capacity and structural integrity for drilling in about the style of the Glomar Challenger and the Deep Sea Drilling Project. Equipment currently exists, and these opportunities to accomplish significant deep basin drilling and coring, having stratigraphic recovery achievable to hundreds of meters, as well as providing full logistics support for attendant geophysical studies and also a whole spectrum of other scientific studies, should be explored.

2.1 Scientific Requirement

The scientists at the workshop determined the following requirements:

1. Continuous coring providing the recovery of relatively undisturbed samples.
2. Continuous, high-resolution well logging whenever and wherever required subject the competing demands of time for penetration and continuous sampling verses logging.
3. Drilling Project in about the style of the early Deep Sea Drilling Project in water depths ranging from 10m - 400m. Actual water depths are greater in the Arctic but it is assumed that topographic highs will be the primary targets.
4. Reaching target depths of 100 to 1000m below seabed.
5. Operating within the landfast, shearzone, and polar pack ice conditions of the high Arctic.

Inevitably the depth of penetration issue impinges on the hydrocarbon safety issue and on the geophysical program, and the programmatic solution will largely differ for the main categories of water depth, ice condition, and drilling strategy; thus envelope statements, which can be valid for one strategy, may not be universal.

2.2 Operational Considerations

The Arctic will impose several operational constraints upon the program which will need to be considered.

2.2.1. Logistics:

Depending on the drilling technology employed, the following logistical elements must be considered:

a. Base camp for scientific and technical personnel and equipment including servicing facilities for drilling rig and other scientific investigations.

b. Transportation for personnel, equipment, fuel, and food, including airstrip construction and maintenance and servicing facilities for helicopter and fixed wing aircraft.

c. Storage of fuel, drill pipe, and drilling muds (if required)

d. Communications

e. Medical services

f. Navigation instrumentation for locating the camp and positioning the rig.

2.2.2 Ice Management:

Depending on the nature of the drilling system employed, this could take the form of icebreaker support vessels or equipment to develop and maintain ice platforms or to constrct protective berms or rubble fields.

2.2.3. Ice Loads:

Depending on whether the drilling system is directly exposed to ice loading or protected by a surrounding berm, the structure must be able to withstand the static and dynamic, regional and local ice loads that may vary form a few hundred PSI to several thousand tons.
The value used in the design of offshore structures for use in the Beaufort Sea is 300 PSI. This is the maxium pressure that ice is assumed to be able to exert on a structure. It is also close to the crushing strength of sea ice, and offshore engineers tend to feel that the figure is unrealistically high, since other failure machanisms in a converging icefield will relieve the stress before the ultimate crushing stress is reached. However, it is used as a conservative design value. A real maximum that a ship might experience is more likely to lie in the range 100-200 PSI.

2.2.4. Lateral Motion:

The maximum acceptable horizontal or lateral movement allowed during the drilling of a particular hole appears to be about ten percent of water depth for substantial water depths. This could vary slightly with water depth and drilling equipment.

2.2.5. Drilling Hazards:

Drilling hazards that must be considered in the selection of prospective sites include: ice scouring by sea-ice (damage of seabed installations); permafrost degradation during drilling; hydrate decomposition; overpressured water zones; shallow gas and potential hydrocarbon traps. In general, the risk of encountering hazardous or unacceptable conditions decreases with increasing water depth, particularly beyond the shelf. Shallow holes of less than 500 to 1000m are also less problematic.

Selected sites must satisfy the scrutiny of safety review involving the best scientific and technical knowledge such as is represented in JOIDES and ODP Safety Panels as well as any national safety regulations . However, it should be noted that Arctic conditions will restrict the site surveys in comparison to more temperate areas.

In addition, regulatory and environmental protection agencies guidelines and requirements must be met for shallow wells on the continental margin. Sufficient evidence to document minimum hazard risk in order to minimize or eliminate the need for risers, blowout preventors, relief wells, and oil spill contingency planning will be needed.

2.2.6. ODP Technology:

The adaptation of ODP technologies including the hydraulic poston corer (HPC), the extened core barrel and high resolution well log tools to existing Arctic drill rigs appears feasible. It is therefore proposed to use DSDP/ODP technonology for scientific drilling where feasible

2.3 EXISTING TECHNOLOGIES

2.3.1 Bottom Founded

This method is practical only at very shallow depths (less than 45 meters water depth). Cost is about one million per day. It is our opinion that drilling in these shallow depths can be accomplished more cost effectively by shallow drilling methods either by ship or occupying abandoned gravel islands or other platforms of opportunity, unless a "buy in" for continuous cores in areas of scientific intrest is possible.

2.3.2 Ice (Thickened)

This method appears to be useable in shorefast ice and stable pack ice. It is not certain if thickened sea ice could resist forces in the shear zone. It should fare relatively well in the central pack but under compressive strains may break up. This method could be used on selected sea ice which is well located scientifically. There are some drawbacks however. It will be an expensive project as approximately 80 C-130 flights will required to establish the drilling station. If accomplished in PANARCTIC style it will take approximately 6 months to set up and drill a deep hole. In the interim the ice station may well have drifted away from the selected target.

2.3.3 Drill Ship

If a light ice year is utilized the JOIDES RESOLUTION could drill the Alaskan/Canadian Beaufort and Norwegian Greenland sites (including sites north of Svalbard) on the shelf and slope provided BOP or riser are not required. Ice breaker support would be required. However, existing ice reinforced vessels would be a more certain investment and if modified for continuous coring could satisfy the scientific objectives under any but the heaviest ice years. Present ice drilling ships cannot operate in greater than 4/10 ice with a 2 foot thickness. In the pack ice a modified barge or an ice strengthened round bottom vessel would be optimum because they would offer the flexibility of mobility under power and/or tow when ice conditions permit plus providing a state of the art drilling rig. An attendant icebreaker would be desirable for safety in relocation or maintaining station. Major relocation would probably require the use of the proposed class 8 Canadian or a Soviet icebreaker. The proposed scientific configuration of the Canadian class 8 ice breaker will apparently permit cost effective scientific drilling and coring through a moon pool.

Depth of coring would be dependent on ice motion but multiple cores should be possible during quiet conditions. Preliminary ice drift data suggest that coring in the pack will be possible 25% of the time.

2.3.4 Frozen in Barge

Drilling barges frozen into the sea ice have some potential capability as drilling ships; however, they lack mobility and must drift with the sea ice. Mobility to reach identified targets is mandatory and may be satisfied by icebreaker towing. It would be anticipated that a small icebreaker would be needed to accompany the barge. A more cost effective approach may be to incorporate state-of-the-art Arctic and industry drilling technology into the construction of a mobile barge.

2.3.5 ODP - Joides Resolution

JOIDES RESOSUTION has the capability to drill the Beaufort and Yermak proposed sites if ice conditions are light however, a pressure management system will be required. Icebreaker escort will be a necessity.

It is suggested that JOIDES PCOM include appropriate sites when the vessel is in the geographic area in case favorable ice conditions exist.

2.3.6 The use of a gattling gun core approach to obtain samples up to 50 m long is a very promising new technology.

2.4 SITE SURVEY FOR ARCTIC DRILLING

2.4.1 Data Compilation

Action is required to develop a detailed plan and program for a multi-agency Arctic Ocean Basin geology and geophysics program. The initial phase of the program should be a compilation of all existing U.S. and international Arctic Ocean Basin sediment and geophysical information by NOAA's National Oceanographic Data Center (NODC). The USGS could establish an "Artic Geographic Information System (GIS)" which could provide both foreign and domestic investigators with an index, and access to the NODC compiled data, and also serve as a mechanism for combining newly collected data into the basic data set. This would establish an analytical environment for comparing and studying the multiple data sets, and would provide a single point for access into the vast Arctic data collection.

A combined marine and airborne geological and geophysical data collection program needs to be instituted to study the continental margin and the deep basin using aircraft, ships and ice islands to maximize data collection whenever possible. Surveys should attempt to gather data from 30 to 50 km - wide swaths using both multi-channel to gather deep penetration seismic and high resolution seismic reflection instrument packages, sonobouy refraction, gravity, magnetic, bathymetric, large area mapping sonar (such as GLORIA). Profiles should be spaced to provide three dimensional coverage of important features, and should be supplemented by a systematic program of seabed dredging, coring, hydraulic piston coring, and shallow borings from both continental margin and deep basin sites. Cooperation in international deep drilling programs should be encouraged wherever possible.

The highest priority of the combined marine and airborne geological and geophysical data collection program is the completion of geophysical transects across the northern Alaskan margin including the Chukchi Sea and the Beaufort SEa. Data from the USSR and Canadian margins are also needed. Gravity and magnetic surveys of margins, basins, and ridges can effectively be conducted via airborne surveys. New technologies developed by the Naval Research Laboratory consists of a La Coste-Romberg air/sea gravimeter, Global Positioning System (GPS) navigation, radar and pressure altimeters, magnetometer, and digital data collection capability. A. U.S. survey using this instrumentation could be flown to complement and slightly overlap existing data collected by Canada for the CAnadian Arctic.

2.4.2 Marginal Regions

Beaufort Shelf

This geographic region although ice infested can be worked by geophysical vessels. There are also commercial wells available in many locales to provide stratigraphic data. For the proposed sites adequate geophysical data are or can be made available.

Yermak Plateau

During favorable ice years multi-channel data can be obtained to provide and adequate basis for a site survey. All proposed drill sites have some multi-channel reflection data except 4 (Table 1). The Norwegian extensive geophysical data base on the Yermak Plateau and the Northern Svalbard margin will be supplemented this summer with high-quality, deep penetration, seismic reflection data, acquired by the ships "Mobil Search" and "Hakon Mosby". This will throw more light on this margin, one of the few parts of the Arctic Ocean accessable by conventional seismic methods. In particular the relation between the "basement" on the Spitsbergen and on the Yermak plateau will be investigated with an objective of determining future potential drilling sites.

Deep Arctic

Specific Sites

One option is to drill only where adequate data now exists such as regions covered by CESAR or LOREX seismic reflection and refraction data.

Second option is to develop new technologies to do site surveys where the ice cover precludes ship operations.

Seismic reflection may be done in two ways. On the ice surface the Germans have recently demonstrated that gimbeled geophones may be dragged over the ice and that sufficient coupling is achieved by stopping. Using this method a Skidoo can tow the geophones stopping every 50 meters to drill a hole for a 1 pound dynamite charge. Data are recorded on a PC. The drill would be sled mounted so the hole drilling time would be minimal. It is estimated that 100 km a week could be covered. This approach is presently being investigated by Seismological Observatory, University of Bergen and by University of Munster in field tests at Svalbard. Hopefully within a years time it will be possible to do site-surveys at proposed drill-sites at reasonable costs.

The second way is to tow a source and hydrophone array from a ship. In this instance the array is depressed by a heavy weight below the ice and attached to the ship by ice resistant heavy support cables. This system will work if the vessel does not have to suddenly back down and therefore will be limited to moderate ice conditions. A field test will be conducted by USGS in the summer of 1988. Arrays towed by submarines are the most portable; however, the availability of a submarine is unlikely. Studies are now underway to determine if a drone can be designed which will be able to tow a super thin streamer and carry explosive charges for energy. Preliminary engineering studies are encouraging.

Geophysical drones are a distinct possibility, Drones for physical oceanography are now under development. A sub set of these might be equipped with a streamer array (very thin wire). Sound sources could be chemical set to detonate at depth or impulsive. A study to determine which is most power effective would be required.

The ultimate would be a manned submarine equipped for geophysical work. This now appears to be possible. SAGA-N is the first nuclear powered commercial submarine vehicle now under construction in France and Canada. This vessel will have a submerged range of 300 nautical miles and will be configured for oceanographic research an resource development in Arctic waters. Of particular interest will be her capability to conduct deep and shallow seismic exploration ahd thus geophysical site surveys. She was also equiped to take shallow cores and drill samples and thus could sample outcrops.

Free Drift

If the drilling vessel drifts with the pack ice and "in house" site survey capability will be needed. Some salient features might include:

A. An array of hydrophones or sonobuoys, linked to the ship by hard wire or radio, and deployed through the ice, would symmetrically surround the drilling platform. The effective radial distance from the drilling platform would be the equivalent of about one to several days common drift distance. A common sound source, probably an air gun, would be employed. Drift rates are slow, so even at a very slow pulse repetition recorded, giving a set of continuous recordings, each with its directionality. The pulse repetition rate could be linked to drift rate or distance traversed. The array could be established, maintained and repaired with vehicular or helicopter support. The multiplicity of the array offers some redundancy, in case of partial failure.

B. Opposite ends of the array or purposeful extensions, or even a satellite array, beyond that needed for the site survey function, could give substantial aperture for deep penetration reflection or refraction study.

C. A hull-mounted sub-bottom profiler would give information directly beneath the drilling platform, particulary in the detail of the upper 100-200 meters of sediment.

D. Geophysical work could be linked to the drilling program only by the potential logistic support from the platform, such as refraction lines across major geological features within reach of the drift track.

2.5 Potential multi-disciplinary science

The drilling platform will provide an excellent opportunity for scientists of all disciplines. Depending upon location the following are potential scientific targets.

2.5.1 Atmosphere - ionosphere - magnetosphere

Substorm phenomena: What is the spatial distribution of energy deposited by energetic particles (and the associated visual auroral emissions and geomagnetic disturbances) during various phases of substorms?

Particle entry through the magnetospheric cusp: Where is the cusp; what particle flux variations occur within it; how far in local time does it extend in local time; and what are the variations with geomagnetic activity?

Convective electric fields across the polar cap and their connection the global ionospheric potential: Can separated ground-based static electric field measurement be used to monitor transpolar electric fields and be related to interplanetary phenomena such as the direction and intensity of the interplanetary magnetic field?

Maintenance of the polar nighttime ionosphere: In the absence of solar radiation during long polar nights, what are the important ionization sources?

Minor species in the polar-cap atmosphere: What is the effect of prolonged periods of sunlight or darkness on the abundances of O_3 NO, O_2 (^{1} g), for example?

Effects of solar activity on surface weather: Are particle bombardment of the polar cap, field-aligned current systems in the auroral region, or polar-cap convective electric fields associated with major meteorological patterns?

2.5.2 Oceanography/Tracers

Investigation of the distribution of water masses in the Canada, Amundsen and Makarov Basins:

° Description of water mass formation in the Canada, Amundsen and Makarov Basins

° Deep water formation on the Siberian shelf

° Circulation and renewal rate of the deep waters in the Arctic basins

° Development of the Arctic halocline

2.5.3 Sea Ice

Origin, transport and transformation of sea ice and regional variations:

° Formation of sea ice on continental shelves

° Linkage of shelf ice with the Transpolar Drift

° Convergence/transition zone between ice of the Canada and easter Arctic Basins over the Lomonosov Ridge
  - variations in sea ice type
  - material content

2.5.4 Meteorology

Transport and deposition paths and rates of continent-derived aerosols through air masses over the Arctic Ocean:

° Deposition rates of aerosols on the sea ice cover

° Radiative and turbulent heat fluxes heat fluxes in both leads and ice covered regions.

2.5.5. Biology

Biologic dynamics as related to shelf and basin water processes. Evolution and adaptation of biologic systems to Arctic environment.

3.0 IMPLEMENTATION

This section describes the major commitments, subject to available resources by the international community to word implementing Arctic Scientific Drilling.

3:1 Shipboard Operations

US - USGS, ONR NOAA, NSF
Canada
Norway

Survey mobility is a key issue in exploration of the Arctic Ocean by geophysical techniques and geological sampling as a site survey data base for optimum drill site locations needs to be established. An engineering effort is clearly required to improve on the technology for Arctic geoscientific research. We intend to pursue the following development/improvement in instrumentation:

- development of an active geological sampling device for long (20 m) sediment cores transportable by a Twin-Otter plane

- over ice seismic reflection measurements by small crew (4) traveling on skidoos. Estimated minimum production is 100 km per week with a single channel data density similar to conventional marine surveys. Support by one Twin-Otter flight per week.

Norway is actively considering the following field activities in the deep Arctic Ocean during the 1990-ties:

- an ice drift with a ship in the Eurasia Basin north of Franz Josef Land - Svalbard

- air supported over-ice geophysical surveys and geological sampling

- participate with survey crews on other international platforms.

Germany

3:2 Site Surveys

3:2.1 Data Compilation

USA - USGS, ONR, NSF, NOAA would consider support of site surveys.
Canada
Germany
Norway

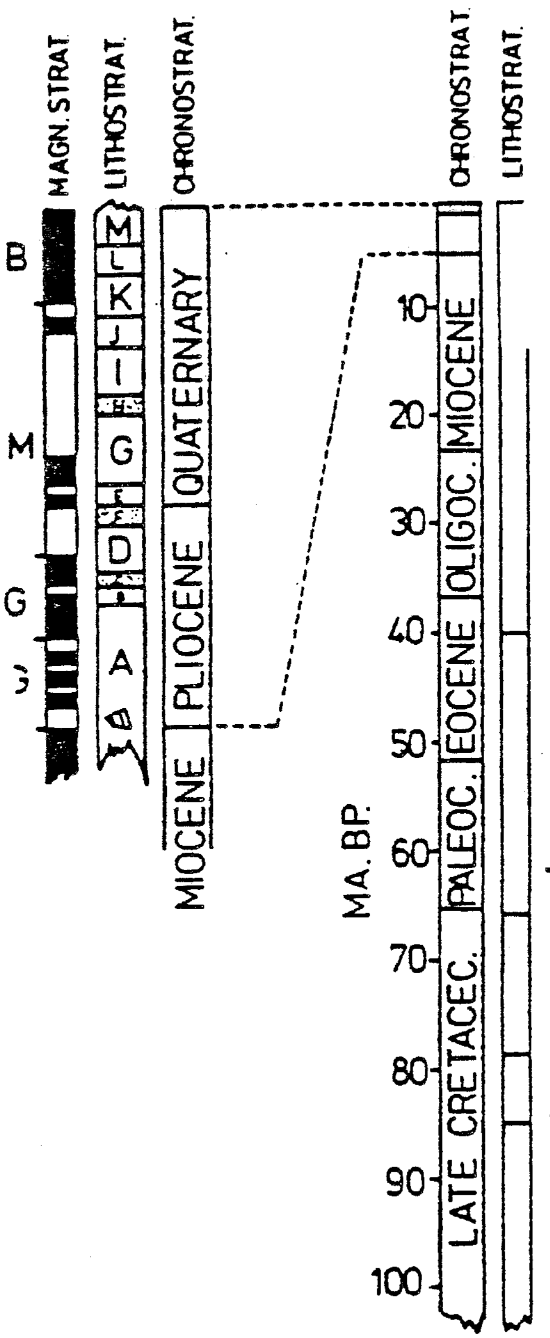
3:3 Multi-disciplinary Science USA: Office of Naval Research will consider funding of multi-disciplinary research that can be done in conjunction with the drill operations. These might include biology, geophysics, physical oeanography and glaciology.

NSF
USGS
NOAA

Fig 1

SEDIMENTS AND HISTORY OF THE ARCTIC OCEAN:

TEMPORAL DOCUMENTATION



Numerous cores:
Fossil-rich and -poor layers of clays with ice-rafted debris. Episodic ice-free?

?

One core:
Orange yellow sediment with silicoflagellates and diatoms. Affinities to temperate floras. FL422

One core:
Orange yellow sediment with silicoflagellates and diatoms. FL437

One core: Approx. 2m of laminated diatom size. CESAR6

One core:
Black mud with marine dinoflagellates and terrestrial plant debris. FL533

?

APPENDIX 9

PROPOSAL

NANSEN ARCTIC OCEAN DRILLING, (NAD)

Objectives

The Arctic Ocean Basin and adjacent extensive continental margins are poorly understood in terms of their tectonic and paleoenvironmental history. The primary goals of the of the NAD-research are to develop a satisfactory understanding of:

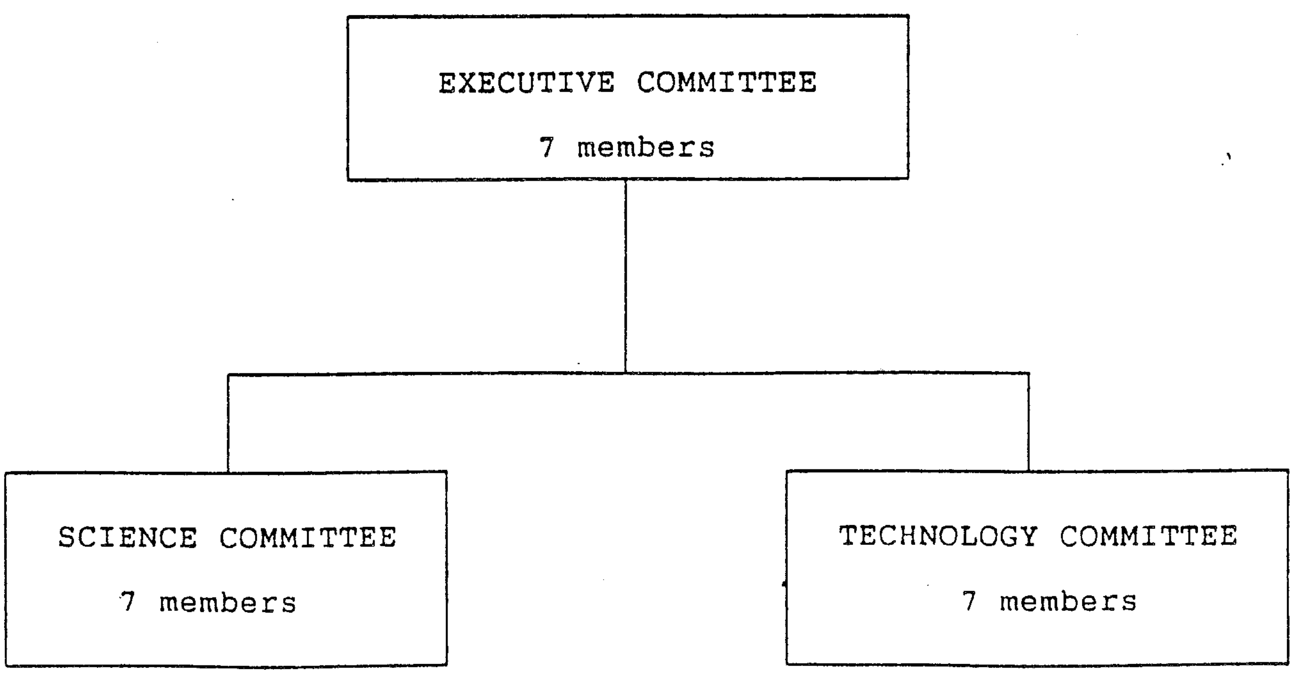
(1) the climatic and paleoceanographic evolution of the Arctic region and its effects on global climate, biosphere, and the dynamics of the world´s ocean and atmosphere; and

(2) the nature and evolution of the major structural features of the Arctic Ocean Basin and circum-Arctic continental margins.

