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OCEAN DRILLING PROGRAM PROPOSAL FOR ARCTIC OCEAN DRILLING

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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).

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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 depth of 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.

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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 Thematic Panel:SOHP,TECT
09o 32.7'E 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

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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

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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

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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 whererebу 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.

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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.

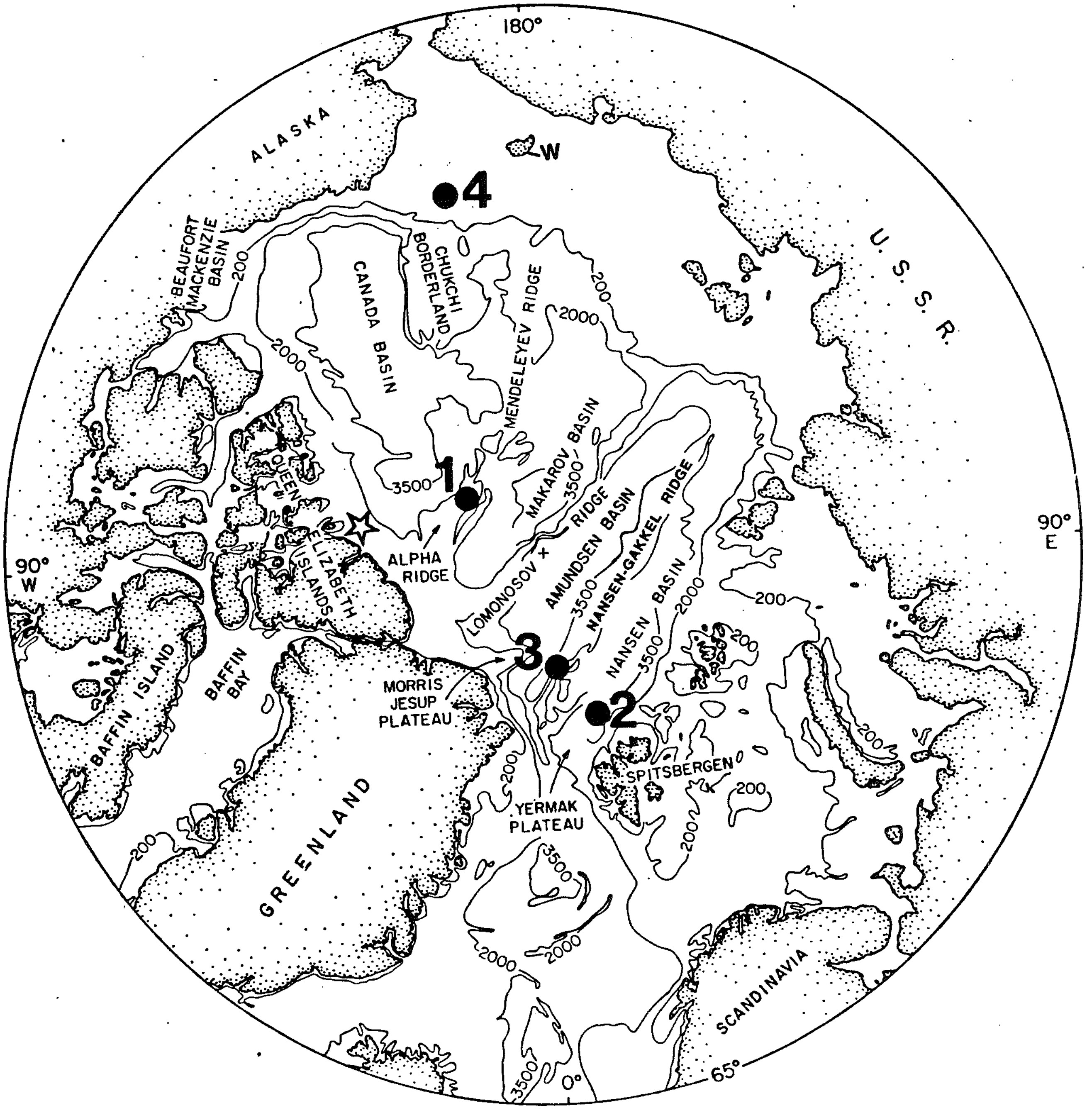

180°
ALASKA
U. S. S. R.
W
4
BEAUFORT MACKENZIE BASIN
CHUKCHI BORDERLAND
CANADA BASIN
MENDELEYEV RIDGE
MAKAROV BASIN
1
ALPHA RIDGE
QUEEN ELIZABETH ISLANDS
90° W
90° E
LOMONOSOV RIDGE
AMUNDSEN BASIN
NANSEN-GAKKEL RIDGE
NANSEN BASIN
3
2
MORRIS JESUP PLATEAU
BAFFIN ISLAND
BAFFIN BAY
GREENLAND
YERMAK PLATEAU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