NAD = NANSEN ARCTIC DRILLING

Organization

ORGANIZATIONS



Executive committee:

1. This committee shall formulate scientific and policy recommendations with respect to the Arctic Ocean Drilling.

2. The Executive Committee shall be advocates for the NAD-program by interacting with the international scientific community. Formal ties to the proper international scientific organizations and to the Nansen Centennial Arctic Program shall be established by this committee.

3. The Executive Committee shall work to create funds for the NAD program from national research councils, industrial and other potential sources.

4. Membership: Membership will be open to nations who are willing to contribute resources to the NAD program.

   Members of the Executive Committee shall be representative of institutions or agencies which have a major scientific interest in the study of the Arctic sea-floor.

   The initial membership of this committee will be comprised of one representative of each of the seven countries......

5. The Executive Committee shall reach all its decisions by the affirmative vote of at least five of its seven members. If a member of the Executive Committee is absent from a duly called meeting, he or she may designate an alternate from his or her institution, with full authority to act in his or her absence.

Science committee

1. The Science Committee shall define and recommends research priorities within arctic ocean drilling to the Executive Committee.

2. The Science Committee shall convene conferences on scientific problems/objectives of arctic ocean geological and geophysical research.

3. Membership: Each member of the Executive Committee shall designate one member of the Science Committee and an alternate to serve in the absence of the designated member.

Technology committee

1. The Technology Committee is responsible for recommending and evaluating drilling-platforms, drilling-tools, drilling-techniques to meet the scientific objectives.

2. The Technology Committee shall identify new drilling-platforms, drilling-tools, drilling-techniques to be developed.

3. The Technology Committee shall recommend to the Executive Committee plans designated to optimize arctic ocean drilling.

4. Membership: Each member of the Executive Committee shall designate one member of the Technology Committee and an alternate to serve in the absence of the designated member.

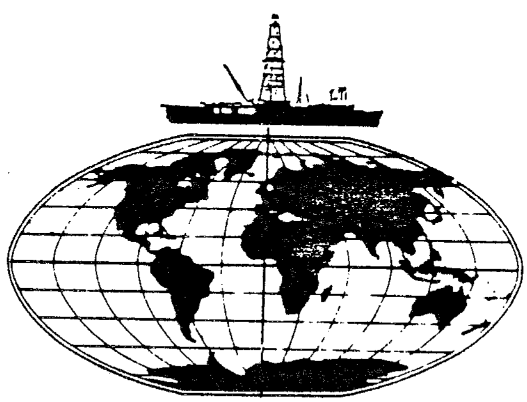
OCEAN DRILLING PROGRAM PROPOSAL FOR ARCTIC OCEAN DRILLING

Peta J. Mudie, H. Ruth Jackson and Steven M. Blasco

Geological Survey of Canada,
Atlantic Geoscience Centre,
Box 1006, Dartmouth,
Nova Scotia B2Y 4A2.

ABSTRACT

Four multiple drill sites are proposed for hydraulic piston coring and rotary coring in the Arctic Ocean. These pioneering sites address first-order paleooceanographic-climatic, biogenic geochemical, sedimentary and plate-tectonic objectives. Sites include ARC 1- Alpha Ridge transect; ARC 2- Yermak Plateau and ARC 3- Nansen Ridge(Atlantic gateway); ARC 4-Chukchi Basin (Pacfic gateway).



OCEAN DRILLING PROGRAM PROPOSAL FOR ARCTIC OCEAN DRILLING

Peta J. Mudie, H. Ruth Jackson and Steven M. Blasco,

Geological Survey Canada, Atlantic Geoscience Centre,
Box 1006, Dartmouth, N.S., Canada B2Y 4A2.

INTRODUCTION

The scientific rational for drilling in the Arctic Ocean was discussed in detail at the COSOD II Conference, Strasbourg 1987, and is summarized in the Proceedings of this conference (COSOD II, 1987). In brief, Arctic drilling is needed because:

- THE ARCTIC OCEAN IS A KEY CORRIDOR LINKING MAJOR OCEAN BASINS, SO THE TECTONIC & OCEANOGRAPHIC EVOLUTION HAVE HAD A MAJOR IMPACT ON THE HISTORY OF CIRCUM-ARCTIC PLATE MOTIONS, MOUNTAIN BELTS AND THE GLOBAL OCEAN/CLIMATE SYSTEM

- MESOZOIC-CENOZOIC EVOLUTION AND BIOMASS PRODUCTIVITY OF ARCTIC OCEAN BIOTA IS ALMOST UNKNOWN AND NEEDS TO BE UNDERSTOOD IN RELATION TO RATES OF BIOTIC EVOLUTION IN LOWER LATITUDES

- COOLING OF ARCTIC OCEAN SURFACE WATER IS A SOURCE OF MUCH OF THE WORLDS BOTTOM WATERS. EVOLUTION OF THE COLD ARCTIC HYDROSPHERE IS THUS LINKED TO EVOLUTION OF GLOBAL DEEP-SEA CIRCULATION PATTERNS

- CHANGES ASSOCIATED WITH THE TRANSITION FROM ICE-FREE TO ICE-COVERED ARCTIC OCEAN GOVERN GLOBAL THERMAL GRADIENTS, GEOCHEMICAL RESERVOIRS, CLIMATIC & BIOTIC EVOLUTION.

The feasibility of Arctic drilling has also been examined closely by a panel of government, university and industry specialists(Blasco et al., 1987). It is now clear that the technology exists for drilling either from ships in summer-open Arctic waters (Figs. 1, 2) or within the permanent sea ice cover, using polar icebreaker support ships or other special platforms now employed by industry.

The original document outlining an Arctic Drilling program (Blasco, 1987) was reviewed by the ODP PCOM and returned for clarification of the global significance of Arctic drilling. This issue is adressed in the next section.

GLOBAL SIGNIFICANCE OF ARCTIC DRILLING

Both Arctic and Antarctic polar regions are integral parts of the total global environment:

1) Polar atmospheric circulation governs climatic conditions in both high and mid latitudes;

2) Polar seas are primary sources of deep water circulation and nutrient fluxes in the world's oceans;

3) The configuration of land masses, size and depthof ocean basins in polar regions governs the distribution, nature and extent of permanent ice sheet formation, ocean circulation and productivity within the polar seas, and the extent to which polar ocean water is exchanged with global oceans;

4) The tectonic history of polar regions constrains the timing of plate motions and nature of crustal tectonic processes in adjacent mid- to high latitude regions.

5) The Nansen-Gakkel Ridge in the Eurasian Basin of the Arctic Ocean is a unique, very slow spreading centre, which represents an end member of crustal generation processes. Drilling of this ridge is needed to provide understanding of the full spectrum of seafloor spreading processes.

Knowledge of polar processes, paleoenvironmental history and geological origins is therefore essential for understanding of world-wide phenomena, such as long term climatic changes, geochemical cycles, and the nature, rate and direction of crustal plate motions. The global significance of polar drilling studies has been demonstrated by results from the circum-Antarctic DSDP drilling program which showed that (i) Cenozoic glacial conditions started as early as the Late Oligocene (25Ma) in the southern hemisphere; (ii) Antarctic glaciations are manifest in sediment regimes of both North and South Atlantic Oceans;(iii) sea ice formation can promote rather than suppress ocean productivity. Global impacts of comparable magnitude are expected to accompany the paleoenvironmental and tectonic evolution of the

Arctic Ocean. The different geometry of the Arctic land-sea configurations, however, means that Antarctic data cannot be directly or simply applied to interpretation of the Arctic Ocean history. Tectonic processes in the Arctic are also entirely different from the Antarctic and they must be studied separately. Conversely, the global impact of Antarctic glaciation cannot be evaluated fully without knowledge of the timing and nature of cryosphere evolution in the Arctic Ocean. Hence, there is need for detailed coring of the Mesozoic-Cenozoic Arctic Ocean sediments and uppermost crust to fully constrain global models of ocean-atmosphere circulation, biotic evolution and dispersal,geochemical cycles and plate tectonics.

MAIN OBJECTIVES

I. Late Mesozoic-Cenozoic stratigraphy

The lack of well-defined late Mesozoic-Cenozoic reference stratigraphies for Arctic Ocean basins and margins presently precludes correlation with events in Antarctica and the global oceans. This major gap must be closed before an understanding of the paleoenvironmental and geochemical evolution of global ocean basins is resolved. Critical aspects of Arctic stratigraphy that must be adressed are outlined as follows.

A. Paleoclimate/paleoceanography

1) Four short cores from the Alpha Ridge (Fig.1) provide fragmentary records of Late Mesozoic to Early Paleogene sediments in the central Arctic Ocean. The oldest sediment is organic-rich black mud of probable Campanian age; all cores contain Cretaceous-Paleogene biosiliceous sediment with little clastic influx.Interpretation of these sequences presently ranges from high productivity and rapid deposition in an upwelling environment to very slow deposition in ponded basins characterised by periodic hydrothermal venting. Numerical models of global ocean-

atmosphere circulation at the K-T boundary require that well constrained paleoenvironmental data be obtained from the Arctic Ocean basins and margins. Knowledge of the size and location of ocean gateways linking the Arctic and global oceans is also necessary to evaluate hypotheses pertaining to global heat budgets and ocean circulation. Continuous drilling at selected sites on the Alpha Ridge and submarine plateaus of the Arctic margin should provide biostratigraphic and sedimentological data for reconstruction of Arctic Ocean paleoenvironments from Late Cretaceous to Paleocene/Oligocene time intervals.

PRIMARY SITE: PROPOSAL ARC 1 - Alpha Ridge

2) At present,there are no records for the Late Paleogene to Early Neogene interval in the Arctic Ocean. These data are needed to evaluate the magnitude of global changes in climate and bottom water circulation that are presently attributed to Antarctic ice sheet growth in the Oligocene and Middle Miocene. Pollen-spore data from the Arctic margin further suggest that a major climatic cooling event in the Early Oligocene may have predated or accompanied the onset of Antarctic glaciation. Palynological and sedimentological data from widely separated parts of the N. Hemisphere (Voering Plateau, Iceland and Alaska) also indicate major cooling events during the Middle-Late Miocene. Continuous records from western & eastern Arctic Ocean basins are needed to fully document the timing and magnitude of these cooling events and to evaluate their significance with respect to events in the Antarctic.

PRIMARY SITE: PROPOSAL ARC 1 (Alpha Ridge) & ARC 2 (Yermak)
?SECONDARY SITE: RE-CORING AT SELECTED DSDP LEG 19 SITES

3) Many short cores from the Alpha-Mendeleyev Ridge appear to indicate the onset of N. Hemisphere glaciation and sea ice cover as early as 4-5 Ma, which is approximately synchronous with the major Pliocene glaciation in Antarctica. In contrast, most land records from the circum-Arctic regions and paleoceanographic data from ODP Leg 105 indicate the persistance of boreal climatic conditions until the end of the Late Pliocene (ca. 3-2 Ma). Continuous cores of Neogene sediment from ridge basin and submarine plateau areas with relatively high sedimentation rates (ca. 1 cm/Ka) are needed to resolve the timing of glacial onset in the Arctic Ocean. Cores with relatively high sedimentation rates are also needed for interpretation of the evolution of high amplitude Late Pliocene-Quaternary glacial-interglacial climatic oscillations.

PRIMARY SITES: PROPOSAL ARC 2 - Yermak Plateau
PROPOSAL ARC 4 - Bering Sea-N. Chukchi Basin

B. Biostratigraphy

Accurate dating of Arctic Ocean sediments will rely heavily on biochronostratigraphic correlation with well constrained datums from high latitude regions of the global oceans. At present discontinuous records and/or poor preservation of microfossil and palynological records in circum-Arctic regions constrains the accuracy of dating. Drilling of deep water sediments in the Arctic Ocean should provide continuous biostratigraphic records that can be correlated with global deep sea records, with supporting data being provided by continuous magnetostratigraphic records. When a basic biochronology has been erected for the Arctic Ocean, detailed studies may also be made on the evolution of specialized regional Arctic biota and their probable links with ancestral lineages in Baffin Bay, and Atlantic/Pacific Oceans. Evolutionary studies of this kind may assist in understanding the history of ocean corridor connections between the Arctic and global oceans.

PRIMARY SITES: PROPOSALS ARC 1,2 & 4

C. Chemostratigraphy and sea level fluctuations

The existing fragmentary records from deep water Arctic Ocean cores suggest that the timing of carbonate and opal accumulation is remarkably diachronous compared to that of the global oceans. For example, siliceous oozes were deposited in the Late Cretaceous Arctic Ocean more than 15 Ma earlier than equivalent deposits in the Atlantic; siliclastic sediments occur in the Late Pliocene when carbonate and opal were accumulating in the Atlantic and Pacific, respectively; biogenic carbonate accumulation appears to be continuous through most of the Upper Pleistocene in contrast to the cyclicity evident in high latitude oceans of the N. Hemisphere. New oceanographic data from the Arctic Ocean and Norwegian Seas indicate that the chemical content and ventilation of the Arctic Ocean is largely controlled by a) thickness and distribution of the sea ice cover which is the source of brines flowing over the polar margins;and b) fluvial influx of organic carbon, Ca and Mg which control the pH of surface and Atlantic water layers in the Arctic Ocean,and hence the accumulation/dissolution of carbonates. The history and extent of sea ice formation on the continental shelves and the influx of fluvial sediments, in turn, are largely affected by changes in relative sea level. Comparison of geochemical and sedimentological records from continental margin and deep water drill sites is needed for full understanding of factors controlling rates of CO3 and Si accumulation in the Arctic Ocean and the export of nutrients to the global oceans.

PRIMARY SITE: PROPOSALS ARC 1,2 & 4

D. Extent of northern ice margins

The timing and extent of continental ice sheet expansion on the Polar margins of North America and Europe is presently poorly constrained for for most of the circum-Arctic region. There is considerable dispute regarding the synchronous expansion and decay of ice sheet/ice caps in western and eastern parts of the Arctic. Drill sites in deep water areas off Beaufort Sea and Spitsbergen may provide continuous sections that can be dated by magneto- and biochronological methods in order to establish well constrained reference sections from which other discontinous glacial/interglacial sequences can be properly dated (e.g. those in the Banks Island Formation).

PRIMARY SITE: NOT YET SPECIFIED (probably Axel Heiberg Shelf, Fig. 1)

E. Crustal properties of slow spreading oceans

The Arctic Mid-Ocean Ridge (Nansen-Gakkel Ridge) is spreading very slowly at 5mm.yr. Refraction studies also show that the crust is thinner (2-3 km) than standard oceanic crust (Jackson et al. 1982). At faster spreading centers in the Atlantic & Pacific, crustal thicknesses of 6-8 km are found which suggests that similar igneous and tectonic processes are operating in these oceans (White,1984). Theoretical modelling of melting & flow beneath mid-ocean ridges (Reid & Jackson, 1981) has shown that thinner crust is produced at spreading rates of 20 mm/yr or less. In the Eurasian Basin, the end member of this slow spreading process should be sampled to provide petrological, geochemical and high resolution geotechnical data for understanding how crust is produce and for constraining models. This is a first order problem of understanding crustal generation.

PROPOSED SITE ARC 3 : Nansen-Gakkel Ridge

F. Plate Reconstructions

The plate tectonic reconstructions of the Arctic Ocean Eurasian Basin have not been verified by dating of sedimentary or crustal material. Futhermore, although plate reconstructions for the Eurasian Basin are relatively well established, overlapping crust occurs in the Yermak and Morris Jessup Plateau regions. Several hypotheses have been suggested for their crustal origin (Crane et al., 1982; Jackson et al., 1982), including paired oceanic plateaus, and stretched continental crust for the S. Yermak Plateau cf. oceanic crust for the northern plateau.

PRIMARY SITE: PROPOSAL ARC 2 (Yermak Plateau)
ACESSORY SITE: PROPOSAL ARC 3 (Nansen Ridge)

ARCTIC DRILLING: SITE ARC 1

ODP SITE PROPOSAL SUMMARY FORM

Proposed Site: Alpha Ridge transect (Sites ARC 1A,1B,1C)
General Objective: Continuous Cretaceous to late Cenozoic stratigraphic and paleoenvironmental record; bedrock drilling for age and nature of the ridge
General Area: Central Arctic Ocean (Fig. A1-1)
Position: 85o 06'- 59.9'N   Thematic Panel: SOHP,TECT,LITH

Specific Objectives

1. HPC and XCB coring to ca.500m on the northern Alpha Ridge crest (ARC 1A, Fig.A1-2), to obtain a complete Cenozoic litho- and biostratigraphic section for the western (Canadian/Beringian) sector of the Arctic Ocean for study of the evolution of climate, ocean circulation and polar microbiota.(NOTE: a complementary reference section in the eastern/Eurasian sector is described in Proposal 2 for drilling at Site ARC 2 on the Yermak Plateau (Fig. 1).

2. Continuous HPC coring to refusal (ca.250m?) at Ridge sites where the K/T boundary is at shallow depths (ARC 1B, Fig A1-2; ARC 1C, Fig.A1-3) - to determine the paleoenvironmental, geochemical and petrological events that mark this interval in the Arctic, and for comparison with visually similar K/T sections in the Antarctic (= the Woodside Creek type section in New Zealand).

3. Rotary drilling to refusal at Sites ARC 1A,1B and 1C to determine the age, nature and origin of Alpha Ridge "bedrock","grabens" and "volcanic peaks", and to confirm a possible origin as thick oceanic crust similar to that under large Pacific oceanic plateaus e.g. Otong Java.

Background Information

Regional Geophysical Data:

- seismic reflection profiles: sparker records (Hall,1979); airgun records (Jackson, 1985)

- seismic refraction: CESAR survey (Jackson et al.,1986; Forsyth et al.,1986) includes a complete section: 0-1 km sediment; bedrock layer of 5.1km/s typical of ocean layer 2; 6.45 km/s layer with high velocity gradient; 7.3 km/s layer 10-16 km thick, above a mantle depth of up to 40 km.

- cores & dredge samples (Mudie & Blasco,1985; Clark et al.,1980)

Site specific data:

-Seismic profiles show stratified sediments conformably overlying apparent bedrock which appears to crop out as conical seamounts on the ridge crests. Dredge samples from these seamounts contain highly altered (weathered) tholeolitic basalt (Van Wagoner & Robinson, 1985). A few cores on the margins of the ridge crests have recovered unaltered Cretaceous-Paleogene laminated biosiliceous ooze (Mudie et al. 1986). At the CESAR site, the top of the ooze apparently corresponds to a strong reflector which can be traced to 200 m sub-bottom (Fig A1-2). A second reflector at ca. 400m sub-bottom is believed to mark the bedrock surface. Most piston cores from the stratified surficial sediment layer contain continuous sequences of carbonate-rich hemipelagic Pleistocene muds overlying Late Miocene-Pliocene oxidised siliclastic muds (?red clays), with sandy interbeds (Mudie & Blasco,1985; Aksu & Mudie,1985;Clark et al.,1980.

Operational Considerations

Water Depth (m): 1360 - 1855m Sed. Thickness (m):400-800m
Total Penetration: ARC 1A = 500m; ARC 1B = 500m
ARC 1C = 900m
HPC: Double HPC X Rotary Drill X
Sediments/rock anticipated: ca.10 m Plio-Pleistocene carbonate mud
200msiliclastic red clay &fine sandy interbeds
10-50m Maestrichtian biosiliceous ooze
50-100m Campanian black mud
Tholeolitic basalt(Campian Quiet Zone)

Weather conditions/window:Year-round sea ice cover, with narrow leads in summer; Drill ship would require 2 or more Class 6-8) support icebreakers (e.g. PVRV Polarstern, Arktika or the proposed Canadian MV Polar 8), from ca. July 1 to Sept. 15. The shortest access distance from summer open water is from Spitsbergen. Access may be faster & more efficient, however, by entry through northern Bering Strait and following the Beaufort Gyre Current to the drill sites (see Fig. 2B).

Territorial jurisdiction: International.

Special Requirements: Icebreaker support ships

Safety Considerations: Some subbottom stratification may indicate gas hydrates which can form at depths of ca. 1000-1200m at present bottom water temperatures.Low organic content and uniform appearance of the reflectors, however, makes hydrates unlikely.

PROPONENT: Peta J. Mudie
H. Ruth Jackson
Steven M. Blasco
Address & Phone:
Geological Survey Canada

FOR OFFICE USE:
Date Received:
Classification No.:
Panel Allocation

Atlantic Geoscience Centre
Box 1006, Dartmouth, NS B2Y 4A2
Phone: 902-426-8720/3791/3932

ARCTIC DRILLING: SITE ARC 2

ODP PROPOSAL SUMMARY FORM

Proposed Site: Yermak Plateau Sites ARC 2A, 2B
General Objective: Continuous Paleogene to Late Cenozoic stratigraphic and paleoenvironmental record for the eastern Arctic Ocean entrance (Fig. 1); bedrock drilling for age and nature (oceanic/continental) of the marginal plateau northwest of Svalbard (Fig. A2-1).
General Area: Southeastern Arctic Ocean
Position: *ARC 2A-ca. 82o 41.7'N 09o 32.7'E
*ARC 2B-ca. 80o 53'N, 07o 19'E
Thematic Panel: SOHP, TECT
Regional Panel: Arctic, AOP
*Exact location to be determined pending further study of available seismic data and/or site surveys

---

Specific Objectives

1.Continuous HPC and XCB coring to refusal at Site ARC 2A on the northeastern Yermak Plateau (Fig.A2-2) to obtain a complete Eocene-Pleistocene litho- and biostratigraphic section for the eastern (Eurasian) sector of the Arctic Ocean, to verify the oceanic origin of the outer plateau, and to confirm its former proximity to Greenland and Canada (see Fig.A2-3).

2.Rotary drilling to refusal at Site ARC 2A Fig.A2-2) to verify the presence of oceanic crust, determine the its age and petrological characteristics (volcanic dike?).

3. Continuous HPC & XCB coring and rotary drilling to refusal at Site ARC 2B on the southern axis of Yermak Plateau (Fig. A2-4) to determine the age and paleoenvironmental characteristics (continental/marine?) of velocity layers 1.7,2.0-2.1,2.2,2.5-2.6 and reflector O, and to sample the basement layer (v=5.0-5.8m/sec) for confirmation of its continental origin and possible correlation with the Precambrian gneiss Heckla Hoek Formation of Spitsbergen (Jackson et al. 1984).

Background Information

Regional Geophysical Data:

- seismic reflection profiles: multichannel 120 cu in. airgun records (Kristofferson,1982; Sundvor et al.,1982a,b); 3.5 kHz profile of Sofia Basin (Thiede et al.,1988)

- seismic refraction: sonobuoy profiles have been made at or near the proposed drill sites (Sundvor et al. 1977, 1982a,b)

- cores & dredge samples: Sundvor et al.(1982a) report on short cores & dredge samples from the site areas; most cores from the west slope, however, appear to include turbidite or slump deposits; in contrast, core ARKIV/3-396 from the area of well stratified sediments on the northeast plateau (Fig. A2-5) appears to comprise only fossiliferous hemipelagic muds interbedded with ice-rafted detritus.
- at Site ARC 2B, Tertiary and older sediments are probably similar to formations exposed onshore in W. Svalbard (Mork and Bjoroy, 1984)

Site Specific Data

-At present, an ideal site for both stratigraphic and bedrock objectives cannot be located precisely. Seismic profiles for the general target area, however, show bedrock within 1 sec. of the seabed at the proposed sites (Figs. A2-2, A2-4). In the vicinity of Site ARC 2A, there is a sediment cover ca. 0.7-1.0 sec. thick in most areas (see Fig. A2-2). The upper 0.4 sec is strongly stratified & probably comprises interbedded glaciogenic and hemipelagic muds of Late Cenozoic age; the lower 0.3 sec. are weakly stratified and appear to be pelagic marine muds. Bedrock at Site ARC 2A is expected to be lava flows with intercalated tuffaceous sediments similar to the volcanics drilled on ODP Leg 104, Voering Plateau.

At Site ARC 2B (Fig.A2-4), sediments appear to be more uniformly stratified, suggesting a more consistent terrigenous clastic component.Strong reflectors are regional in occurrence and they probably mark erosional events accompanying eustatic changes in sea level. Bedrock at this site may include high grade Precambrian gneiss which has been dredged from Yermak Plateau near otcrops. Reflector O , marking basement top, has been traced to within 25 km of the Hekla Hoek Formation in W. Svalbard; this rock succession includes metamorphosed/deformed rocks of Late Riphean to Early Paleozoic age; overlying Devonian and younger Paleozoic rocks are unmetamorphosed clastics with some carbonates and evaporites (Steel & Worsley, 1984).

Operational Considerations

Water Depth (m): 2A- ca. 1400 m   Sed. thickness: ca.600m
2B- ca. 800m   ca.800m
Total Penetration: ARC 2A = ca 1000m
ARC 2B = ca 1200m
HPC: Double HPC: _X_   Rotary Drill_X_
Sediments/rock anticipated:
ARC 2A: ca. 400m Late Tertiary - Pleistocene glaciomarine muds and pelagic marine interbeds
200m Paleogene - Miocene pelagic sediment
Basement = Eocene/older tholeiitic flows and

interlayered clastics

ARC 2B: ca. 300m Plio-Pleistocene glacial marine sediment
200m Pliocene hemipelagic muds
300m Tertiary hemipelagic and clastic sediments
Basement = Paleozoic red sandstone and/or older gneiss/metamorphic rock

Weather conditions/window: In most years, summer open water will allow access by ice re-inforced vessels, ca. July 1 - Sept.15; icebreaker support ships may be needed for safety.

Territorial jurisdiction: ?International and Norway

Special Requirements: See Fig.A2-6 for map of ice conditions.Basement faulting is common through the region, possibly with hydrocarbon traps in small basins; drill sites, however, are over basement highs and are unlikely to encounter significant amounts of hydrocarbons

---

PROPONENT: H.Ruth Jackson1
Peta J. Mudie1
Joern Thiede2
Address and Phone:
1.Geological Survey Canada,
Atlantic Geoscience Centre,
Box 1006, Dartmouth, N.S.; Phone:902-426-3791/8720
2.Geologische Institut Kiel
GEOMAR Forsuchungzentrum fur marine Gewissenschaften,
Wischofstrasse 1-3, Blg. 4,
D-2300, Kiel, FGR; Phone:49-431-720020-15.

FOR OFFICE USE:
Date Received
Classification No.
Panel Allocation:

PROPROSAL 3: ARCTIC DRILLING SITE ARC 3
ODP SITE PROPOSAL SUMMARY FORM

Proposed Site: Nansen Ridge, Eurasian Basin

General Objectives: Bedrock drilling in this area of very thin crust so that petrological and geochemical data from a slow spreading ridge can be used to determine depth of magma formation, amount of melt, and degree of thermal alteration for deeper parts of the crust than possible elsewhere.

General Area: Eastern Arctic Ocean (Fig. 1)
Position: 84o 18' 19.5"N, 8o 06' 29.7" W
Thematic Panel: TECT, LITH Regional Panel:Arctic,AOP

Specific Objectives:
1. Drill to investigate age, thermal properties, petrology and geochemistry of the oceanic crust generated by a slow spreading ridge
2. Continuous coring to investigate sedimentary deposition in the eastern Arctic under the Transpolar Drift Current.

Background Information:
Regional Geophysical Data: single channel seismic reflection data (Jackson et al., 1982)
- ocean bottom seismometer refraction lines (Jackson et al., 1982)
- core and dredge samples

Site Specific Data: Seismic reflection profiles from Fram I show basement highs and lows with sediment cover that ranges from about 1 to 0 km over basement. Crust 2-3 km thick has been measured on seismic refraction lines. The crust is expected to be vertically and laterally heterogeneous. The site selected is next to a basement high with a thin cover of ponded sediments (Fig. A3-1).

Operational Considerations:
Water Depth(m): 3894; Sed. Thickness (m):100; Tot. Pen.(m): 1100
HPC:YES ROTARY DRILL: YES
Nature of Sediments/Rock: 0-100m hemipelagic muds and ice rafted detritus, 1000m pillow basalts interbedded with sediments and possibly layer sheeted dykes.
Weather Conditions: Arctic, temperatures subzero to +2oC; foggy in summer
Territorial Jurisdiction: International waters

Special Requirements: Arctic pack ice requires ice breaker support

---

Proponents: H.R. Jackson and P.J. Mudie
Geological Survey Canada, Atlantic Geoscience Centre
P.O. Box 1006, Dartmouth, N.S. B2Y 4A2; 902-426-3791

PROPOSAL 4: ARCTIC DRILLING SITE ARC 4
ODP SITE PROPOSAL SUMMARY FORM

NOTE: The exact location of this site cannot be given at present because of the lack of released industry/military seismic data for this region where basement is complex and spatially variable. The site described here, however, provides a perspective of the type of conditions and problems that may be encountered in this region. A final site, however, will be selected after examination of more seismic data, hopefully including lines to be shot from the USCG icebreaker Polar Star in summer 1988.

Proposed Site: North Chukchi Basin
General Objctives: Continuous coring for Cretaceous- Pleistocene paleoecological records of the Pacific-Arctic Ocean gateway; rotary drilling for age and nature of basement.
General Area: Chukchi Sea, Western Arctic Ocean
Position: ca. 74o N, 170oW
Thematic Panel:SOHP,TEC

Specific Objectives

1. HPC and XBC coring to ca. 750 m at ARC 4A on the southern edge of the N. Chukchi Basin (Fig.A4-1,A4-2) to obtain a high resolution Neogene-Holocene litho- and biostratigraphic section for the Pacific entrance to the Arctic Ocean, in an area that has not been eroded or deformed by Pleistocene ice sheet or ice cap growth.

2.Continuous coring to refusal of Jurassic/Cretaceous to Plio-Pleistocene sediments at Site ARC-4B (Fig.A4-2) in order to establish a biostratigraphy for the western Arctic, and to determine the paleoenvironmental history of the Pacific-Arctic gateway, particularly with respect to the immigration and evolution of siliceous microfossils and dinoflagellates which are the main biochronological markers in the Alpha Ridge sections.

3. Rotary coring of basement at Sites ARC 4C and 4C'(Fig. A4-3) to determine its age and nature, and to confirm models (Grantz and May, 1983; Jackson and Johnson, 1986) for the origin of the Canada Basin by Jurassic rifting, followed by rotational spreading wherereby the Canadian Polar Margin became separated from the Chukchi Borderland by the opening of the ocean basin (Fig. 4-4).

Operational Considerations

Water Depth (m): ca. 200 m Sediment thickness: 4A = ca.900m; 4B = 600m; 4C = ca. 100 m
Total Penetration: ARC 4A,4B = ca. 1200m
ARC 4C = ca. 300 m
HPC: double HPC _X_ Rotary Drill _X_

Sediments/rock anticipated:

ARC 4A: ca. 300 m Plio-Pleistocene hemipelagic mud interbedded with gravelly ice-rafted detritus(IRD)
ca. 400 m Neogene hemipelagic mud
ca. 200 m Paleogene ?hemipelagic mud
Basement = Upper Cretaceous-Paleogene hemipelagic/deltaic mud

ARC 4B: ca. 200 m Plio-Pleistocene hemipelagic & glaciogenic mud
ca. 100 m Neogene hemipelagic mud
ca. 300 m U. Cretaceous-Paleogene hemipelagic/deltaic mud
Basement = Jurassic/L. Cretaceous clastics & shale

ARC 4C ca. 100 m Plio-Pleistocene hemipelagic/glaciogenic mud
ca. 200 m Jurassic-L. Cret. clastics (?Ellesmerian rocks, shale

Weather conditions/window: In most years, accessible to ice reinforced vessels in summer, ca. Aug. 15 - Oct.1

Territorial jurisdiction: International and USSR

Special Requirements: See Fig. 2A for map of ice conditions. Basement faulting is common but overlying Neogene-Recent sediments are not gassy (Grantz et al. 1975) and underlying sediments are unlikely to contain significant amounts of hydrocarbons. Diapirs (probably shale) reach seafloor in places.

PROPONENT: Peta J. Mudie
H. Ruth Jackson
Steven M. Blasco
Address and Phone:
Geological Survey Canada
Atlantic Geoscience Centre
Box 1006, Dartmouth, N.S.
Phone: 902-426-8720/3791/3932

FOR OFFICE USE:
Date Received:
Classification No.
Panel Allocation:

BIBLIOGRAPHY

Aksu, A.E. and Mudie, P.J., 1985. Magnetostratigraphy and palynology demonstrate at least 4 million years of Arctic Ocean sedimentation. Nature v. 318, 280-283.

Barry, R.G.,1986. Aspects of the meteorology of the seasonal ice zone. In: Untersteiner, N. ed., The Geophysics of Sea Ice. NATO ASI Series v. 146, Plenum Press, New York, p.993-1020.

Blasco, S.M., 1987. Arctic drilling. In: Gradstein, F.M. and Horne, L. V.-B., eds.,Canadian Proposals for the Ocean Drilling Program, Dalhousie U. Press, Halifax, p. 96-99.

Blasco, S.M., Johnson, G.L., Mayer, L. and Thiede, J., 1987. Drilling will reveal important changes. Geotimes v.32, 8-9.

Clark, D.L., Whitman, R.R., Morgan, K.A., Mackey, S.D., 1980. Stratigraphy and glacial-marine sediemnts of the Amerasian Basin, Central Arctic Ocean. Geol. Soc. Amer. Special Paper 181, 57 pp.

COSOD II, 1987. Report of the Second Conference on Scientific Ocean Drilling ("COSOD II"). Joint Oceanographic Institutions for Deep Earth Sampling, Inc., Washington D.C., 142 pp.

Crane, K., Eldholm, O., Myhre, A.M., Sundvor, E., 1982. Thermal implications for the evaluation of the Spitsbergen transform fault. Tectonophysics v. 89, 1-32.

Forsyth, D.A., Asudeh, I., Green, A.G., and Jackson, H.R., 1986. Crustal structure of the northern Alpha Ridge. Nature v. 322, 349-352.

Grantz,A. and May,S.D.,1983. Rifting history and structural development of the continental margin north of Alaska. In: Watkins, J.S. and Drake, C.L., eds.,tudies in Continental Margin Geology; Amer. Assoc. Petrol. Geologists Memoir 34, 77-100.

Grantz,A., Holmes, M.L., and Kososki, B.A., 1975. Geologic framework of the Alaskan continental terrace in the Chukchi and Beaufort Seas. In: Yorath, C.J., Parker, E.R. and Glass, D.J. eds, Canada's Continental Margins and Offshore Petroleum Exploration; Canad. Soc. Petrol. Geologists Memoir 4,669-699.

Hall, J.K., 1979. Sediment waves and other evidence of paleo-bottom currents at two locations in the deep Arctic Ocean. Sedimentary Geology v. 23, 269-299.

Jackson, H.R., 1985. Seismic reflection results from CESAR. Geol. Survey Canad. paper v. 84-22, 19-24.

Jackson, H.R. and Johnson, G.L., 1986. Summary of Arctic geophysics. J. geodynamics v. 6, 245-262.

Jackson, H.R., Reid, I., and Falconer, R.K.H., 1982. Crustal structure near the Arctic mid-ocean ridge, J. Geophys. Res. v. 87, 1773-1783.

Jackson, H.R., Johnson, G.L., Sundvor, E. and Myhre, A.M.,1984. The Yermak Plateau: formed at a triple junction. J. Geophys. Res. v. 89, 3223-3232.

Jackson, H.R., Forsyth, D.A., and Johnson, G.L. 1986. Oceanic affinities of the Alpha Ridge, Arctic Ocean. Marine Geology v. 73, 237-261.

Kristofferson, Y. 1982. U.S. ice drift station FRAM IV: report on the Norwegian field program. Norsk Polarinstitutt Rapportserie Nr. 11, 60 pp.

Mork, A. and Bjoroy,M., 1984. Mesozoic source rocks on Svalbard. In: A.M. Spencer et al., eds, Petroleum Geology North European Margin; Norweg. Petrol. Soc., Graham and Trotman, Publ., ~~Oslo~~ London, p.371-382.

Mudie, P.J. and Blasco, S.M., 1985. Lithostratigraphy of the CESAR cores. Geol. Surv. Canad. Paper 84-22, p.59-99.

Mudie, P.J., Stoffyn-Egli, P., and Van Wagoner, N.A., 1986. Geological constraints for tectonic models of the Alpha Ridge. J. Geodynamics v. 6, 215-236.

Reid, I. and Jackson, H.R., 1981. Oceanic spreading rate and crustal thickness. Marine Geophysical Researches v. 5, 165-172.

Steel, R.J. and Worsley, D., 1984. Svalbard's post-Caledonian strata - an atlas of sedimentation patterns and palaeogeographic evolution. In: ~~Graham, . and Trotman, ., eds~~ Petroleum Geology North European Margin; Norwegian Petrol. Soc., Graham and Trotman Publ. ~~Oslo~~ London, p. 109-135.

Sundvor, E., Elholm, O., Gidskehaug, A. and Myhre, A., 1977. Marine geophysical survey on the western and northern continental margin off Svalbard. Univ. Bergen Seismological Observatory Scientific Rept. No. 4, 20 pp.

Sundvor, E., Myhre, A.M., Austegard, A., Haugland, K., Eldholm, O. and Gidsgehaug, A. 1982a. Marine geophysical survey on the Yermak Plateau. Univ. Bergren Seismological Observatory Scientific Rept. No. 7, 14 pp.

Sundvor, E., Johnson, G.L. and Myhre, A. 1982b. Some aspects of morphology and structure of the Yermak Plateau NW of Spitsbergen. Univ. Bergren Seismological Observatory Scientific Repts No. 8, 15 pp.

Thiede, J. et al., 1988. Scientific Cruise Report of Arctic

Expedition ARK IV/3. Berichte zur Polarforschung, v.43, 237 pp.

Untersteiner, N. 1982. The sea-air interface. In Rey,L. (ed.) The Arctic Ocean, MacMillan Press Ltd., London, p. 113-133.

Van Wagoner, N.A. and Robinson, P., 1985. Petrology and geochemistry of a CESAR bedrock sample: implications for the origin of the Alpha Ridge. Geol. Surv. Canad. Paper 84-22, 25-45.

FIGURE CAPTIONS

Figure 1. Map of Arctic Ocean and adjacent geographic regions, showing locations of proposed drilling areas ARC 1 to ARC 4, and bathymetry in metres. * = Axel Heiberg Shelf; W = Wrangel Island.

Figure 2A. Sea ice distribution in the Arctic and circum-Arctic region, showing maximum and minimum extent of sea ice>1/8 concentration (after Barry,1986). Unshaded and hatched areas are summer open waters with scattered bergs and sea ice floes; heavily stippled area is navigable to Class 3 or >3 icebreakers in summer; ice north of the Absolute Minimum line is navigable only via the most powerful (>6) icebreakers. Large dots are proposed drilling areas.

Figure 2B. Normal pattern of average ice drift in the Arctic Ocean (from Untersteiner, 1982), showing the predominantly clockwise drift in the western Arctic from ca. 90-180o W, and southeasterly drift over the eastern Arctic basins. Large dots are proposed drilling areas.

Figure A1-1. Map of the Alpha Ridge, showing bathymetry (in metres), and areas of proposed drill sites: solid square = Sites 1A and 1B; open square = Site 1C. Inset shows detailed bathymetry for seismic profile A-B; large dots are locations of CESAR cores (from Mudie and Blasco, 1985).

Figure A1-2a. Seismic reflection profile A-B of Fig. A1-1, showing sediment thickness, tectonic setting,locations of Sites ARC 1A, ARC 1B and CESAR piston cores. Broken line marks the probable unconformity between Paleogene biosiliceous oozes and Neogene hemipelagic sediments.

Figure A1-2b. Predicted lithostratigraphy for Sites ARC 1A,1B, 1C

Figure A1-3a. Bathymetry of western Alpha Ridge area, incorrected metres x 100, showing location of seismic profile P-K, Site ARC 1C and piston cores FL 437 and FL422 (from Hall,1979).

Figure A1-3b. Digitized seismic reflection profiles (20:1 V.E.), inferred basement (black shading) and location of Site ARC 1C (from Hall, 1979).

Figure A2-1. Bathymetric chart of the Yermak Plateau, showing locations of seismic lines and proposed drill sites. Contours in uncorrected metres (from Sundvor et al.,1982b). S.B. = Sofia Basin.

Figure A2-2. Seismic reflection profile A-B of Fig.A2-1 and location of ARC 2A (from Kristofferson 1982).

Figure A2-3. Modelled reconstruction of tectonic fits for Greenland and Svalbard at 4 time intervals in the Paleogene (from Sundvor et al., 1982b). Graphic symbolsindicate possible locations of core sites (dots = ARC 2; star = ARC 3) according to different models.

Figure A2-4. Seismic reflection profile C-D (Lines 1-79,2-79) of Fig. A2-1 and location of Site ARC 2B (from Sundvor et al., 1982a). SB are sonobouy locations, with corresponding velocity-depth profiles shown in columns at upper right.

Figure A2-5. 3.5 kHz records showing >25 m of conformably draped late Cenozoic sediments on thenortheasternYermak Plateau. A. N.E. plateau slope; B. Sofia Basin.

Fig. A2-6. Seasonal changes in ice conditions of the Fram Strait region (from Thiede et al., 1988).

Fig. A2-7. Predicted lithostratigraphies for Sites ARC 2A,2B and for ARC 3.

Fig. A3-1. Seismic profile and location of Site ARC 3 (from Kristofferson, 1982.

Fig. A3-2. Predicted stratigraphy for Site ARC 3.

Fig. A4-1. Bathymetric map of N. Chukchi Basin, showing A) regional setting, and B)locations of seismic profiles and proposed drill sites (from Grantz et al., 1975).

Figure A4-2. Seismic reflection profiles and locations of Sites ARC 4A and 4B (from Grantz et al., 1975). WA = Wrangel Arch; DA = possible anticlinal diapiric zone; DFZ = diapiric fault zone.

Figure A4-3. Expected lithofacies for Sites ARC 4A, 4B and 4C (from Grantz et al.,1975). I.R.D. = ice rafted detritus.

Figure A4-4. Model of tectonic evolution of Canada Basin from ca. 120 - 70 Ma (Figs. A-D)(after Jackson and Johnson, 1986). Black dot marks Site ARC 4C; black triangles mark ARC 1 drill sites. W = Wrangel Island.

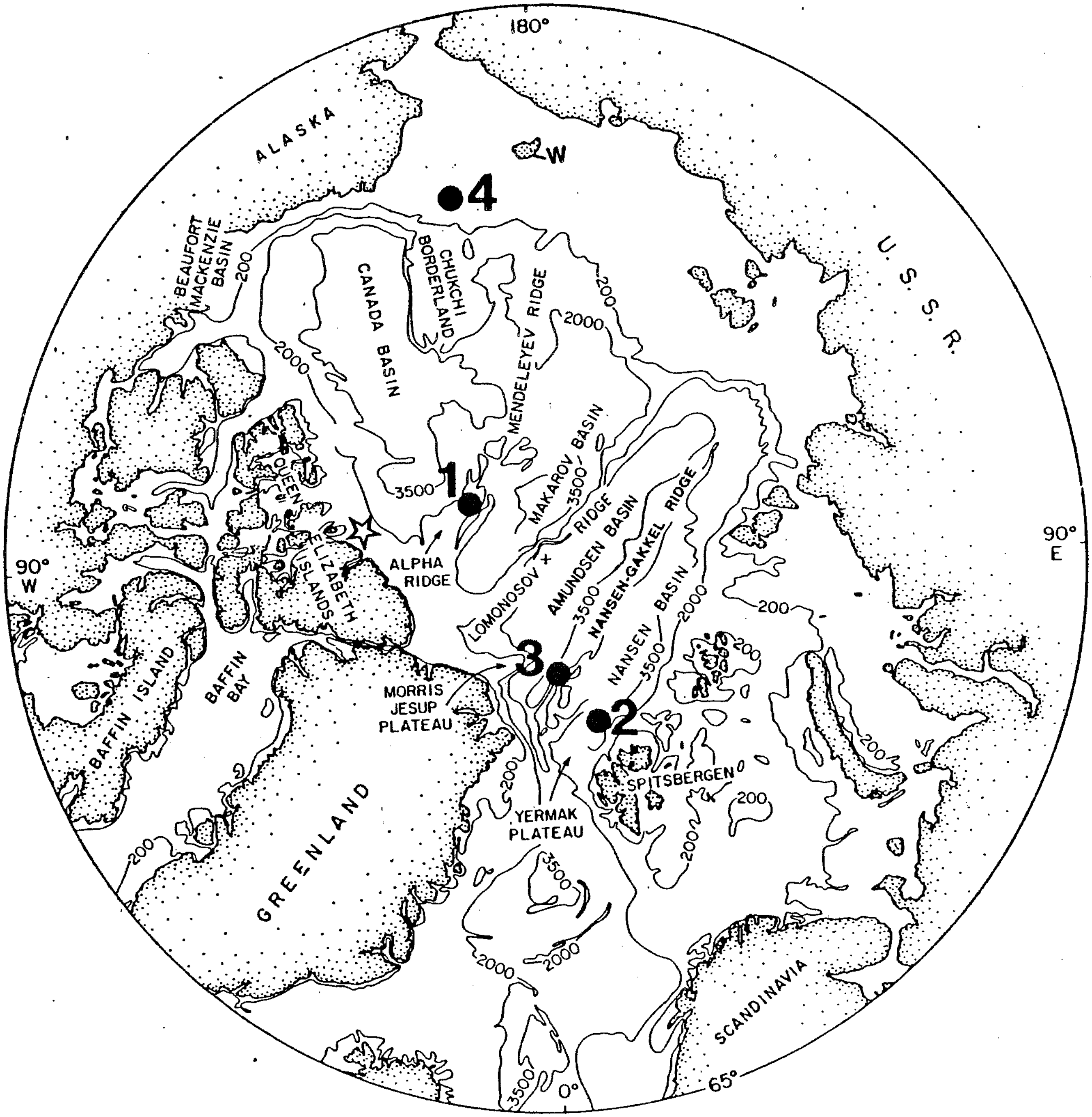

180°
ALASKA
U. S. S. R.
W
4
BEAUFORT MACKENZIE BASIN
CHUKCHI BORDERLAND
CANADA BASIN
MENDELEYEV RIDGE
MAKAROV BASIN
LOMONOSOV RIDGE
AMUNDSEN BASIN
NANSEN-GAKKEL RIDGE
NANSEN BASIN
1
2
3
ALPHA RIDGE
QUEEN ELIZABETH ISLANDS
90° W
90° E
BAFFIN ISLAND
BAFFIN BAY
MORRIS JESUP PLATEAU
GREENLAND
YERMAK PLATEAU
SPITSBERGEN
SCANDINAVIA
65°
0°
200
2000
3500