Figure 1

2A

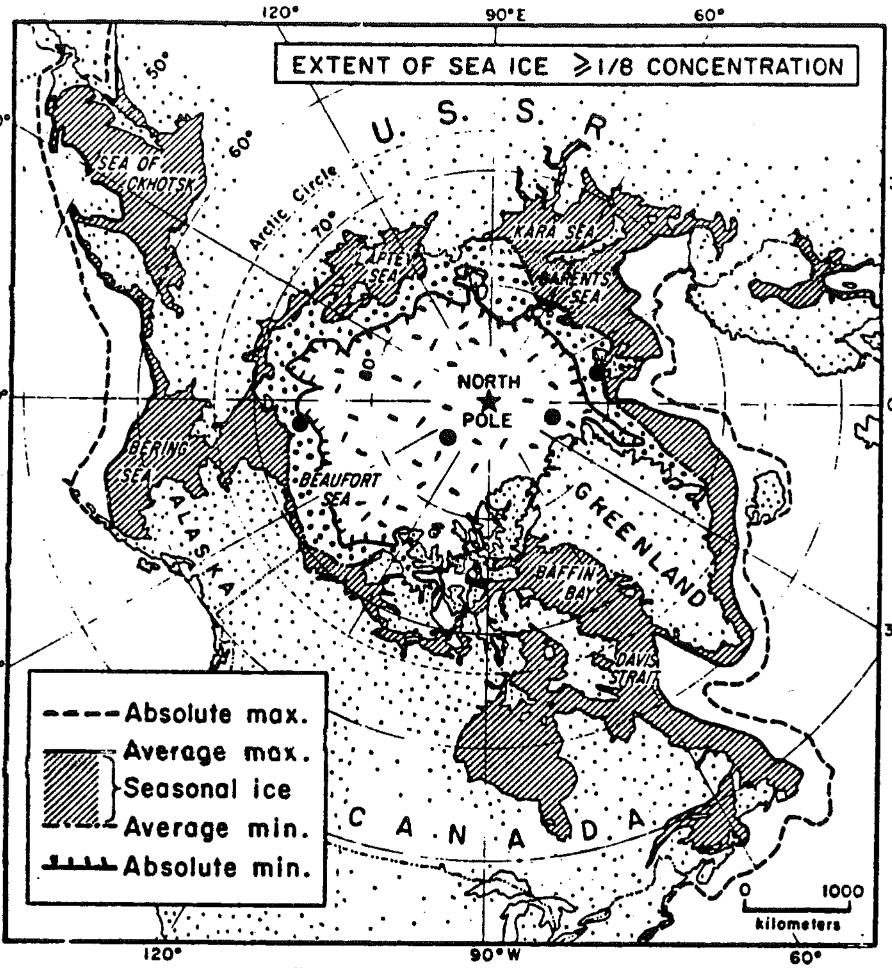


Figure 2A

2B

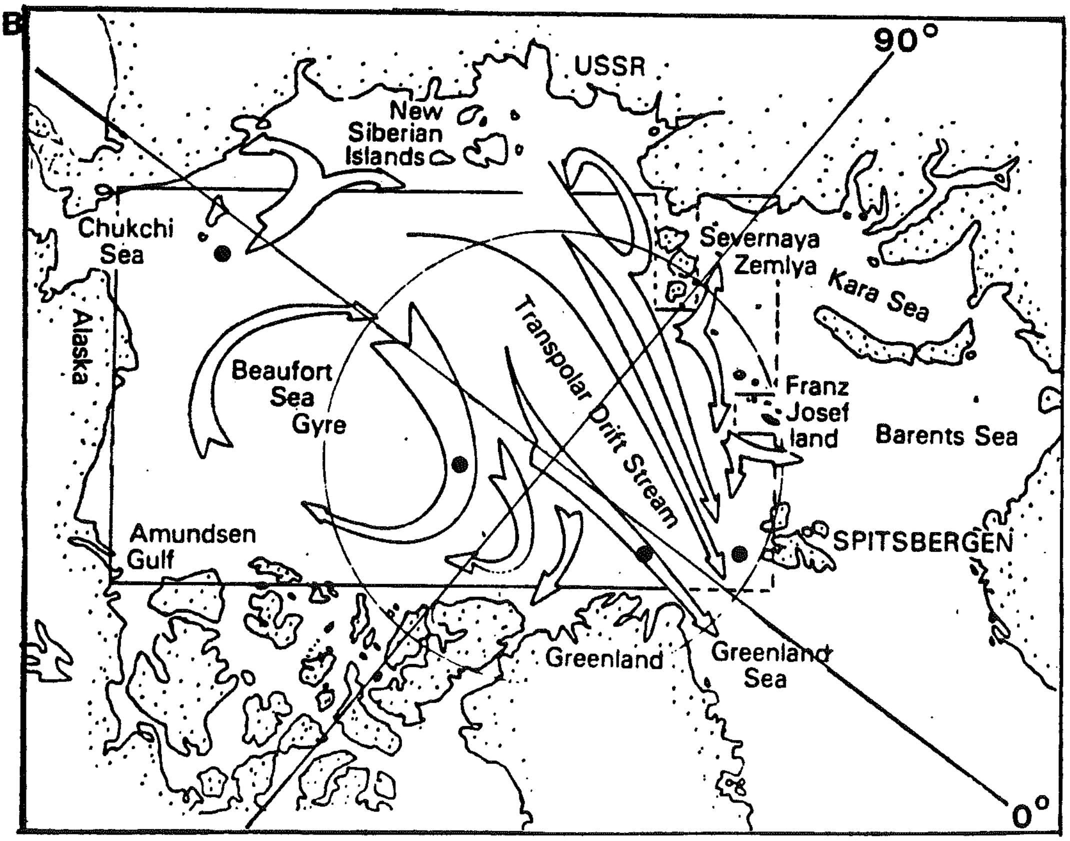


Figure 2B

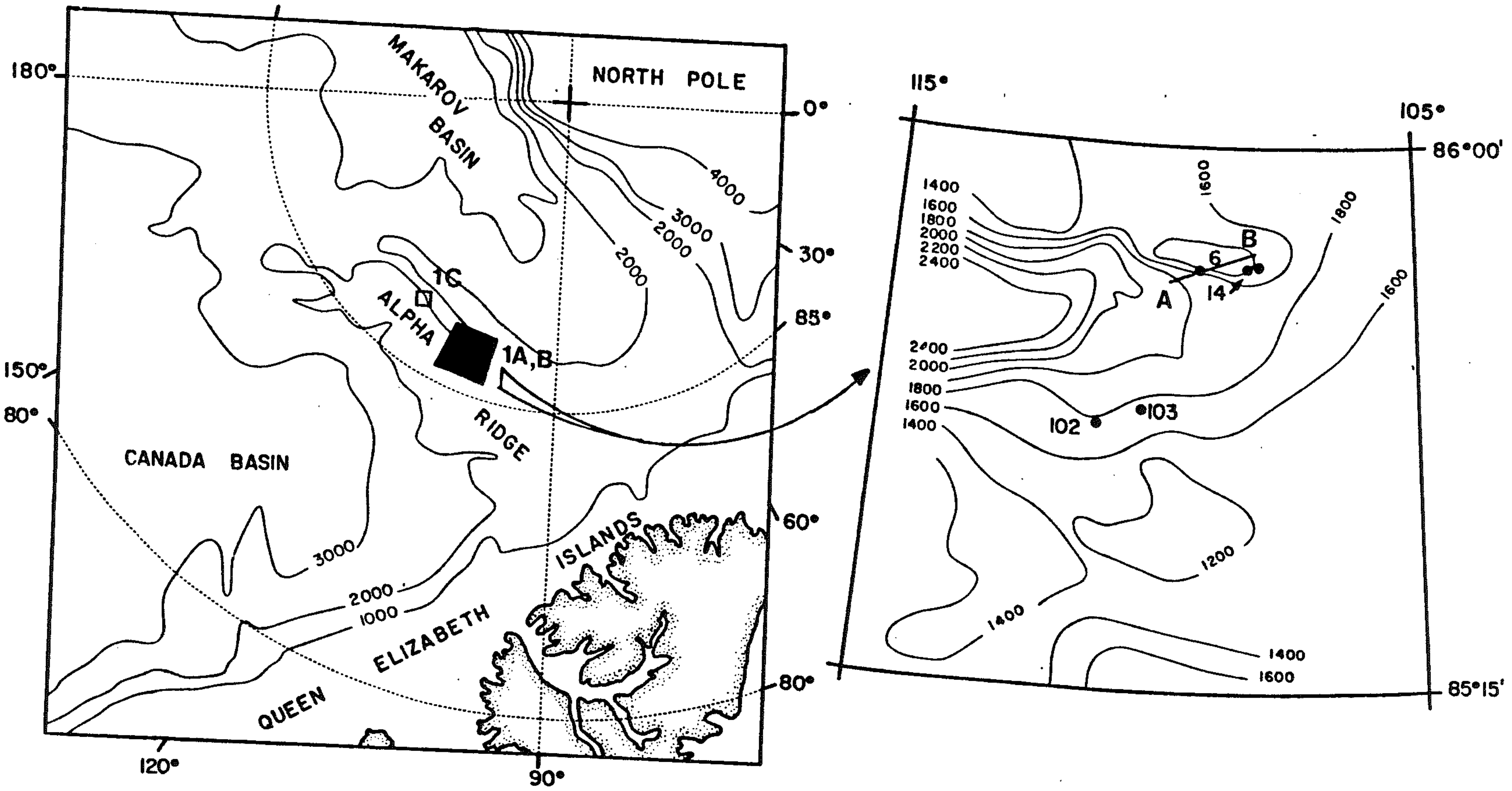

NORTH POLE
MAKAROV BASIN
ALPHA RIDGE
1C
1A,B
CANADA BASIN
QUEEN ELIZABETH ISLANDS
4000
3000
2000
2000
3000
2000
1000
180°
150°
80°
0°
30°
85°
60°
80°
120°
90°
115°
105°
86°00'
85°15'
1400
1600
1800
2000
2200
2400
2400
2000
1800
1600
1400
1600
1800
1600
1200
1400
1400
1600
A
B
6
14
102
103