Figure 1

2A

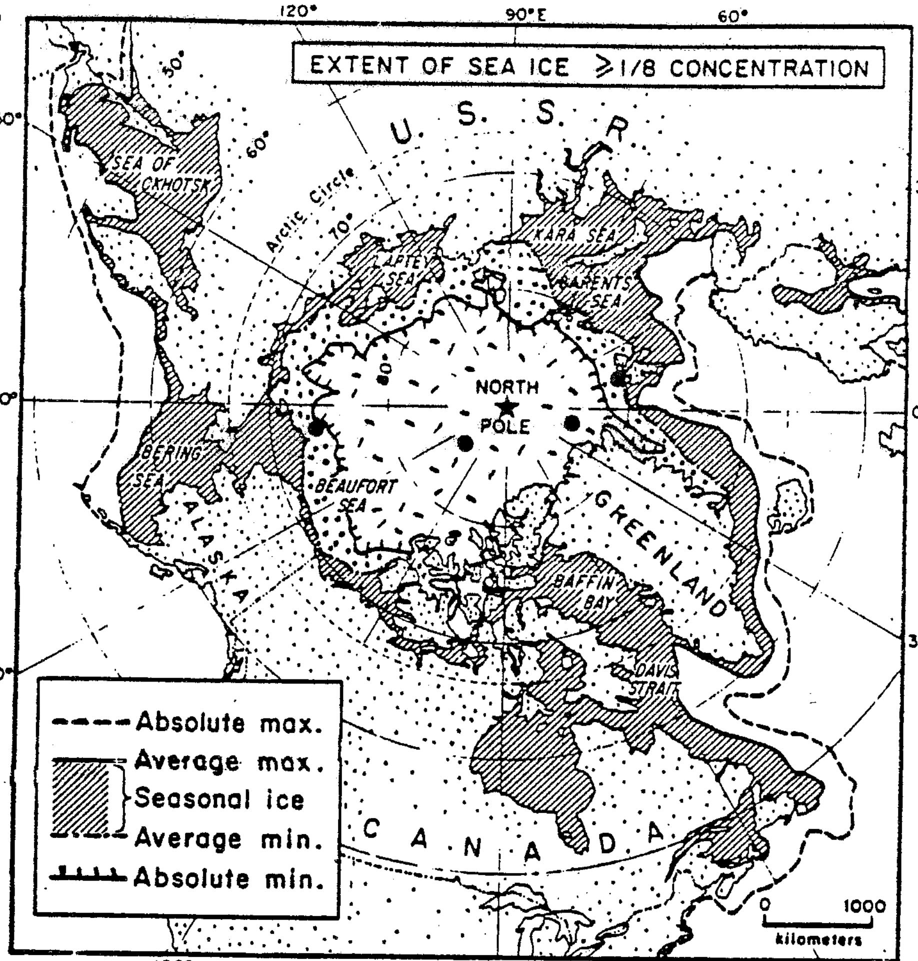
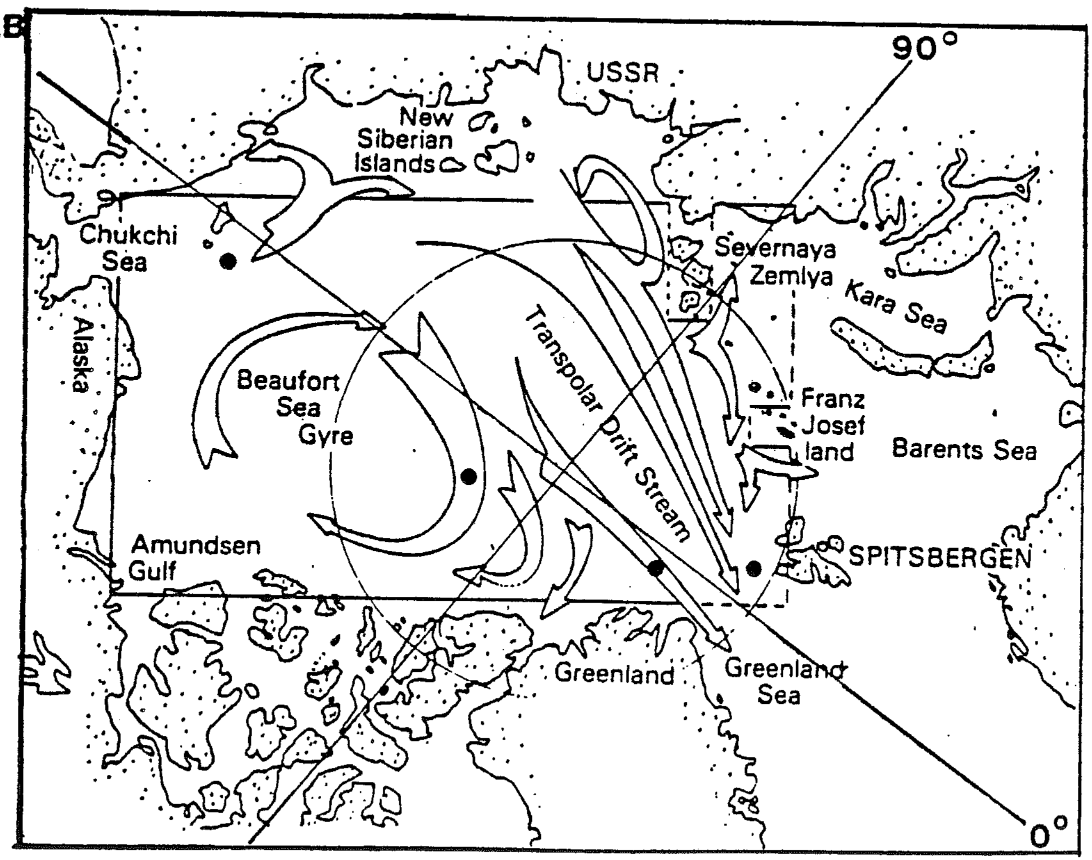


Figure 2A

2B



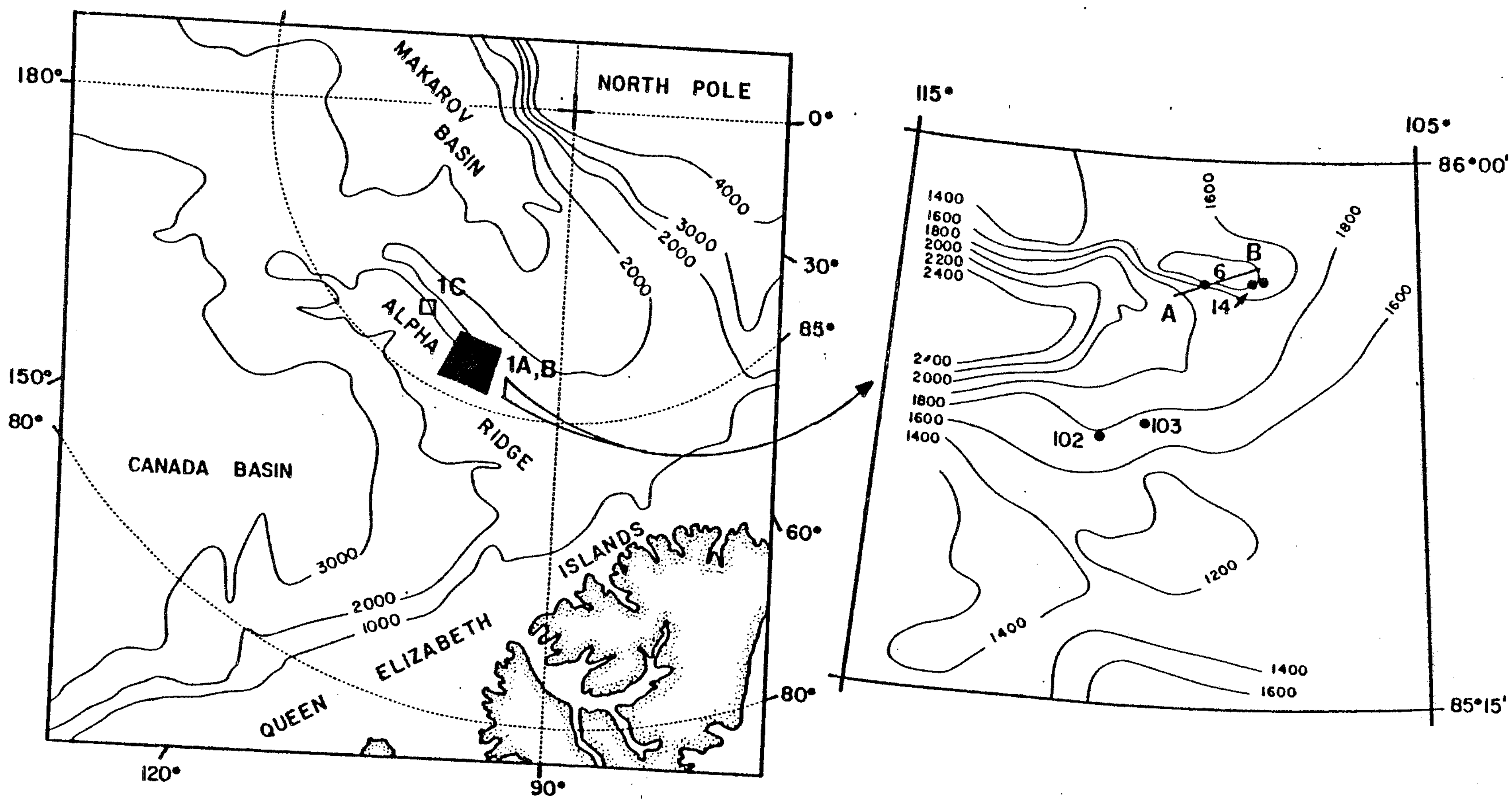

NORTH POLE
MAKAROV BASIN
ALPHA RIDGE
CANADA BASIN
QUEEN ELIZABETH ISLANDS
1C
1A,B
4000
3000
2000
2000
3000
2000
1000
180°
0°
30°
85°
150°
80°
60°
80°
120°
90°
115°
105°
86°00'
85°15'
1400
1600
1800
2000
2200
2400
2400
2000
1800
1600
1400
1600
1800
1600
1200
1400
1400
1600
A
B
6
14
102
103

Figure A1-1

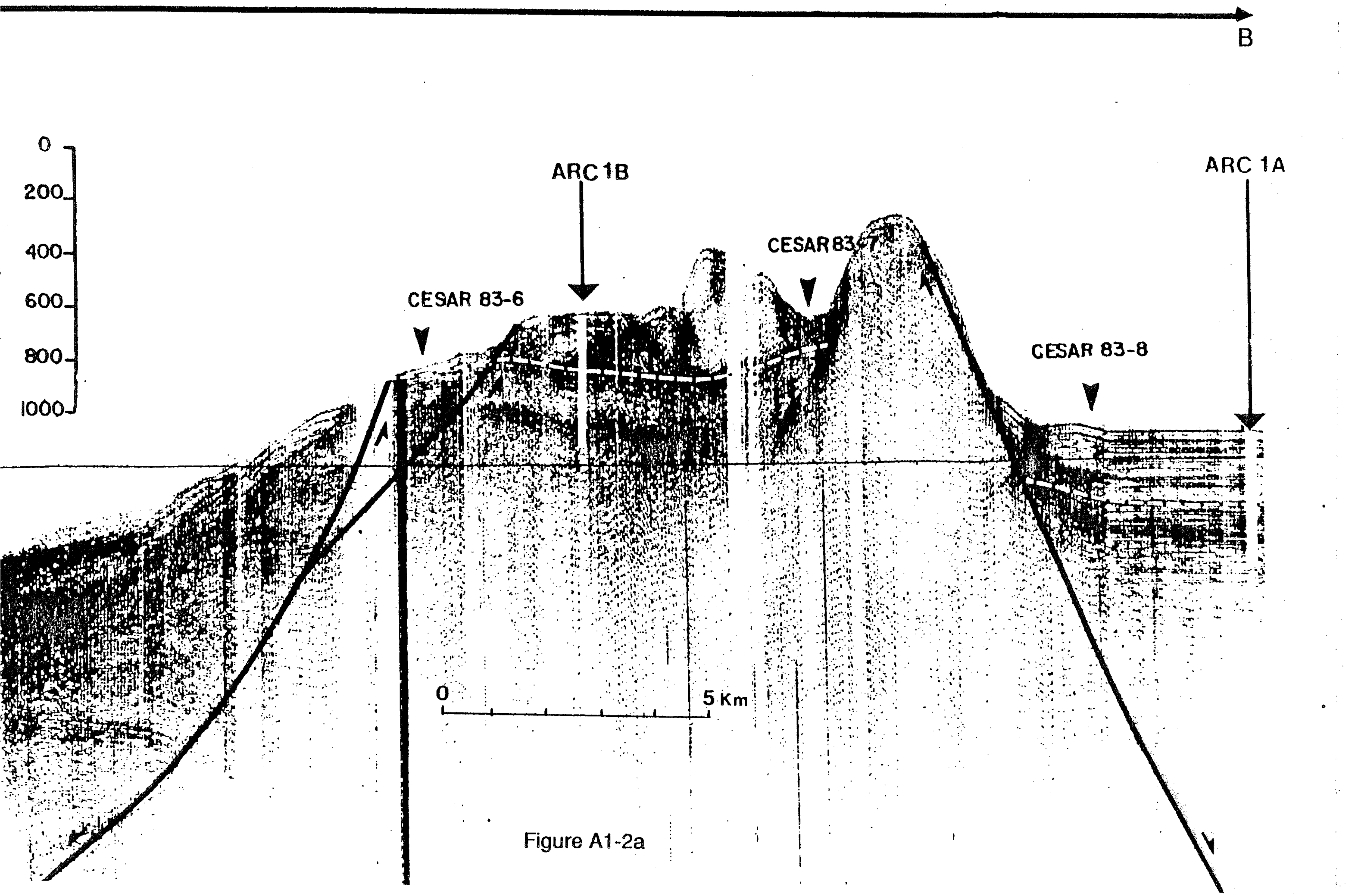

B
0
200
400
600
800
1000
ARC 1B
ARC 1A
CESAR 83-6
CESAR 83-7
CESAR 83-8
0
5 Km

Figure A1-2a

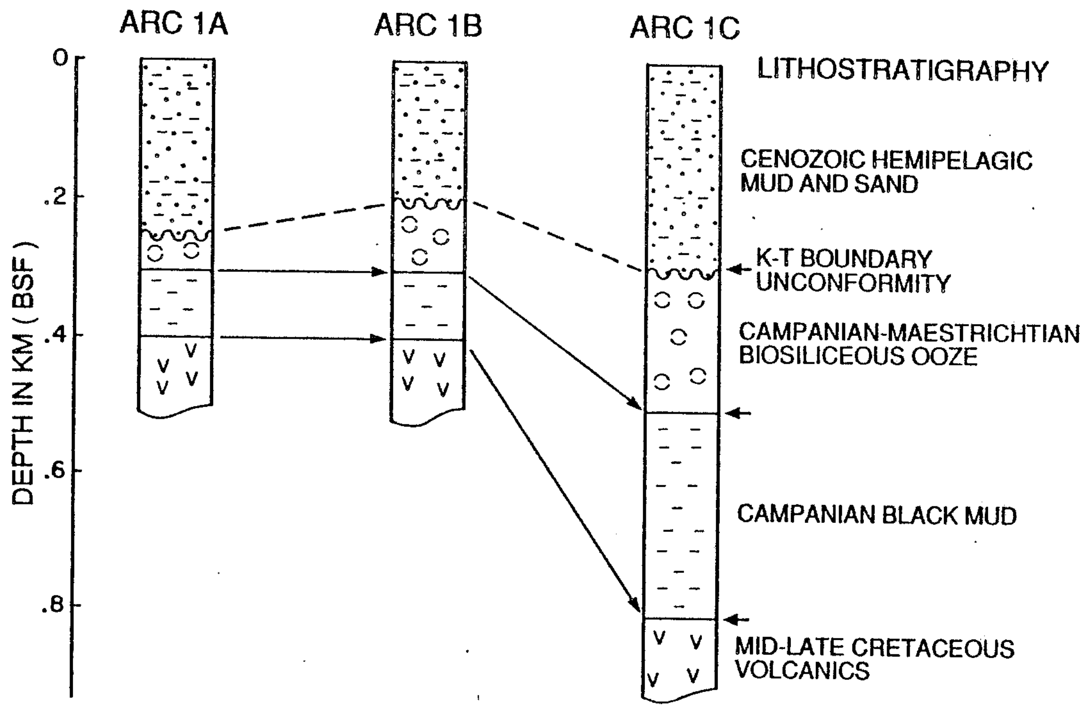

ARC 1A
ARC 1B
ARC 1C
LITHOSTRATIGRAPHY
0
.2
.4
.6
.8
DEPTH IN KM (BSF)
CENOZOIC HEMIPELAGIC MUD AND SAND
K-T BOUNDARY UNCONFORMITY
CAMPANIAN-MAESTRICHTIAN BIOSILICEOUS OOZE
CAMPANIAN BLACK MUD
MID-LATE CRETACEOUS VOLCANICS

FIGURE A1-2b

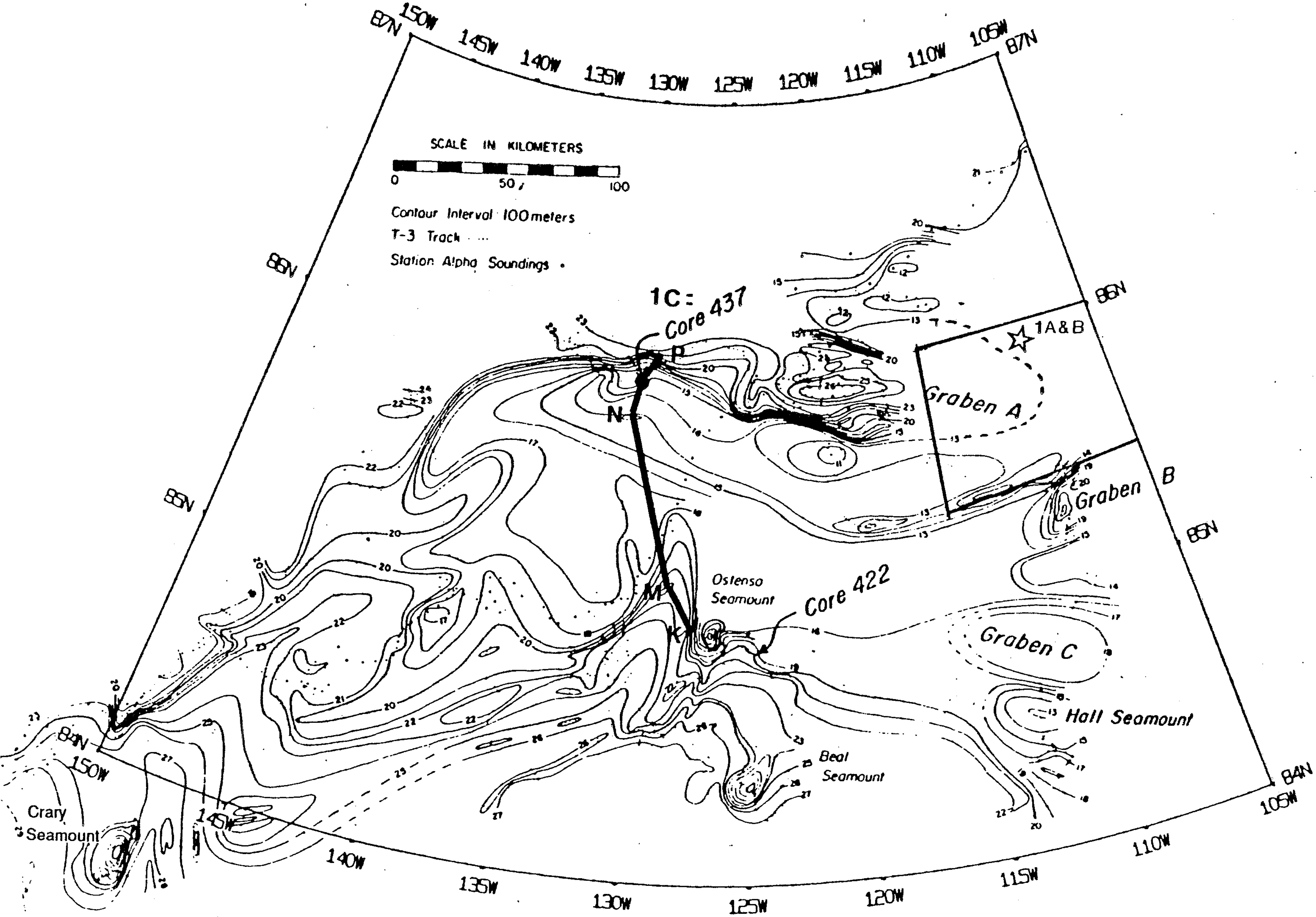

SCALE IN KILOMETERS
0
50
100
Contour Interval 100 meters
T-3 Track
Station Alpha Soundings
1C: Core 437
Core 422
1A&B
Graben A
Graben B
Graben C
Hall Seamount
Ostenso Seamount
Beal Seamount
Crary Seamount
87N
86N
85N
84N
150W
145W
140W
135W
130W
125W
120W
115W
110W
105W

Figure A1-3a

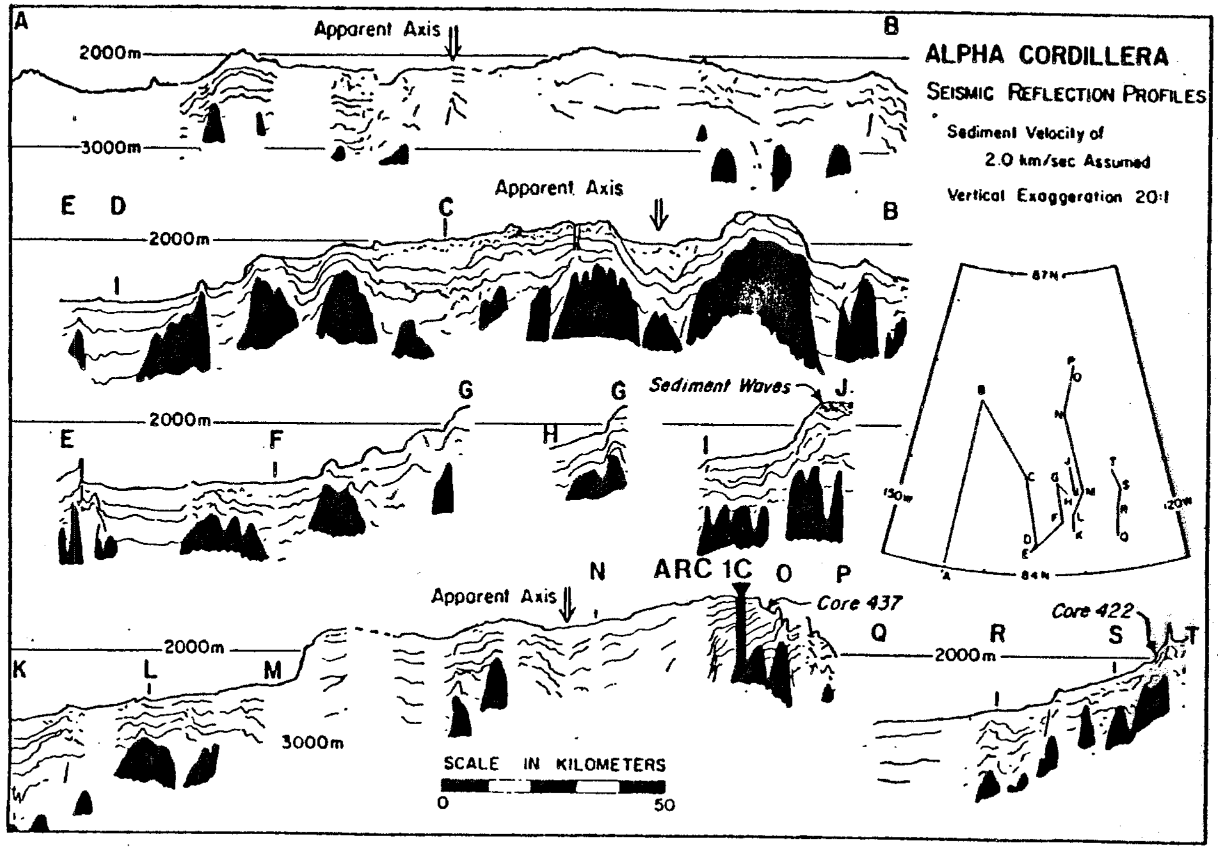
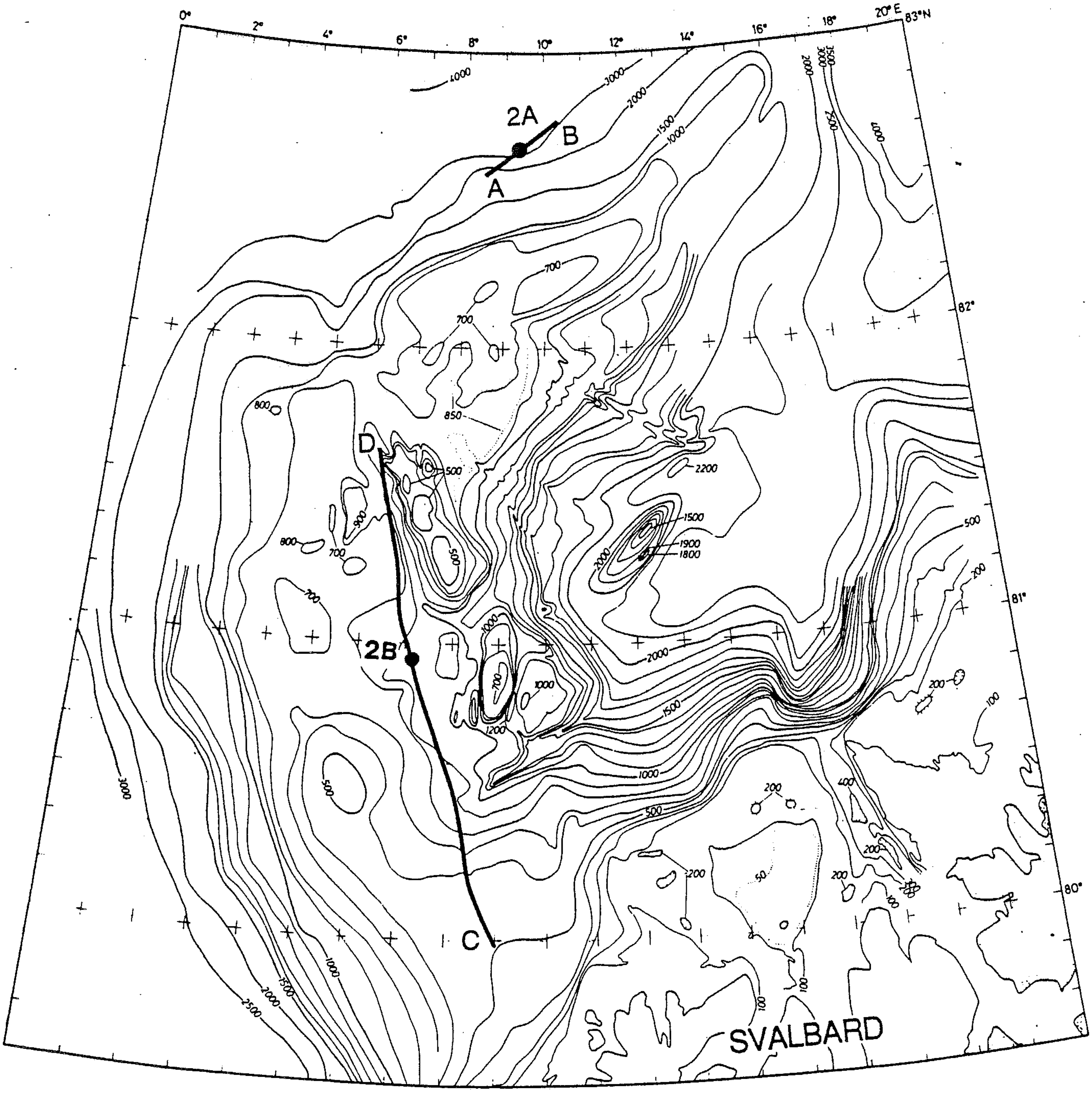

ALPHA CORDILLERA
SEISMIC REFLECTION PROFILES
Sediment Velocity of 2.0 km/sec Assumed
Vertical Exaggeration 20:1
Apparent Axis
Sediment Waves
ARC 1C
Core 437
Core 422
2000m
3000m
SCALE IN KILOMETERS
0
50

Figure A1-3b



0°
2°
4°
6°
8°
10°
12°
14°
16°
18°
20° E
83°N
82°
81°
80°
2A
A
B
2B
C
D
SVALBARD
4000
3000
2000
1500
1000
700
850
800
900
500
2200
1900
1800
1200
200
100
400
50
2500

Figure A2-1

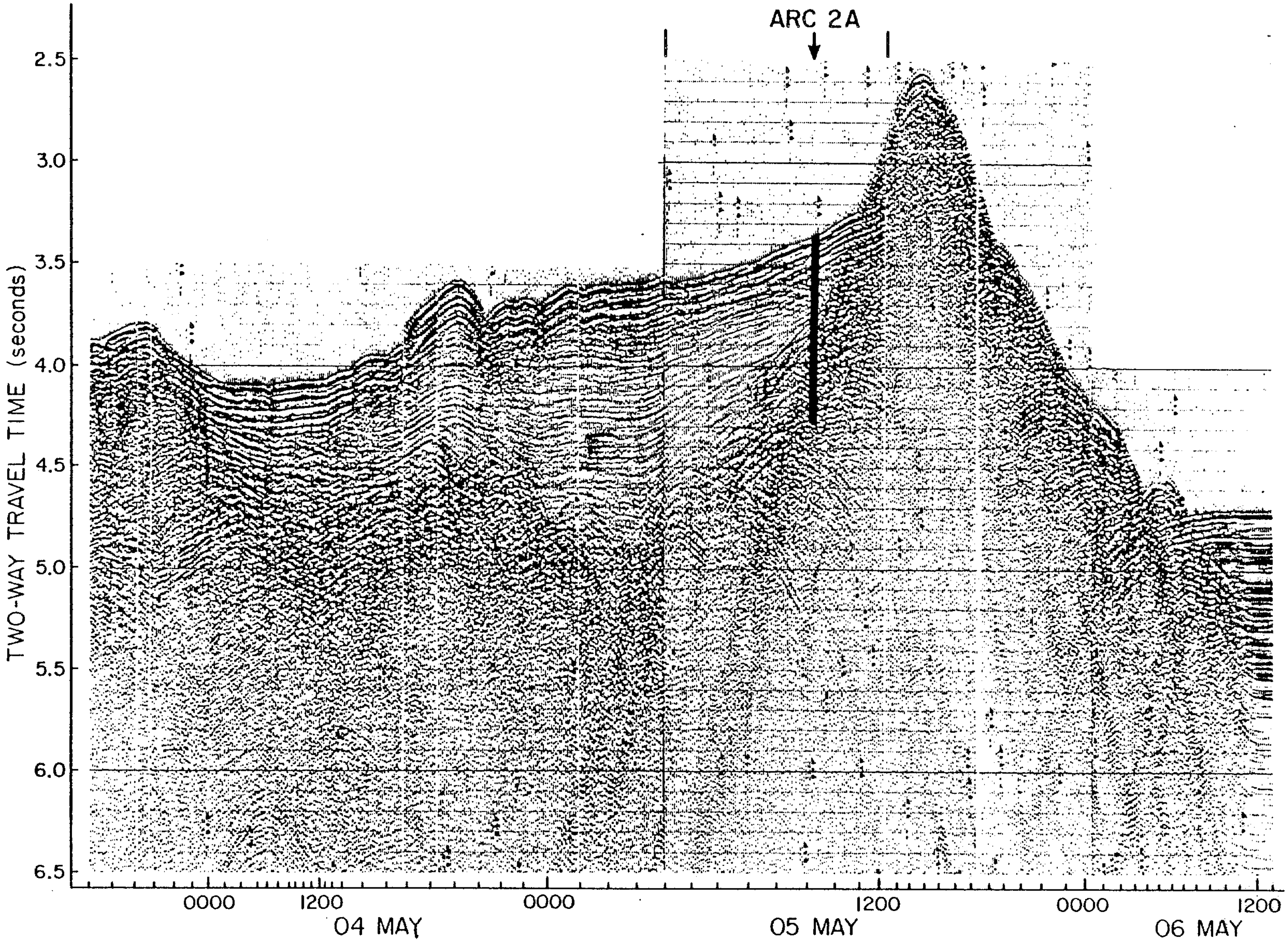

ARC 2A
TWO-WAY TRAVEL TIME (seconds)
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
0000
1200
04 MAY
0000
05 MAY
1200
0000
06 MAY
1200

Figure A2-2

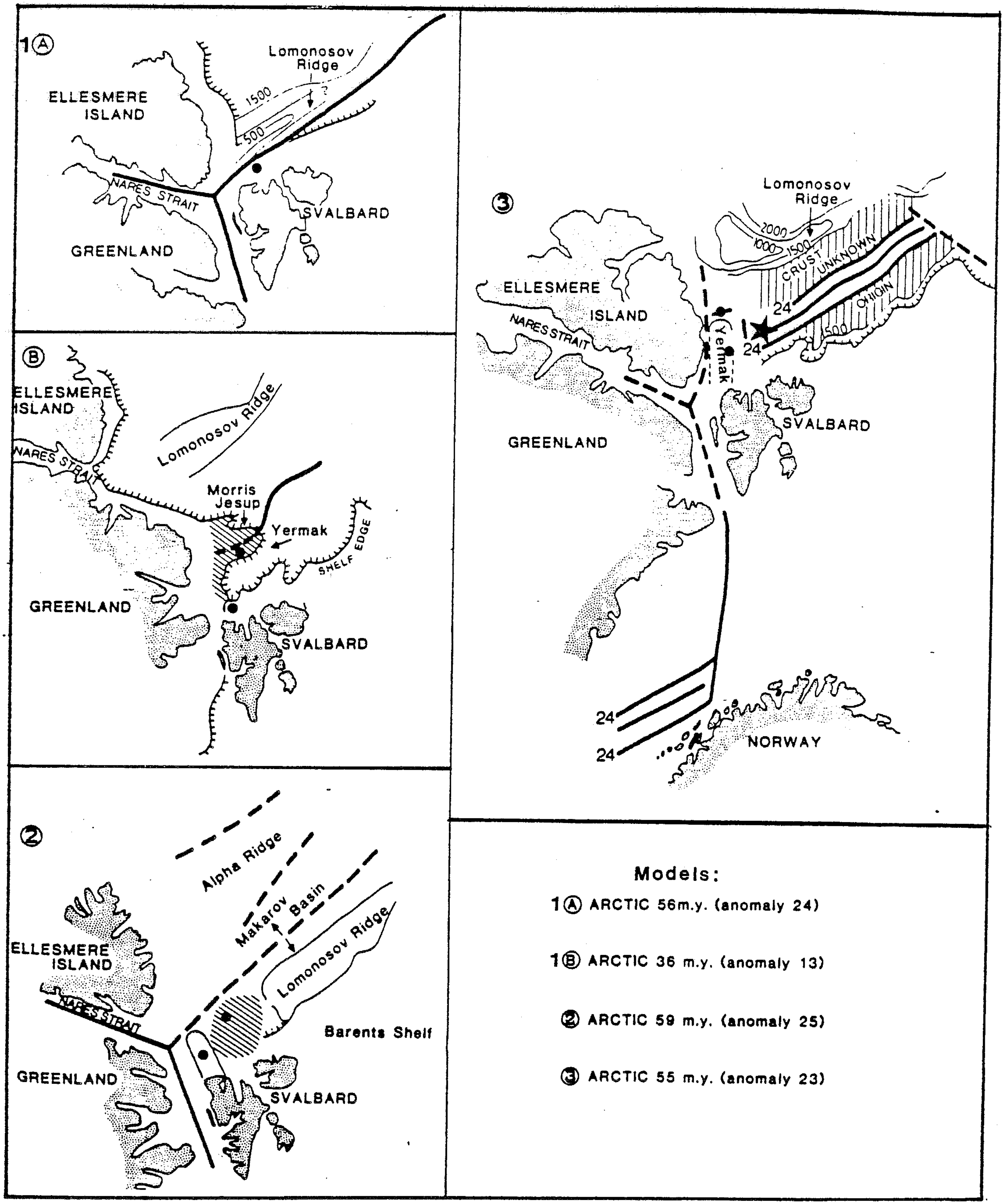
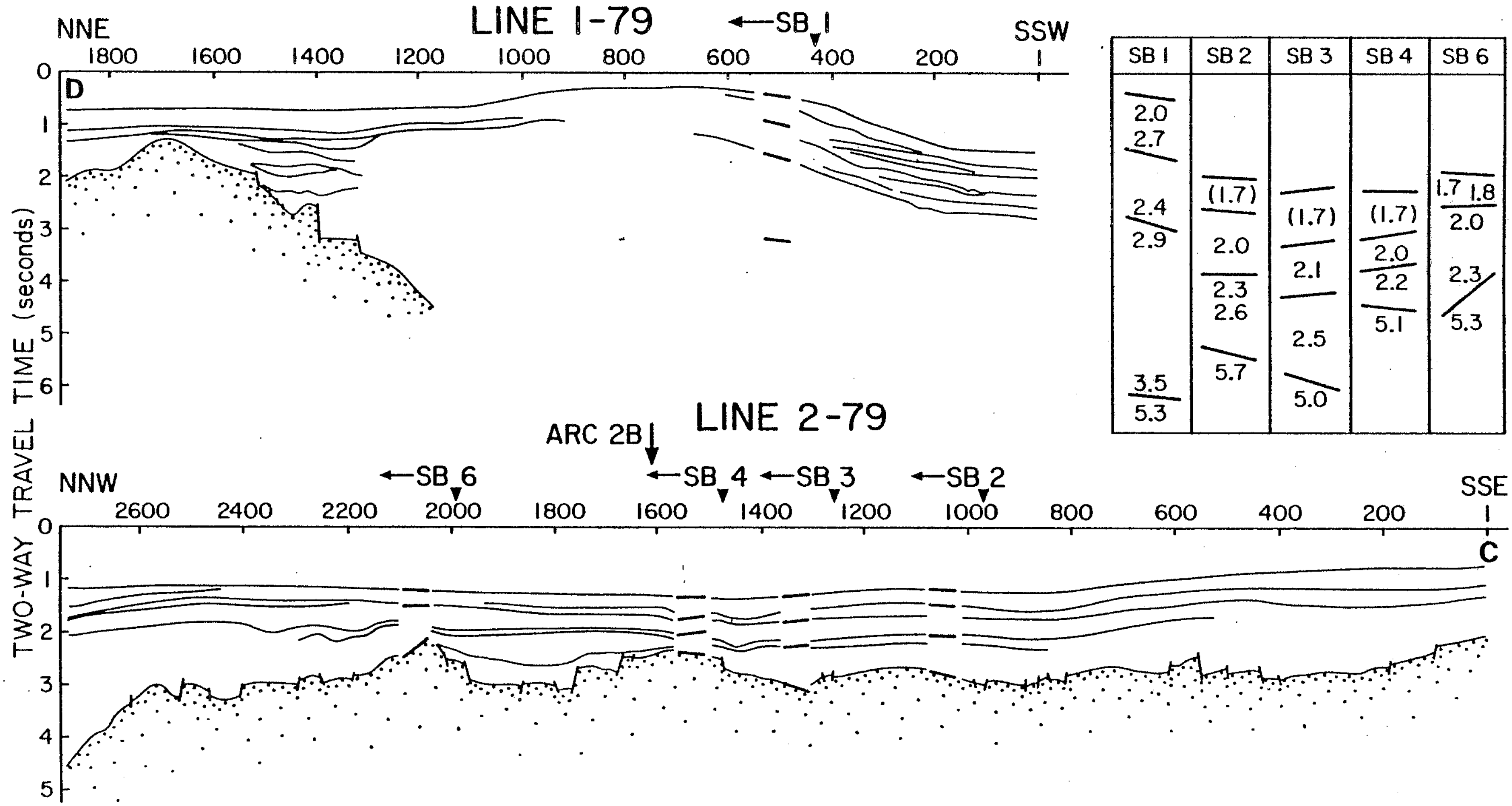

1Ⓐ
Lomonosov Ridge
ELLESMERE ISLAND
1500
500
NARES STRAIT
SVALBARD
GREENLAND
Ⓑ
ELLESMERE ISLAND
NARES STRAIT
Lomonosov Ridge
Morris Jesup
Yermak
SHELF EDGE
GREENLAND
SVALBARD
②
Alpha Ridge
Makarov Basin
Lomonosov Ridge
ELLESMERE ISLAND
NARES STRAIT
Barents Shelf
GREENLAND
SVALBARD
③
Lomonosov Ridge
2000
1000
1500
CRUST UNKNOWN ORIGIN
500
24
ELLESMERE ISLAND
NARES STRAIT
Yermak
SVALBARD
GREENLAND
NORWAY
Models:
1Ⓐ ARCTIC 56m.y. (anomaly 24)
1Ⓑ ARCTIC 36 m.y. (anomaly 13)
② ARCTIC 59 m.y. (anomaly 25)
③ ARCTIC 55 m.y. (anomaly 23)

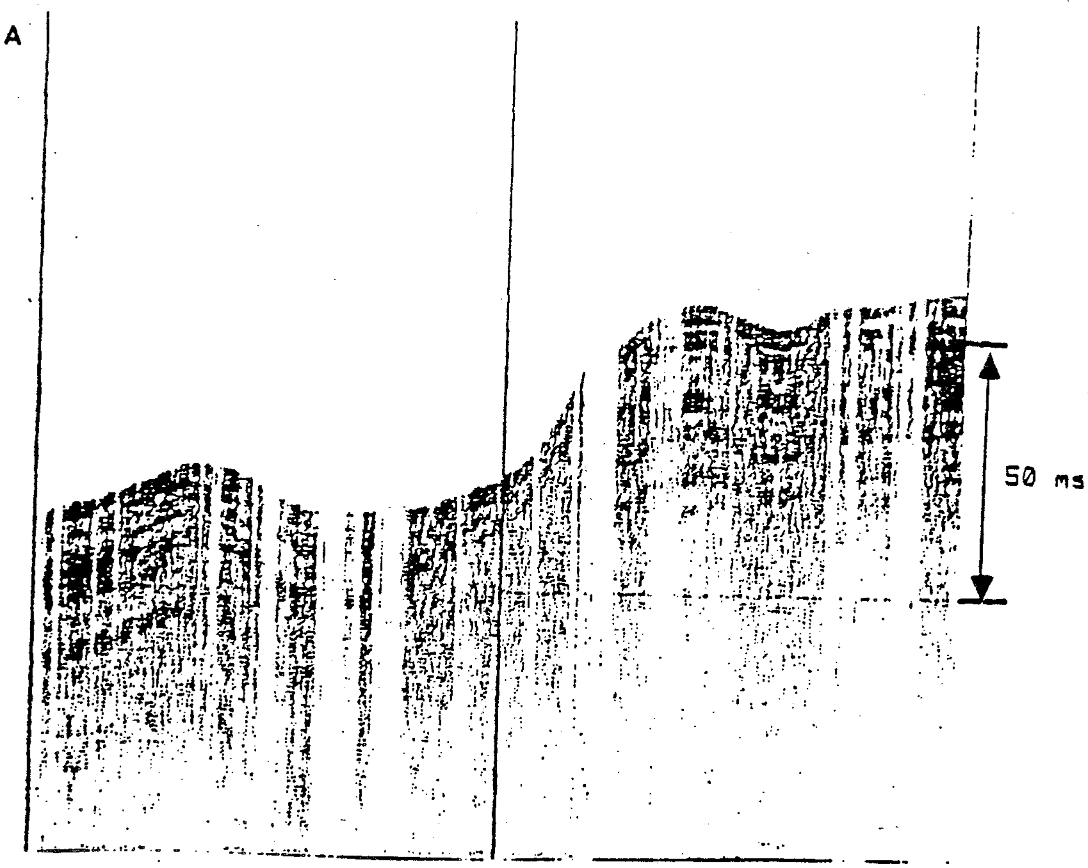
Figure A2 - 3



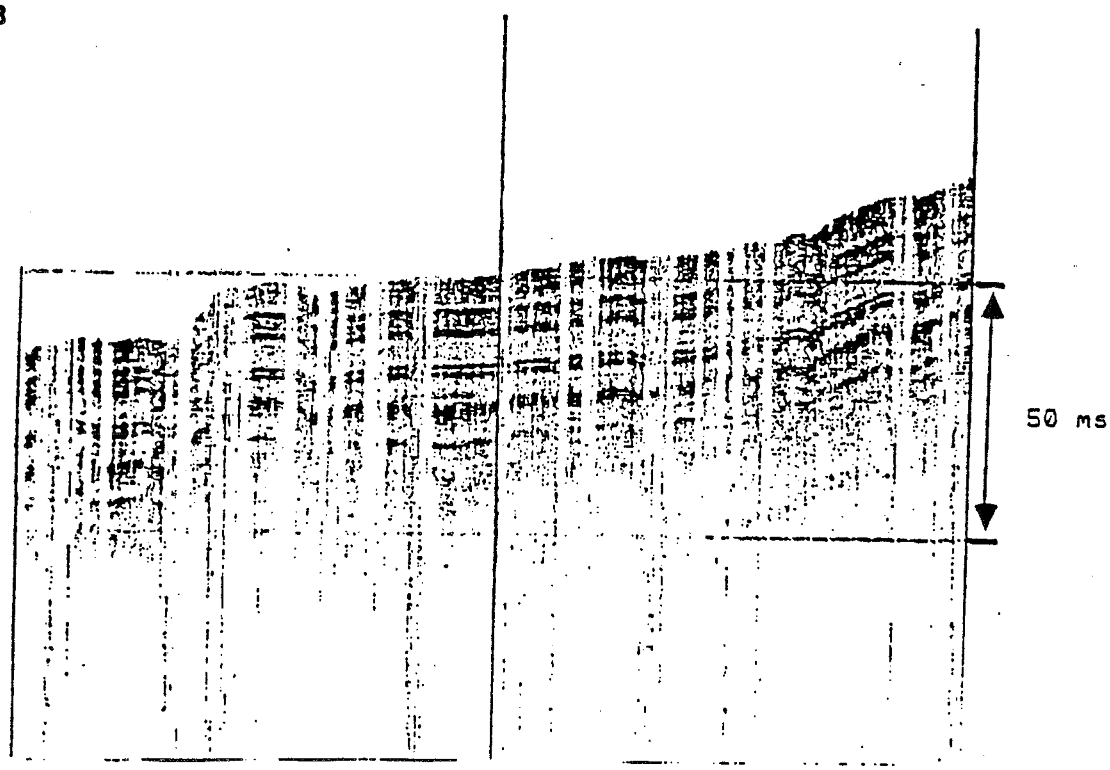
LINE 1-79
NNE
SSW
SB 1
1800
1600
1400
1200
1000
800
600
400
200
1
D
0
1
2
3
4
5
6
TWO-WAY TRAVEL TIME (seconds)
SB 1
SB 2
SB 3
SB 4
SB 6
2.0
2.7
2.4
2.9
3.5
5.3
(1.7)
2.0
2.3
2.6
5.7
(1.7)
2.1
2.5
5.0
(1.7)
2.0
2.2
5.1
1.7 1.8
2.0
2.3
5.3
LINE 2-79
ARC 2B
NNW
SSE
SB 6
SB 4
SB 3
SB 2
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
1
C
0
1
2
3
4
5