Figure A1-1

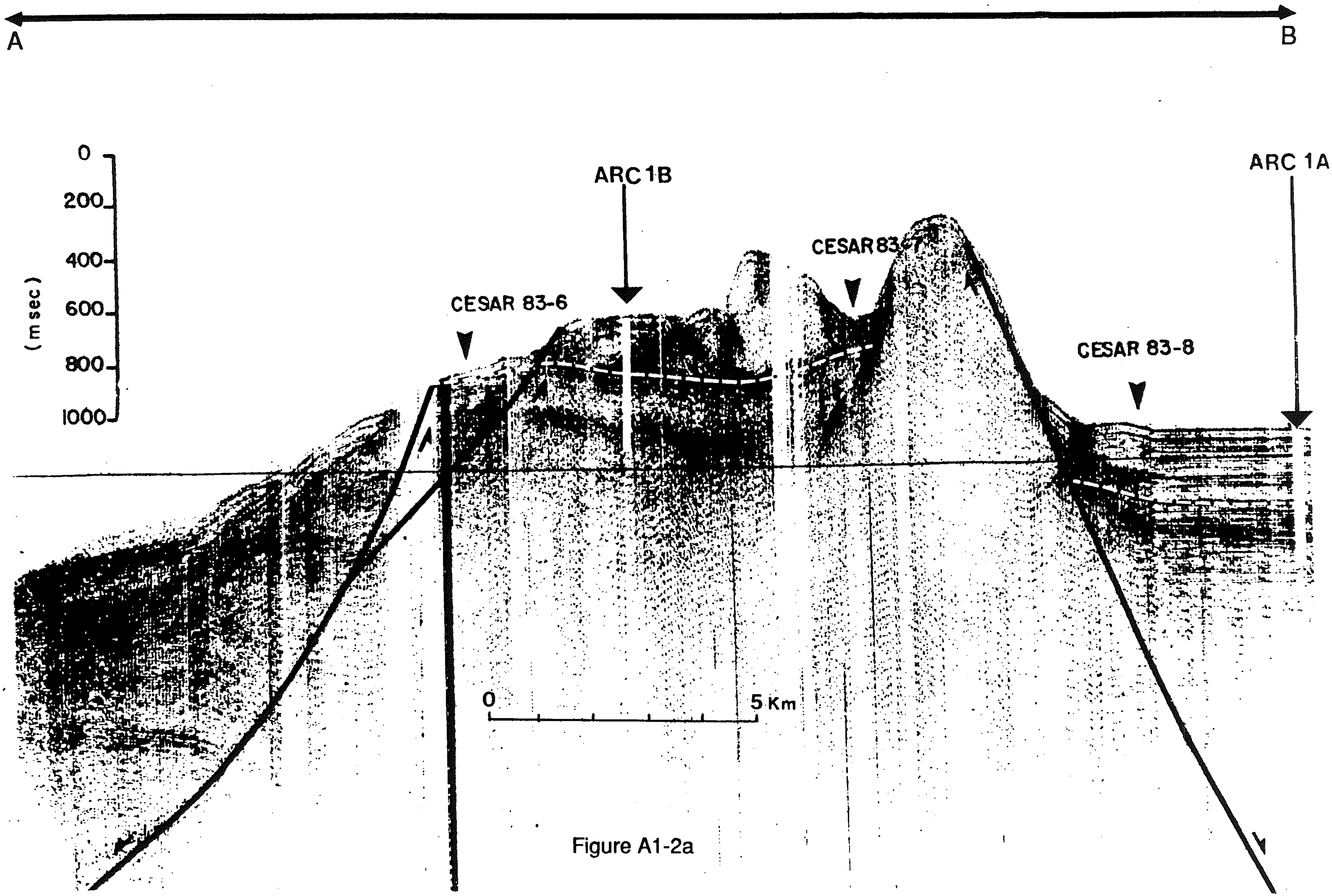

A
B
0
200
400
600
800
1000
(msec)
ARC 1B
ARC 1A
CESAR 83-6
CESAR 83-7
CESAR 83-8
0
5 Km

Figure A1-2a

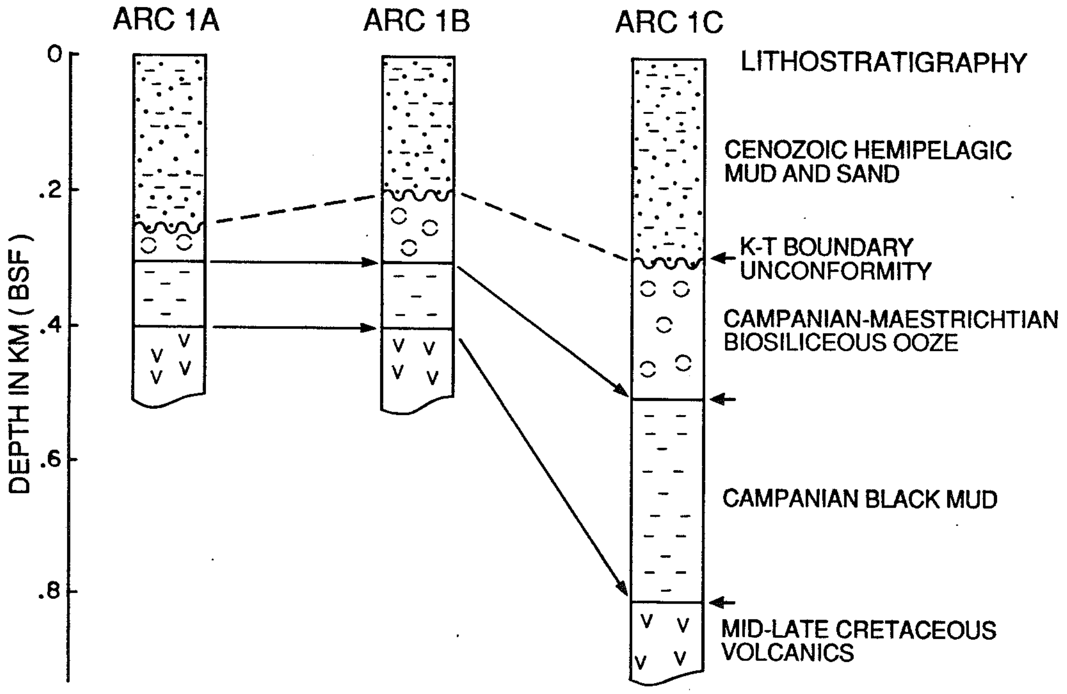

ARC 1A
ARC 1B
ARC 1C
LITHOSTRATIGRAPHY
0
.2
.4
.6
.8
DEPTH IN KM (BSF)
CENOZOIC HEMIPELAGIC MUD AND SAND
K-T BOUNDARY UNCONFORMITY
CAMPANIAN-MAESTRICHTIAN BIOSILICEOUS OOZE
CAMPANIAN BLACK MUD
MID-LATE CRETACEOUS VOLCANICS

FIGURE A1-2b

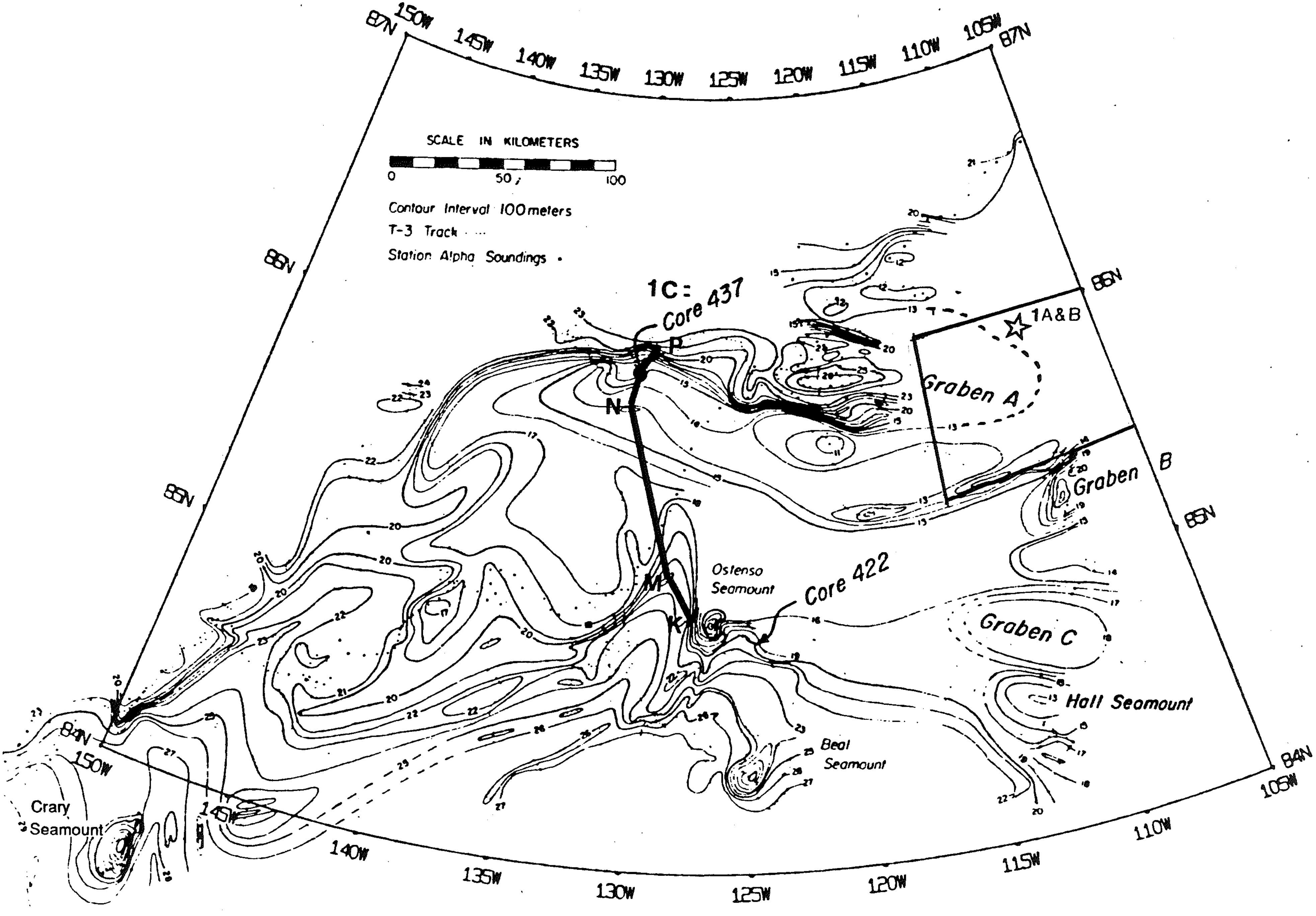
150W
145W
140W
135W
130W
125W
120W
115W
110W
105W
87N
86N
85N
84N
SCALE IN KILOMETERS
0
50
100
Contour Interval 100 meters
T-3 Track
Station Alpha Soundings •
1C:
Core 437
P
N
M
K
Core 422
Ostenso Seamount
Beal Seamount
Hall Seamount
Crary Seamount
1A & B
Graben A
Graben B
Graben C

Figure A1-3a