Figure A2-4

2-5A



2-5B



Sea Ice Distribution 1971 - 1980

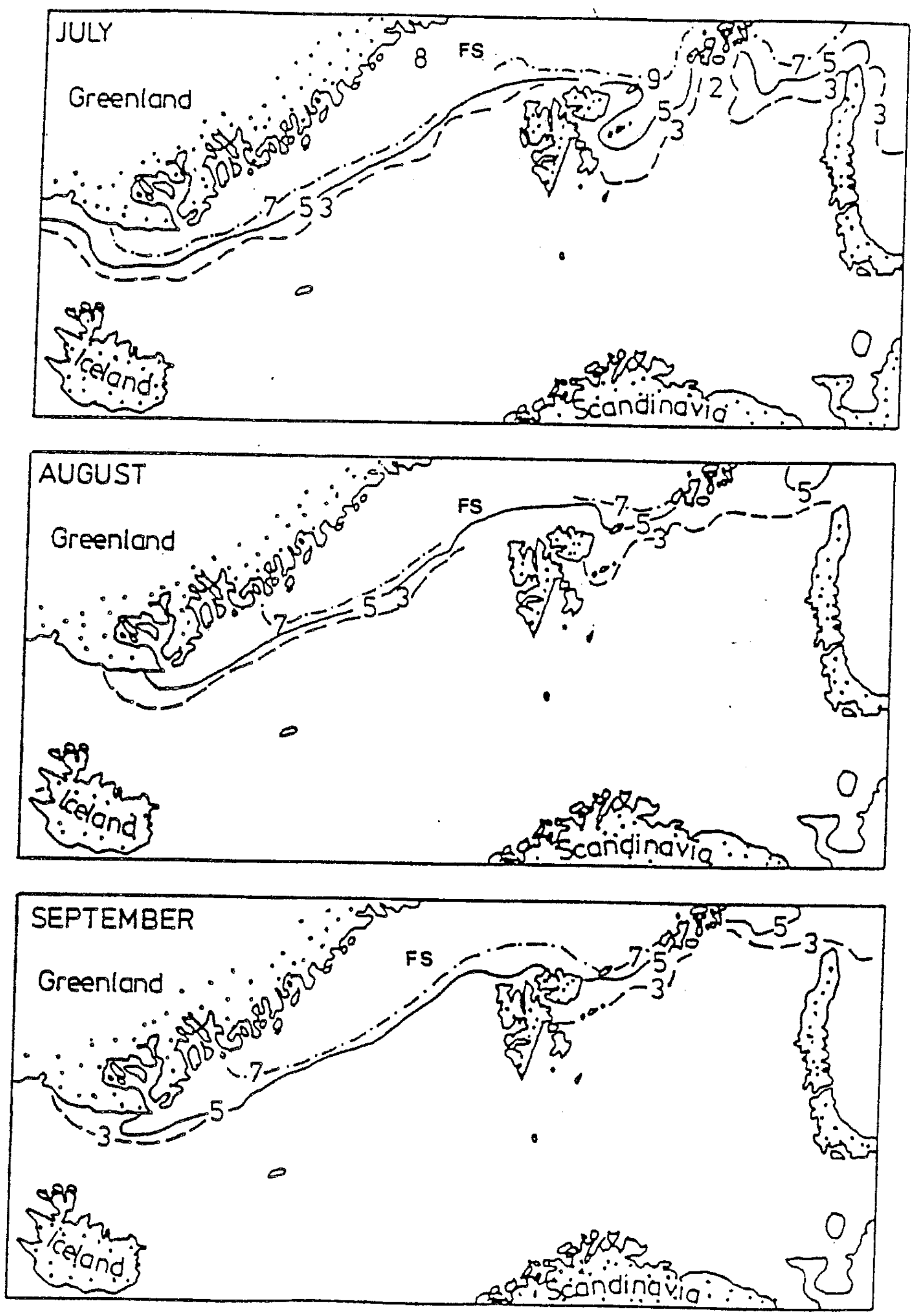


Figure A2-6

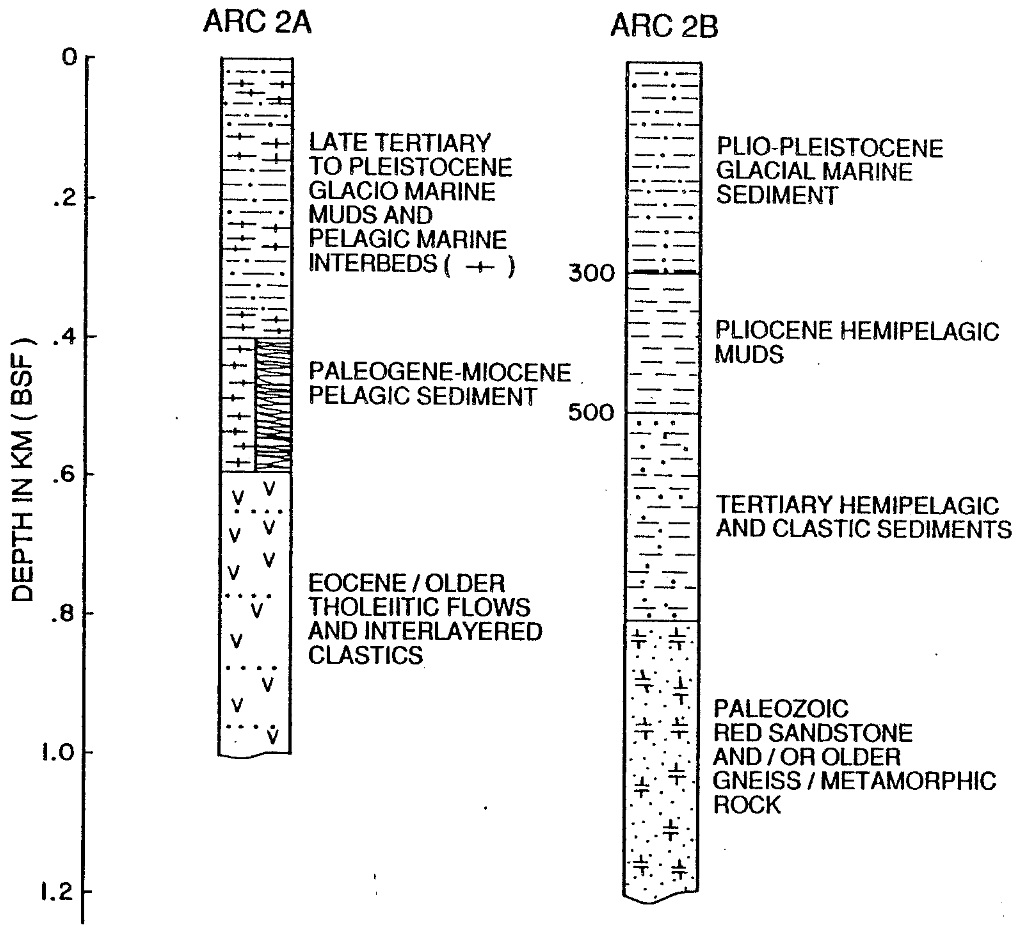

ARC 2A
ARC 2B
DEPTH IN KM (BSF)
0
.2
.4
.6
.8
1.0
1.2
LATE TERTIARY TO PLEISTOCENE GLACIO MARINE MUDS AND PELAGIC MARINE INTERBEDS (-+-)
PALEOGENE-MIOCENE PELAGIC SEDIMENT
EOCENE / OLDER THOLEIITIC FLOWS AND INTERLAYERED CLASTICS
300
500
PLIO-PLEISTOCENE GLACIAL MARINE SEDIMENT
PLIOCENE HEMIPELAGIC MUDS
TERTIARY HEMIPELAGIC AND CLASTIC SEDIMENTS
PALEOZOIC RED SANDSTONE AND / OR OLDER GNEISS / METAMORPHIC ROCK

FIGURE A2-7

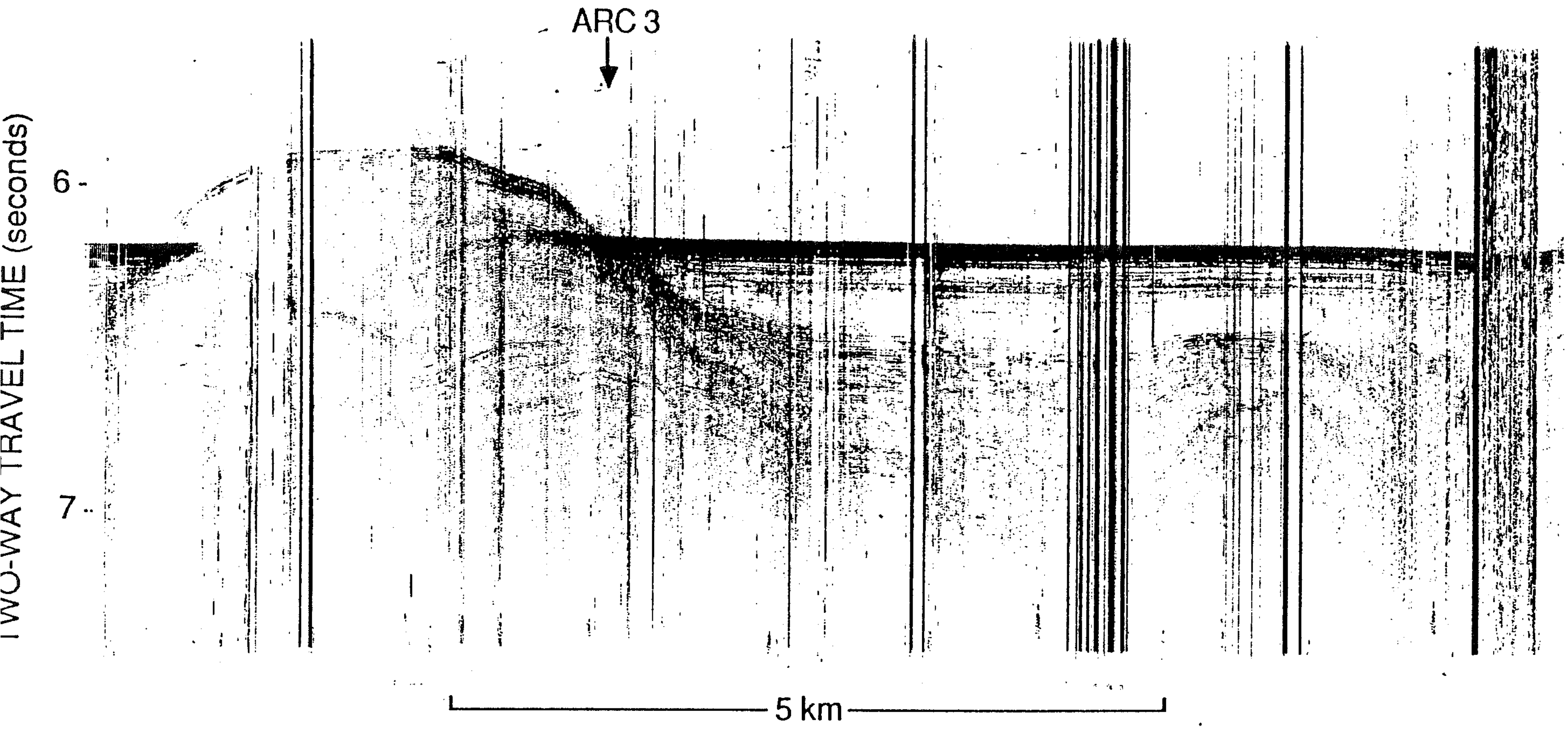
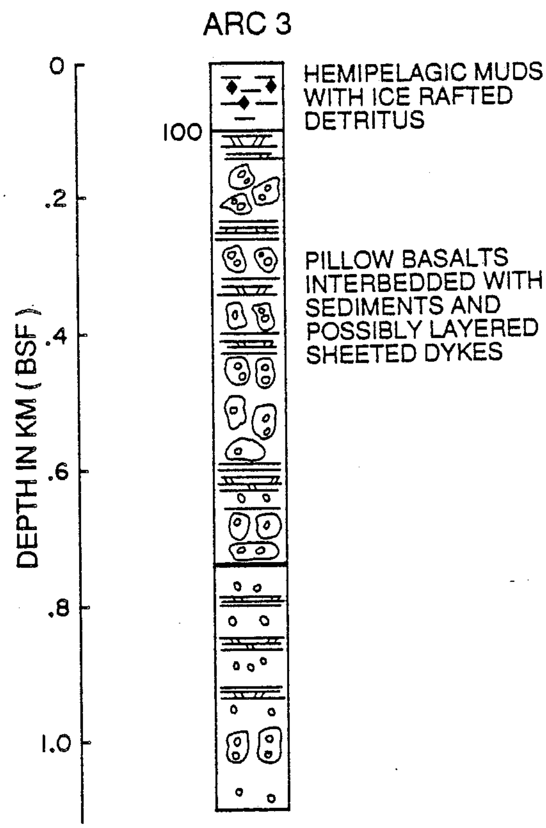
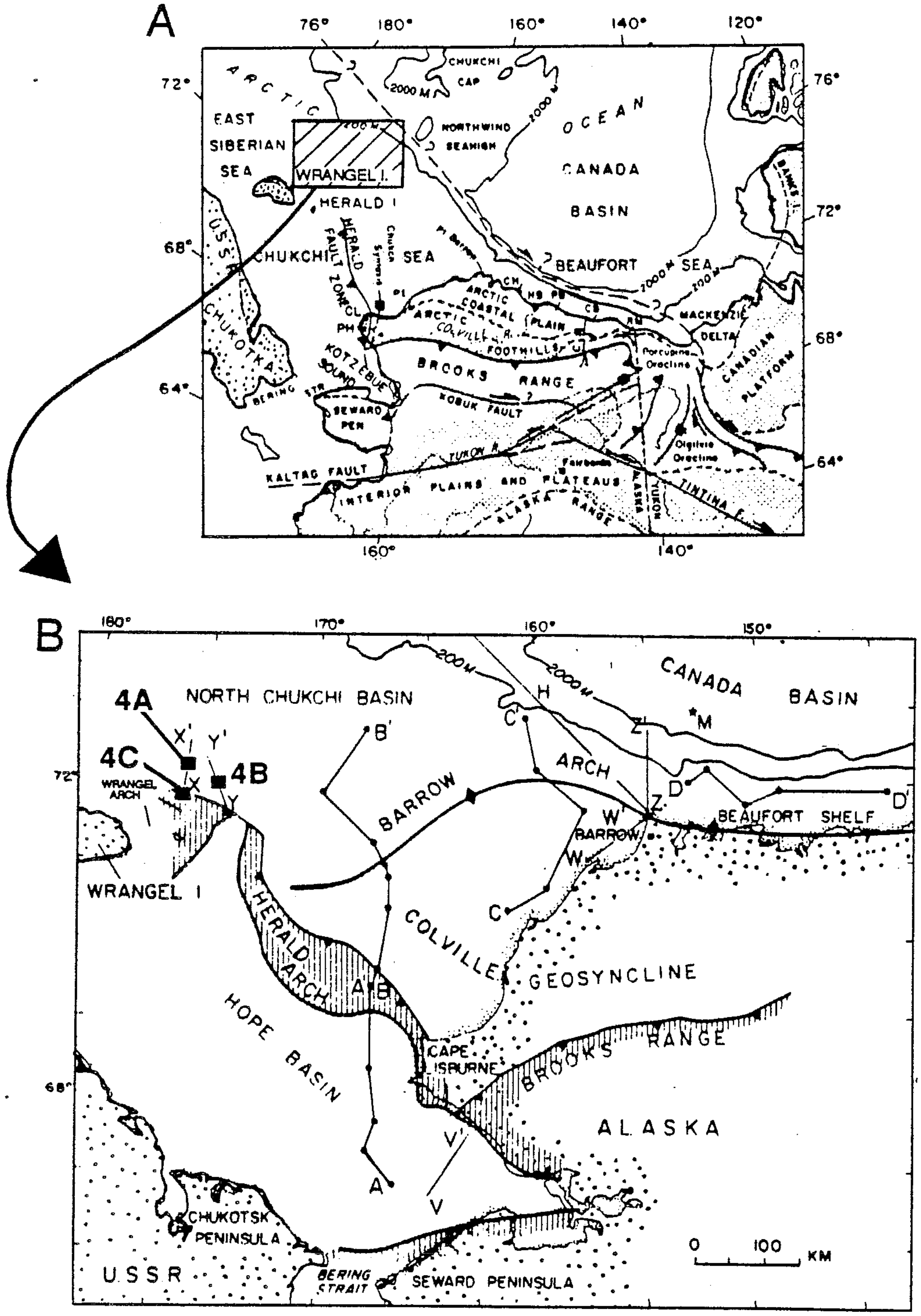


Figure A3-1



ARC 3
0
100
.2
.4
.6
.8
1.0
DEPTH IN KM (BSF)
HEMIPELAGIC MUDS WITH ICE RAFTED DETRITUS
PILLOW BASALTS INTERBEDDED WITH SEDIMENTS AND POSSIBLY LAYERED SHEETED DYKES

FIGURE A3-2



A
B
EAST SIBERIAN SEA
WRANGEL I.
HERALD I
CHUKCHI SEA
BEAUFORT SEA
CANADA BASIN
OCEAN
BROOKS RANGE
KALTAG FAULT
INTERIOR PLAINS AND PLATEAUS
NORTH CHUKCHI BASIN
4A
4B
4C
WRANGEL ARCH
BARROW ARCH
HERALD ARCH
HOPE BASIN
COLVILLE GEOSYNCLINE
CAPE LISBURNE
ALASKA
BEAUFORT SHELF
CHUKOTSK PENINSULA
U.S.S.R
BERING STRAIT
SEWARD PENINSULA
0 100 KM

Figure A4-1

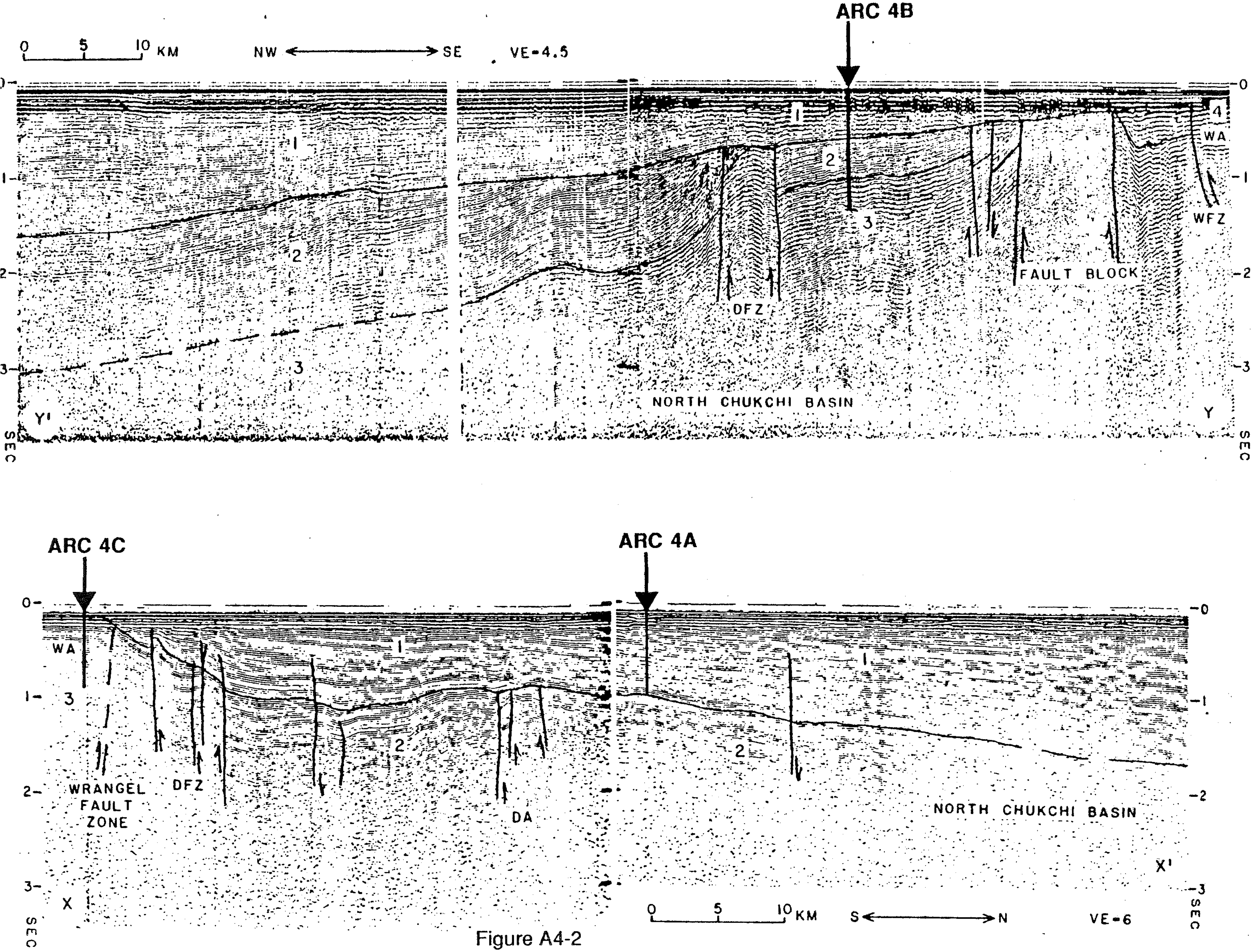

ARC 4B
0 5 10 KM
NW SE
VE-4.5
1
2
3
4
WA
WFZ
FAULT BLOCK
DFZ
NORTH CHUKCHI BASIN
Y'
Y
SEC
ARC 4C
ARC 4A
WA
WRANGEL FAULT ZONE
DFZ
DA
NORTH CHUKCHI BASIN
X
X'
0 5 10 KM
S N
VE-6
SEC

Figure A4-2

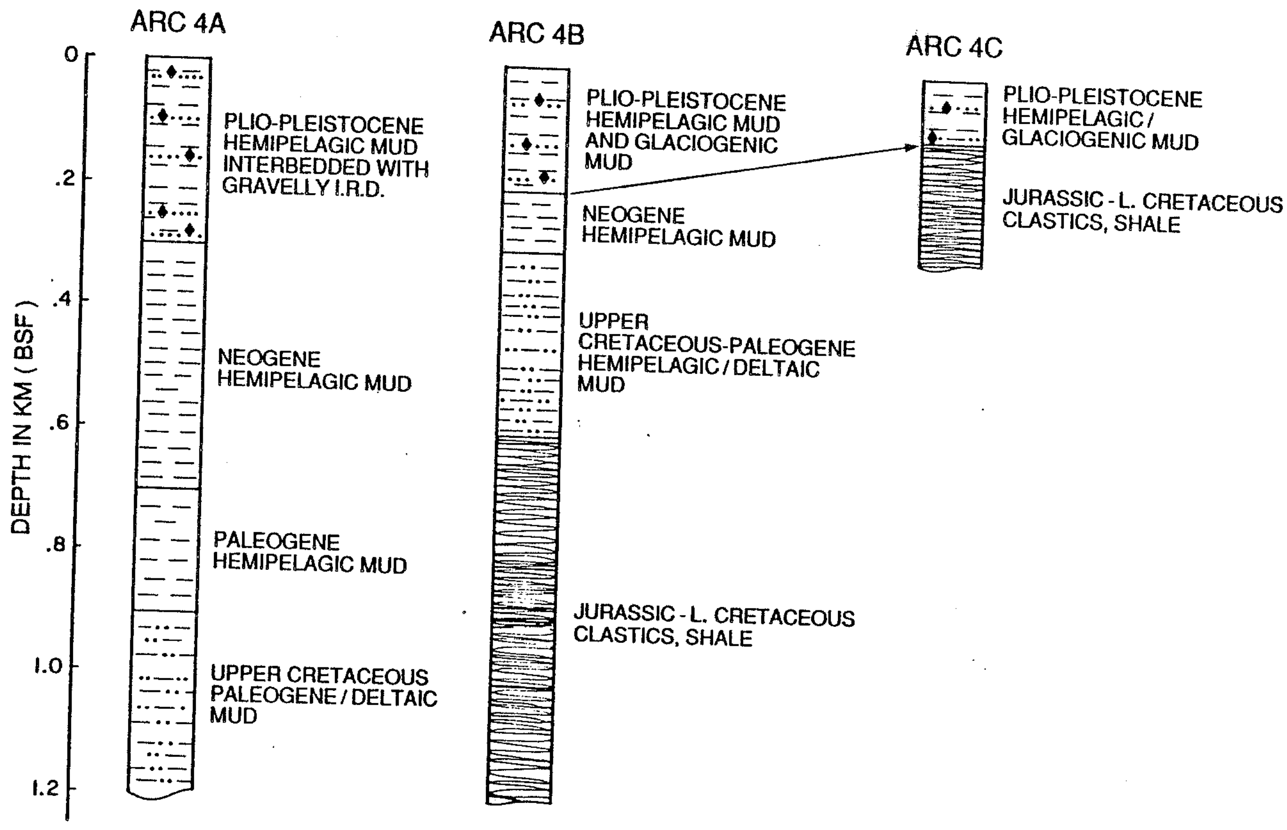

ARC 4A
ARC 4B
ARC 4C
DEPTH IN KM (BSF)
0
.2
.4
.6
.8
1.0
1.2
PLIO-PLEISTOCENE HEMIPELAGIC MUD INTERBEDDED WITH GRAVELLY I.R.D.
NEOGENE HEMIPELAGIC MUD
PALEOGENE HEMIPELAGIC MUD
UPPER CRETACEOUS PALEOGENE / DELTAIC MUD
PLIO-PLEISTOCENE HEMIPELAGIC MUD AND GLACIOGENIC MUD
NEOGENE HEMIPELAGIC MUD
UPPER CRETACEOUS-PALEOGENE HEMIPELAGIC / DELTAIC MUD
JURASSIC - L. CRETACEOUS CLASTICS, SHALE
PLIO-PLEISTOCENE HEMIPELAGIC / GLACIOGENIC MUD
JURASSIC - L. CRETACEOUS CLASTICS, SHALE

FIGURE A4-3

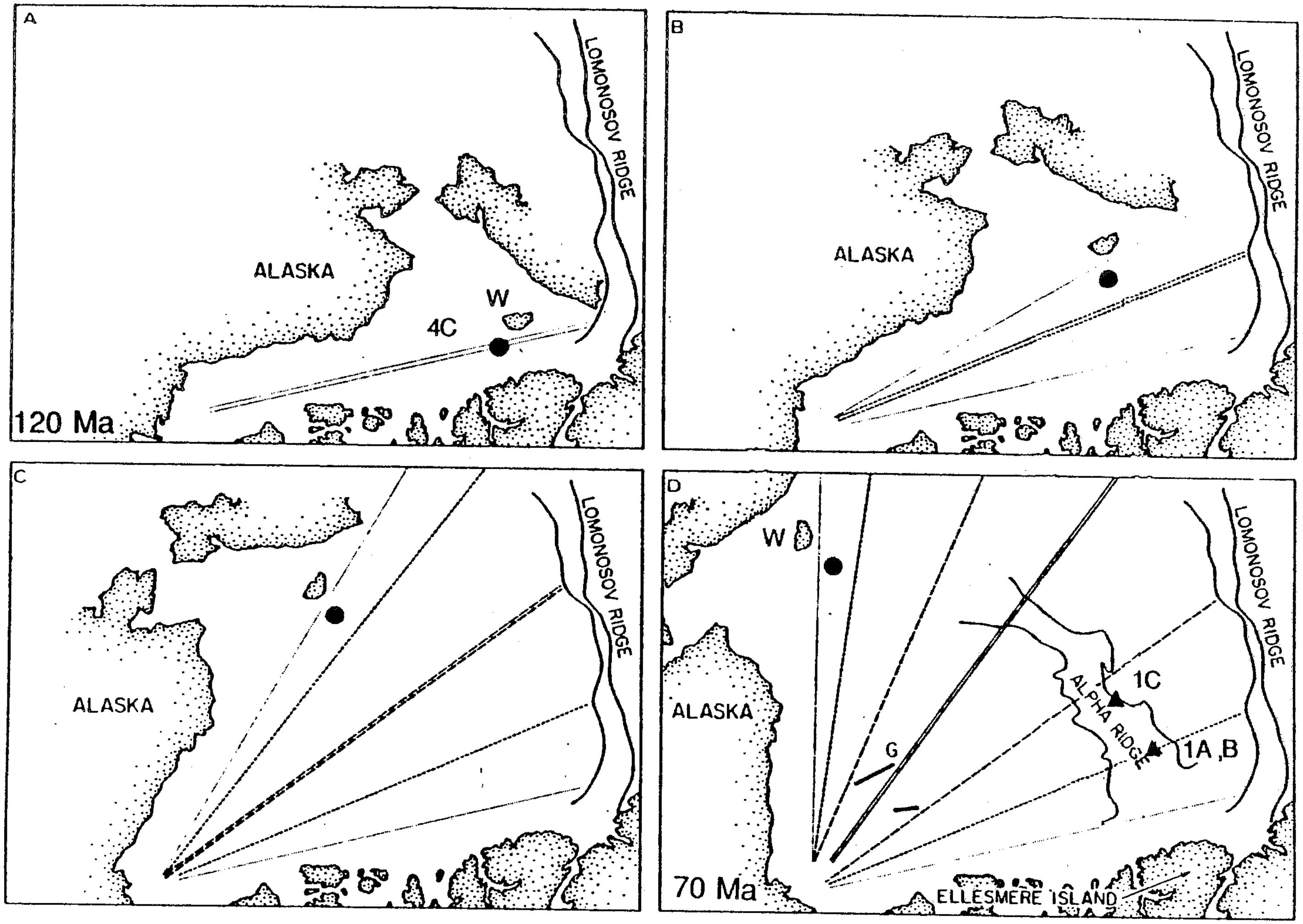

A
120 Ma
ALASKA
W
4C
LOMONOSOV RIDGE
B
ALASKA
LOMONOSOV RIDGE
C
ALASKA
LOMONOSOV RIDGE
D
70 Ma
W
ALASKA
G
ALPHA RIDGE
1C
1A,B
ELLESMERE ISLAND
LOMONOSOV RIDGE

Figure A4-4

PART III: PROPOSED SCIENTIFIC DRILL SITES

PART III

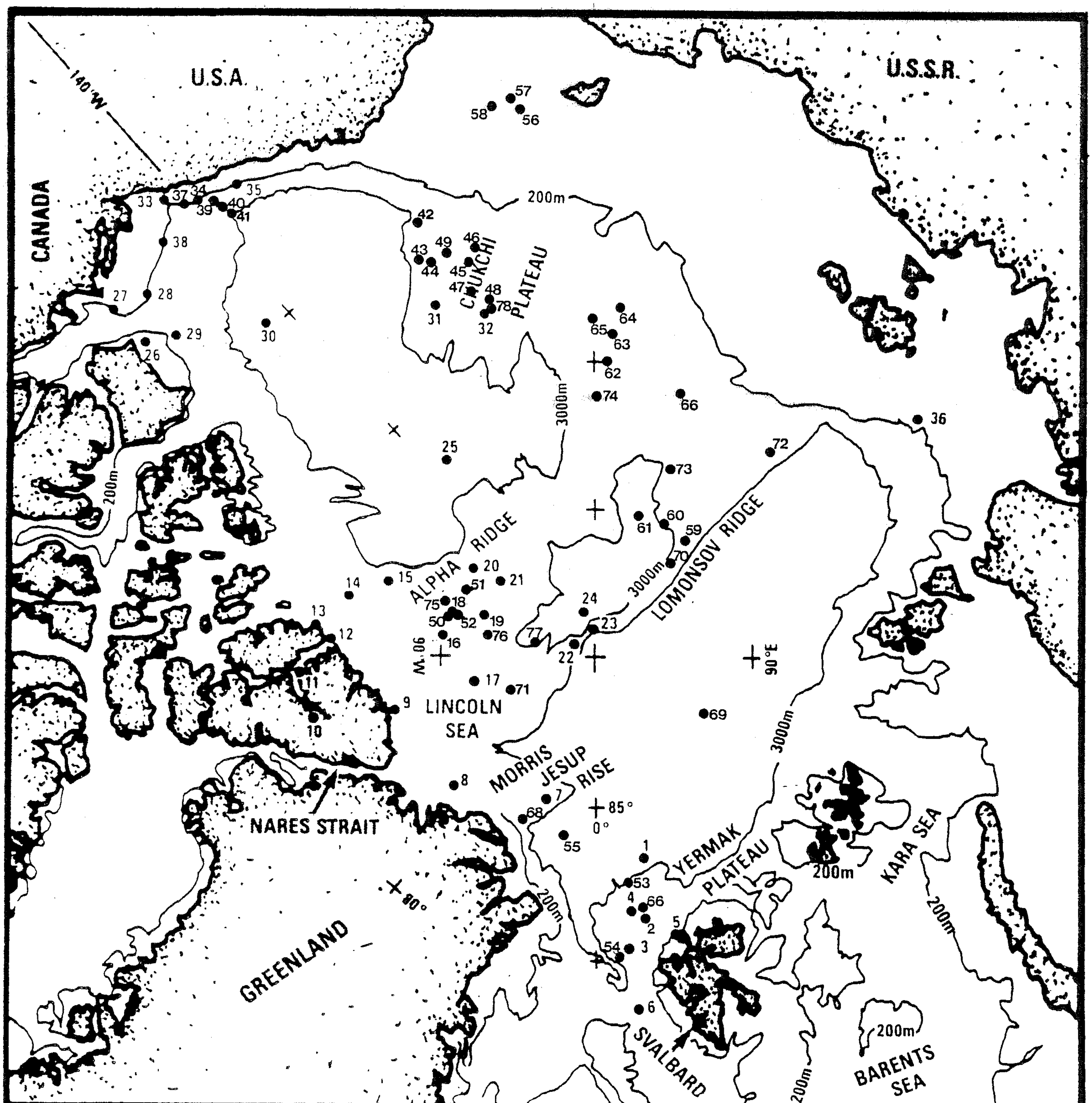
A. Map showing locations of site proposed for Arctic drilling.

B. Table of site locations and water depths.

C. List of new site proposed by USSR.

D. Site summaries for drilling targets proposed by W. Germany.

E. Site summaries for drilling targets proposed by Canada.



Numbers on this map mark proposed sites for scientific drilling in the Arctic Ocean. (From Office of Naval Research)

POTENTIAL ARCTIC DRILLING LOCATION

LOCATION #	LATITUDE	LONGITUDE	WATER DEPTH
1	83° 18'N	13° 00'E	3700m
2	81° 10'N	10° 10'E	2300m
3	80° 20'N	05° 30'E	900m
4	81° 30'N	07° 00'E	800m
5	80° 25'N	16° 00'E	300m
6	78° 20'N	06° 00'E	2000m
7	85° 00'N	20° 00'W	800m
8	84° 00'N	47° 00'W	400m
9	83° 00'N	73° 30'W	200m
10	80° 50'N	78° 00'W	200m
11	80° 30'N	86° 00'W	600m
12	81° 30'N	94° 00'W	300m
13	81° 00'N	97° 00'W	164m
14	82° 00'N	104° 30'W	2000m
15	83° 00'N	110° 30'W	2000m
16	85° 05'N	99° 30'W	1800m
17	86° 05'N	78° 00'W	2000m
18	85° 10'N	109° 00'W	1800m
19	86° 30'N	111° 00'W	2300m
20	85° 00'N	125° 00'W	2000m
21	86° 30'N	129° 00'W	1500m
22	89° 20'N	120° 00'W	1500m
23	89° 10'N	165° 00'W	1600m
24	88° 30'N	165° 00'W	4000m
25	81° 50'N	145° 00'W	3000m
26	72° 30'N	126° 30'W	100m
27	71° 00'N	126° 30'W	200m
28	71° 30'N	131° 00'W	200m
29	73° 00'N	129° 00'W	750m
30	74° 50'N	137° 00'W	3400m
31	77° 10'N	157° 00'W	600m
32	78° 00'N	163° 00'W	500m
33	69° 40'N	138° 00'W	200m
34	70° 30'N	141° 00'W	200m
35	70° 50'N	145° 00'W	200m
36	77° 00'N	127° 30'E	200m
37	70° 10'N	139° 30'W	200m
38	70° 50'N	136° 00'W	750m
39	70° 58'N	143° 00'W	2400m
40	71° 08'N	143° 00'W	2600m
41	71° 21'N	143° 00'W	2800m
42	74° 21'N	160° 24'W	500m
43	75° 48'N	157° 48'W	500m
44	75° 47'N	159° 12'W	2000m
45	76° 12'N	164° 42'W	500m
46	76° 05'N	166° 48'W	300m
47	77° 43'N	164° 00'W	300m
48	77° 48'N	167° 18'W	300m
49	75° 42'N	161° 48'W	2000m

POTENTIAL ARCTIC DRILLING LOCATION

LOCATION #	LATITUDE	LONGITUDE	WATER DEPTH
50-1A	85° 49.8'N	109° 9.2'W	1365m
51-1B	85° 59.87'N	129° 58.76'W	1584m
52-1C	85° 15.0'N	109° 0.0'W	1855m (18)
53-2A	82° 41.6'N	9° 32.7'E	1400m
54-2B	80° 53.0'N	7° 19.0'E	800m
55-3	84° 18.0'N	8° 6.5'W	3894m
56-4A	72° 10.0'N	170° 30.0'W	150m
57-4B	72° 0.0'N	170° 30.0'W	100m
58-4C	72° 0.5'N	169° 50.0'W	150m
59-CKB I	85° 0.0'N	147° 0.0'E	
60-CKB 2	85° 0.0'N	155° 45.0'E	
61-CKB 3	85° 0.0'N	164° 0.0'E	
62-CKB 4	80° 0.0'N	178° 0.0'E	
63-CKB 5	79° 15.0'N	177° 0.0'E	
64-CKB 6	78° 0.0'N	175° 0.0'E	
65-CKB 7	78° 50.0'N	180° 0.0'E	
66-CKB 8	80° 50.0'N	163° 30.0'E	
67	81° 40.0'N	8° 0.0'E	500m
68	84° 40.0'N	20° 0.0'W	1000m
69	86° 40.0'N	60° 0.0'E	2000m
70	86° 30.0'N	148° 0.0'E	1000m
71	85° 30.0'N	60° 0.0'E	500m
72	81° 30.0'N	141° 0.0'E	1000m
73	83° 20.0'N	160° 0.0'E	2500m
74	81° 0.0'N	180° 0.0'W	1800m
75	85° 0.0'N	110° 0.0'W	1400m
76	86° 30.0'N	110° 0.0'W	1100m
77	88° 0.0'N	110° 0.0'W	3000m
78	78° 0.0'N	162° 0.0'W	500m

Region
Участок № I. Хребет Ломоносова
Lomonosov Ridge

Site Скв. I.	85^{0} с.ш.,	147^{0} в.д. ✓
Скв. 2.	85^{0} с.ш.,	$155^{0}45'$ в.д.
Скв. 3.	85^{0} с.ш.,	164^{0} в.д.

Region
Участок № 2. Хребет Менделеева
Mendeleev Ridge

Скв. 4.	80^{0} с.ш.,	178^{0} з.д.
Скв. 5.	$79^{0}15'$ с.ш.,	177^{0} з.д.
Скв. 6.	$78^{0}25'$ с.ш.,	175^{0} з.д.
Скв. 7.	$78^{0}50'$ с.ш.,	180^{0} - мерид.

Region
Участок № 3. Абисс. равнина Менделеева
Mendeleev abyssal plain

Скв. 8.	$80^{0}50'$ с.ш.,	$163^{0}30'$ з.д.

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site:	General Objective:
Yermak Plateau	Paleoceanography, Tectonics

General Area: Arctic Ocean
Position: 81 40'N 8 E
Alternate Site: 80 30 N 6 E

Thematic Panel Interest:

Specific Objectives:

Objectives are to reconstruct the timing and the establishment of the deep-water connection between the Arctic Ocean and the Norwegian-Greenland Sea. Evidently, this is in context with the tectonic and physiographic evolution of the Yermak Plateau, the Morris-Jesup Rise, and the opening of the Fram Strait. The depth-age relationship of the plateau and the rise, an extremely important variable for ocean circulation, the faunal changes, the current influenced sedimentological changes, and unconformities will be studied to determine the Neogene history of the water flow between the Norwegian-Greenland Sea and the Arctic Ocean. Another important target is to determine the nature and the age of the basement which is critical to the paleogeographic reconstruction.

Site Specific Survey Data:

Multi-channel seismic lines (Yngve Kristoffersen, Norway)

Other Data:

Operational Considerations:

Water Depth:(m) 500 ____ Sed. Thickness:(m) .5 sec Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated: silica-rich sediments

Weather conditions/window: September

Territorial jurisdiction: Norway

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site:

Chukchi Plateau

General Objective:

Tectonics, Paleoceanography

General Area: Western Arctic Ocean
Position: 78 N 162 W
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Objectives are to determine the nature and the depth evolution of the Chukchi Plateau, an area which is critical for reconstructing the paleogeography of the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 500 ____ Sed. Thickness:(m) ____ Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Makarov Basin

General Objective: Paleoceanography, Tectonics

General Area: Central Arctic Basin
Position: 83 20' N 160 E
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

The main objective is to determine the development of the Makarov Basin since the Cretaceous, and how it influenced the circulation patterns. Of particular interest is 1) to reconstruct changes in the geometry of the sea floor which requires knowledge of the ocean floor basement ages and the oceanic lithosphere cooling rates, and 2) to reconstruct changes in the oceanic environment through time especially in comparison to the Amundsen Basin. These reconstructions will yield a key for deciphering the early history of the paleoceanographic and paleogeographic evolution of the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 2500 Sed. Thickness:(m) ______ Tot. penetration:(m) ____

HPC ____ Double HPC ____ Rotary Drill ____ Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert / S. Pfirman / J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Alpha-Mendeleyev Ridge /Makarov Basin

General Objective: Paleoceanography, Tectonics

General Area: Central Arctic Ocean
Position: 88 N 110 W
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Main objectives are to determine: how the Arctic Ocean behaved during the early Cretaceous, and how it has developed since then. Of particular interest is 1) to reconstruct changes in the geometry of the sea floor which requires knowledge of the ocean floor basement ages and the oceanic lithosphere cooling rates, and 2) to reconstruct changes in the oceanic environment through time. These reconstructions will yield a key for deciphering the early history of the paleogeographic and paleoceanographic evolution of the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 3000 ____ Sed. Thickness:(m) ______ Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Alpha-Mendeleyev Ridge

General Objective: Paleoceanography, Tectonics

General Area: Central Arctic Ocean
Position: 85 N 110 W
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Main objectives are to determine: how the Arctic Ocean behaved during the early Cretaceous, and how it has developed since then. Of particular interest is 1) to reconstruct changes in the geometry of the sea floor which requires knowledge of the ocean floor basement ages and the oceanic lithosphere cooling rates, and 2) to reconstruct changes in the oceanic environment through time. These reconstructions will yield a key for deciphering the early history of the paleogeographic and paleoceanographic evolution of the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 1400 ____ Sed. Thickness:(m) ______ Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Alpha-Mendeleyev Ridge

General Objective: Paleoceanography, Tectonics

General Area: Central Arctic Ocean
Position: 81 N 180 W
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Main objectives are to determine: how the Arctic Ocean behaved during the early Cretaceous, and how it has developed since then. Of particular interest is 1) to reconstruct changes in the geometry of the sea floor which requires knowledge of the ocean floor basement ages and the oceanic lithosphere cooling rates, and 2) to reconstruct changes in the oceanic environment through time. These reconstructions will yield a key for deciphering the early history of the paleogeographic and paleoceanographic evolution of the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 1800 ____ Sed. Thickness:(m) ______ Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Alpha-Mendeleyev Ridge

General Objective: Paleoceanography, Tectonics

General Area: Central Arctic Ocean
Position: 86 30'N 110 W
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Main objectives are to determine: how the Arctic Ocean behaved during the early Cretaceous, and how it has developed since then. Of particular interest is 1) to reconstruct changes in the geometry of the sea floor which requires knowledge of the ocean floor basement ages and the oceanic lithosphere cooling rates, and 2) to reconstruct changes in the oceanic environment through time. These reconstructions will yield a key for deciphering the early history of the paleogeographic and paleoceanographic evolution of the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 1100 _____ Sed. Thickness:(m) _______ Tot. penetration:(m) ____

HPC _____ Double HPC X Rotary Drill X Single Bit _____ Reentry _____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site:
Lomonosov Ridge

General Objective:
Paleoceanography, Paleoclimate

General Area: Central Arctic Ocean
Position: 81 30' N 141 E
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Reconstructing paleoceanographic and paleoclimatic changes of the Central Arctic Ocean for the Neogene and Paleogene requires drilling on the Lomonosov Ridge. Of particular interest is to determine: 1) the initiation and history of the northern hemisphere glaciation, 2) the distribution of past water masses and their circulation patterns, 3) the development and changes of the sea ice cover, and 4) changes in ocean temperature, salinity, and productivity. Basement drilling together with geophysical studies will allow to determine the nature and depth evolution of the Lomonosov Ridge, a key area to frame the circulation patterns in the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 1000 ____ Sed. Thickness:(m) ______ Tot. penetration:(m) ____

HPC ____ Double HPC X ____ Rotary Drill X ____ Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Morris-Jesup Rise

General Objective: Paleoceanography, Tectonics

General Area: Arctic Ocean
Position: 84° 40'N20° W
Alternate Site: 85° N 130° W

Thematic Panel Interest:

Specific Objectives:

Objectives are to reconstruct the timing and the establishment of the deep-water connection between the Arctic Ocean and the Norwegian-Greenland Sea. Evidently, this is in context with the tectonic and physiographic evolution of the Yermak Plateau, the Morris-Jesup Rise, and the opening of the Fram Strait. The depth-age relationship of the plateau and the rise, an extremely important variable for ocean circulation, the faunal changes, the current influenced sedimentological changes, and the unconformities will be studied to determine the Neogene history of the water flow between the Norwegian-Greenland Sea and the Arctic Ocean. Another important target is to determine the nature and the age of the basement which is critical to the paleoceanographic reconstruction.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 1000 ____ Sed. Thickness:(m) ______ Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction: Greenland

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman / J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Lomonosov Ridge

General Objective: Paleoceanography, Paleoclimate

General Area: Central Arctic Ocean
Position: 85 30' N 60 W
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Reconstructing paleoceanographic and paleoclimatic changes of the Central Arctic Ocean for the Neogene and Paleogene requires drilling on the Lomonosov Ridge. Of particular interest is to determine: 1) the initiation and history of the northern hemisphere glaciation, 2) the distribution of past water masses and their circulation patterns, 3) the development and changes of the sea ice cover, and 4) changes in ocean temperature, salinity, and productivity. Basement drilling together with geophysical studies will allow to determine the nature and depth evolution of the Lomonosov Ridge, a key area to frame the circulation patterns in the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 500 Sed. Thickness:(m) ____ Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site:
MOR slope / Amundsen Basin

General Objective:
Tectonics, Paleoceanography, Paleoclimate

General Area: Eastern Arctic Ocean
Position: 86 40'N 60 E
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Objectives are to determine and to reconstruct 1) paleobathymetric and paleogeographic changes of the MOR, and 2) paleoceanographic changes in context with the cooling and glaciation of the northern hemispere for the Neogene. One important goal is to reconstruct t oceanographic properties of a warm, ice free polar ocean and its transition to a cold, ice covered polar ocean.
Changes in the sedimentological record will be studied in context with the Arctic Ocean's response to late Cenozoic climatic fluctuations. Of major interest are the characteristics, timing, magnitude, and periodicity of late Cenozoic climatic oscillations at high latitudes in comparison to the well documented climatic oscillations of the low latitudes.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 2000 Sed. Thickness:(m) ____ Tot. penetration:(m) ____

HPC ____ Double HPC X Rotary Drill X Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert/ S. Pfirman/ J. Thiede

ARCTIC OCEAN DRILLING SITE SUMMARY

Proposed Site: Lomonosov Ridge

General Objective: Paleoceanography, Paleoclimate

General Area: Central Arctic Ocean
Position: 86 30'N 148 E
Alternate Site:

Thematic Panel Interest:

Specific Objectives:

Reconstructing paleoceanographic and paleoclimatic changes of the Central Arctic Ocean for the Neogene and Paleogene requires drilling on the Lomonosov Ridge. Of particular interest is to determine: 1) the initiation and history of the northern hemisphere glaciation, 2) the distribution of past water masses and their circulation patterns, 3) the development and changes of the sea ice cover, and 4) changes in ocean temperature, salinity, and productivity. Basement drilling together with geophysical studies will allow to determine the nature and depth evolution of the Lomonosov Ridge, a key area to frame the circulation patterns in the Arctic Ocean.

Site Specific Survey Data:

Other Data:

Operational Considerations:

Water Depth:(m) 1000 ____ Sed. Thickness:(m) ______ Tot. penetration:(m) ____

HPC ____ Double HPC X ____ Rotary Drill X ____ Single Bit ____ Reentry ____

Nature of sediments/rock anticipated:

Weather conditions/window:

Territorial jurisdiction:

Other:

Special Requirements (staffing, instructions, etc.):

Proponent:

J. Mienert / S. Pfirman/ J. Thiede

ARCTIC DRILLING: SITE ARC 1

ODP SITE PROPOSAL SUMMARY FORM

Proposed Site: Alpha Ridge transect (Sites ARC 1A,1B,1C)
General Objective: Continuous Cretaceous to late Cenozoic stratigraphic and paleoenvironmental record; bedrock drilling for age and nature of the ridge
General Area: Central Arctic Ocean (Fig. A1-1)
Position: 85o 06'- 59.9'N Thematic Panel: SOHP,TECT,LITH

Specific Objectives

1. HPC and XCB coring to ca.500m on the northern Alpha Ridge crest (ARC 1A, Fig.A1-2), to obtain a complete Cenozoic litho- and biostratigraphic section for the western (Canadian/Beringian) sector of the Arctic Ocean for study of the evolution of climate, ocean circulation and polar microbiota.(NOTE: a complementary reference section in the eastern/Eurasian sector is described in Proposal 2 for drilling at Site ARC 2 on the Yermak Plateau (Fig. 1).

2. Continuous HPC coring to refusal (ca.250m?) at Ridge sites where the K/T boundary is at shallow depths (ARC 1B, Fig A1-2; ARC 1C, Fig.A1-3) - to determine the paleoenvironmental, geochemical and petrological events that mark this interval in the Arctic, and for comparison with visually similar K/T sections in the Antarctic (= the Woodside Creek type section in New Zealand).

3. Rotary drilling to refusal at Sites ARC 1A,1B and 1C to determine the age, nature and origin of Alpha Ridge "bedrock","grabens" and "volcanic peaks", and to confirm a possible origin as thick oceanic crust similar to that under large Pacific oceanic plateaus e.g. Otong Java.

Background Information

Regional Geophysical Data:

- seismic reflection profiles: sparker records (Hall,1979); airgun records (Jackson, 1985)

- seismic refraction: CESAR survey (Jackson et al.,1986; Forsyth et al.,1986) includes a complete section: 0-1 km sediment; bedrock layer of 5.1km/s typical of ocean layer 2; 6.45 km/s layer with high velocity gradient; 7.3 km/s layer 10-16 km thick, above a mantle depth of up to 40 km.

-cores & dredge samples (Mudie & Blasco,1985; Clark et al.,1980)

Site specific data:

-Seismic profiles show stratified sediments conformably overlying apparent bedrock which appears to crop out as conical seamounts on the ridge crests. Dredge samples from these seamounts contain highly altered (weathered) tholeolitic basalt (Van Wagoner & Robinson, 1985). A few cores on the margins of the ridge crests have recovered unaltered Cretaceous-Paleogene laminated biosiliceous ooze (Mudie et al. 1986). At the CESAR site, the top of the ooze apparently corresponds to a strong reflector which can be traced to 200 m sub-bottom (Fig A1-2). A second reflector at ca. 400m sub-bottom is believed to mark the bedrock surface. Most piston cores from the stratified surficial sediment layer contain continuous sequences of carbonate-rich hemipelagic Pleistocene muds overlying Late Miocene-Pliocene oxidised siliclastic muds (?red clays), with sandy interbeds (Mudie & Blasco,1985; Aksu & Mudie,1985;Clark et al.,1980.

Operational Considerations

Water Depth (m): 1360 - 1855m Sed. Thickness (m):400-800m
Total Penetration: ARC 1A = 500m; ARC 1B = 500m
ARC 1C = 900m
HPC: Double HPC X Rotary Drill X
Sediments/rock anticipated: ca.10 m Plio-Pleistocene carbonate mud
200msiliclastic red clay &fine sandy interbeds
10-50m Maestrichtian biosiliceous ooze
50-100m Campanian black mud
Tholeolitic basalt(Campian Quiet Zone)

Weather conditions/window:Year-round sea ice cover, with narrow leads in summer; Drill ship would require 2 or more Class 6-8) support icebreakers (e.g. PVRV Polarstern, Arktika or the proposed Canadian MV Polar 8), from ca. July 1 to Sept. 15. The shortest access distance from summer open water is from Spitsbergen. Access may be faster & more efficient, however, by entry through northern Bering Strait and following the Beaufort Gyre Current to the drill sites (see Fig. 2B).

Territorial jurisdiction: International.

Special Requirements: Icebreaker support ships

Safety Considerations: Some subbottom stratification may indicate gas hydrates which can form at depths of ca. 1000-1200m at present bottom water temperatures.Low organic content and uniform appearance of the reflectors, however, makes hydrates unlikely.

PROPONENT: Peta J. Mudie
H. Ruth Jackson
Steven M. Blasco
Address & Phone:
Geological Survey Canada

FOR OFFICE USE:
Date Received:
Classification No.:
Panel Allocation

ARCTIC DRILLING: SITE ARC 2

ODP PROPOSAL SUMMARY FORM

Proposed Site: Yermak Plateau Sites ARC 2A, 2B
General Objective: Continuous Paleogene to Late Cenozoic stratigraphic and paleoenvironmental record for the eastern Arctic Ocean entrance (Fig. 1); bedrock drilling for age and nature (oceanic/continental) of the marginal plateau northwest of Svalbard (Fig. A2-1).
General Area: Southeastern Arctic Ocean
Position: *ARC 2A-ca. 82o 41.7'N 09o 32.7'E
Thematic Panel: SOHP, TECT
Regional Panel: Arctic, AOP
*ARC 2B-ca. 80o 53'N, 07o 19'E
*Exact location to be determined pending further study of available seismic data and/or site surveys

---

Specific Objectives

1. Continuous HPC and XCB coring to refusal at Site ARC 2A on the northeastern Yermak Plateau (Fig.A2-2) to obtain a complete Eocene-Pleistocene litho- and biostratigraphic section for the eastern (Eurasian) sector of the Arctic Ocean, to verify the oceanic origin of the outer plateau, and to confirm its former proximity to Greenland and Canada (see Fig.A2-3).

2. Rotary drilling to refusal at Site ARC 2A Fig.A2-2) to verify the presence of oceanic crust, determine the its age and petrological characteristics (volcanic dike?).

3. Continuous HPC & XCB coring and rotary drilling to refusal at Site ARC 2B on the southern axis of Yermak Plateau (Fig. A2-4) to determine the age and paleoenvironmental characteristics (continental/marine?) of velocity layers 1.7, 2.0-2.1, 2.2, 2.5-2.6 and reflector O, and to sample the basement layer (v=5.0-5.8m/sec) for confirmation of its continental origin and possible correlation with the Precambrian gneiss Heckla Hoek Formation of Spitsbergen (Jackson et al. 1984).

Background Information

Regional Geophysical Data:

- seismic reflection profiles: multichannel 120 cu in. airgun records (Kristofferson, 1982; Sundvor et al., 1982a,b); 3.5 kHz profile of Sofia Basin (Thiede et al., 1988)

- seismic refraction: sonobuoy profiles have been made at or near the proposed drill sites (Sundvor et al. 1977, 1982a,b)

- cores & dredge samples: Sundvor et al.(1982a) report on short cores & dredge samples from the site areas; most cores from the west slope, however, appear to include turbidite or slump deposits; in contrast, core ARKIV/3-396 from the area of well stratified sediments on the northeast plateau (Fig. A2-5) appears to comprise only fossiliferous hemipelagic muds interbedded with ice-rafted detritus.
- at Site ARC 2B, Tertiary and older sediments are probably similar to formations exposed onshore in W. Svalbard (Mork and Bjoroy, 1984)

Site Specific Data

-At present, an ideal site for both stratigraphic and bedrock objectives cannot be located precisely. Seismic profiles for the general target area, however, show bedrock within 1 sec. of the seabed at the proposed sites (Figs. A2-2, A2-4). In the vicinity of Site ARC 2A, there is a sediment cover ca. 0.7-1.0 sec. thick in most areas (see Fig. A2-2). The upper 0.4 sec is strongly stratified & probably comprises interbedded glaciogenic and hemipelagic muds of Late Cenozoic age; the lower 0.3 sec. are weakly stratified and appear to be pelagic marine muds. Bedrock at Site ARC 2A is expected to be lava flows with intercalated tuffaceous sediments similar to the volcanics drilled on ODP Leg 104, Voering Plateau.

At Site ARC 2B (Fig.A2-4), sediments appear to be more uniformly stratified, suggesting a more consistent terrigenous clastic component.Strong reflectors are regional in occurrence and they probably mark erosional events accompanying eustatic changes in sea level. Bedrock at this site may include high grade Precambrian gneiss which has been dredged from Yermak Plateau near otcrops. Reflector O , marking basement top, has been traced to within 25 km of the Hekla Hoek Formation in W. Svalbard; this rock succession includes metamorphosed/deformed rocks of Late Riphean to Early Paleozoic age; overlying Devonian and younger Paleozoic rocks are unmetamorphosed clastics with some carbonates and evaporites (Steel & Worsley, 1984).

Operational Considerations

Water Depth (m): 2A- ca. 1400 m   Sed. thickness: ca.600m
2B- ca. 800m   ca.800m
Total Penetration: ARC 2A = ca 1000m
ARC 2B = ca 1200m
HPC: Double HPC: _X_   Rotary Drill_X_
Sediments/rock anticipated:
ARC 2A: ca. 400m Late Tertiary - Pleistocene glaciomarine muds and pelagic marine interbeds
200m Paleogene - Miocene pelagic sediment
Basement = Eocene/older tholeiitic flows and

interlayered clastics

ARC 2B: ca. 300m Plio-Pleistocene glacial marine sediment
200m Pliocene hemipelagic muds
300m Tertiary hemipelagic and clastic sediments
Basement = Paleozoic red sandstone and/or older gneiss/metamorphic rock

Weather conditions/window: In most years, summer open water will allow access by ice re-inforced vessels, ca. July 1 - Sept.15; icebreaker support ships may be needed for safety.

Territorial jurisdiction: ?International and Norway

Special Requirements: See Fig.A2-6 for map of ice conditions.Basement faulting is common through the region, possibly with hydrocarbon traps in small basins; drill sites, however, are over basement highs and are unlikely to encounter significant amounts of hydrocarbons

---

PROPONENT: H.Ruth Jackson1
Peta J. Mudie1
Joern Thiede2
Address and Phone:
1.Geological Survey Canada,
Atlantic Geoscience Centre,
Box 1006, Dartmouth, N.S.; Phone:902-426-3791/8720
2.Geologische Institut Kiel
GEOMAR Forsuchungzentrum fur marine Gewissenschaften,
Wischofstrasse 1-3, Blg. 4,
D-2300, Kiel, FGR; Phone:49-431-720020-15.

FOR OFFICE USE:
Date Received
Classification No.
Panel Allocation:

PROPROSAL 3: ARCTIC DRILLING SITE ARC 3
ODP SITE PROPOSAL SUMMARY FORM

Proposed Site: Nansen Ridge, Eurasian Basin

General Objectives: Bedrock drilling in this area of very thin crust so that petrological and geochemical data from a slow spreading ridge can be used to determine depth of magma formation, amount of melt, and degree of thermal alteration for deeper parts of the crust than possible elsewhere.

General Area: Eastern Arctic Ocean (Fig. 1)
Position: 84o 18' 19.5"N, 8o 06' 29.7" W
Thematic Panel: TECT, LITH Regional Panel:Arctic,AOP

Specific Objectives:
1. Drill to investigate age, thermal properties, petrology and geochemistry of the oceanic crust generated by a slow spreading ridge
2. Continuous coring to investigate sedimentary deposition in the eastern Arctic under the Transpolar Drift Current.

Background Information:
Regional Geophysical Data: single channel seismic reflection data (Jackson et al., 1982)
- ocean bottom seismometer refraction lines (Jackson et al., 1982)
- core and dredge samples

Site Specific Data: Seismic reflection profiles from Fram I show basement highs and lows with sediment cover that ranges from about 1 to 0 km over basement. Crust 2-3 km thick has been measured on seismic refraction lines. The crust is expected to be vertically and laterally heterogeneous. The site selected is next to a basement high with a thin cover of ponded sediments (Fig. A3-1).

Operational Considerations:
Water Depth(m): 3894; Sed. Thickness (m):100; Tot. Pen.(m): 1100
HPC:YES   ROTARY DRILL: YES
Nature of Sediments/Rock: 0-100m hemipelagic muds and ice rafted detritus, 1000m pillow basalts interbedded with sediments and possibly layer sheeted dykes.
Weather Conditions: Arctic, temperatures subzero to +2oC; foggy in summer
Territorial Jurisdiction: International waters

Special Requirements: Arctic pack ice requires ice breaker support

---

Proponents: H.R. Jackson and P.J. Mudie
Geological Survey Canada, Atlantic Geoscience Centre
P.O. Box 1006, Dartmouth, N.S. B2Y 4A2; 902-426-3791

PROPOSAL 4: ARCTIC DRILLING SITE ARC 4
ODP SITE PROPOSAL SUMMARY FORM

NOTE: The exact location of this site cannot be given at present because of the lack of released industry/military seismic data for this region where basement is complex and spatially variable. The site described here, however, provides a perspective of the type of conditions and problems that may be encountered in this region. A final site, however, will be selected after examination of more seismic data, hopefully including lines to be shot from the USCG icebreaker Polar Star in summer 1988.

Proposed Site: North Chukchi Basin
General Objctives: Continuous coring for Cretaceous- Pleistocene paleoecological records of the Pacific-Arctic Ocean gateway; rotary drilling for age and nature of basement.
General Area: Chukchi Sea, Western Arctic Ocean
Position: ca. 74o N, 170oW
Thematic Panel: SOHP, TEC

Specific Objectives

1. HPC and XBC coring to ca. 750 m at ARC 4A on the southern edge of the N. Chukchi Basin (Fig.A4-1,A4-2) to obtain a high resolution Neogene-Holocene litho- and biostratigraphic section for the Pacific entrance to the Arctic Ocean, in an area that has not been eroded or deformed by Pleistocene ice sheet or ice cap growth.

2. Continuous coring to refusal of Jurassic/Cretaceous to Plio-Pleistocene sediments at Site ARC-4B (Fig.A4-2) in order to establish a biostratigraphy for the western Arctic, and to determine the paleoenvironmental history of the Pacific-Arctic gateway, particularly with respect to the immigration and evolution of siliceous microfossils and dinoflagellates which are the main biochronological markers in the Alpha Ridge sections.

3. Rotary coring of basement at Sites ARC 4C and 4C'(Fig. A4-3) to determine its age and nature, and to confirm models (Grantz and May, 1983; Jackson and Johnson, 1986) for the origin of the Canada Basin by Jurassic rifting, followed by rotational spreading whererby the Canadian Polar Margin became separated from the Chukchi Borderland by the opening of the ocean basin (Fig. 4-4).

Operational Considerations

Water Depth (m): ca. 200 m Sediment thickness: 4A = ca.900m; 4B = 600m; 4C = ca. 100 m
Total Penetration: ARC 4A,4B = ca. 1200m
ARC 4C = ca. 300 m
HPC: double HPC _X_ Rotary Drill _X_

Sediments/rock anticipated:

ARC 4A: ca. 300 m Plio-Pleistocene hemipelagic mud interbedded with gravelly ice-rafted detritus(IRD)
ca. 400 m Neogene hemipelagic mud
ca. 200 m Paleogene ?hemipelagic mud
Basement = Upper Cretaceous-Paleogene hemipelagic/deltaic mud

ARC 4B: ca. 200 m Plio-Pleistocene hemipelagic & glaciogenic mud
ca. 100 m Neogene hemipelagic mud
ca. 300 m U. Cretaceous-Paleogene hemipelagic/deltaic mud
Basement = Jurassic/L. Cretaceous clastics & shale

ARC 4C ca. 100 m Plio-Pleistocene hemipelagic/glaciogenic mud
ca. 200 m Jurassic-L. Cret. clastics (?Ellesmerian rocks, shale

Weather conditions/window: In most years, accessible to ice reinforced vessels in summer, ca. Aug. 15 - Oct.1

Territorial jurisdiction: International and USSR

<u>Special Requirements</u>: See Fig. 2A for map of ice conditions. Basement faulting is common but overlying Neogene-Recent sediments are not gassy (Grantz et al. 1975) and underlying sediments are unlikely to contain significant amounts of hydrocarbons. Diapirs (probably shale) reach seafloor in places.

PROPONENT: Peta J. Mudie
H. Ruth Jackson
Steven M. Blasco
Address and Phone:
Geological Survey Canada
Atlantic Geoscience Centre
Box 1006, Dartmouth, N.S.
Phone: 902-426-8720/3791/3932

FOR OFFICE USE:
Date Received:
Classification No.
Panel Allocation: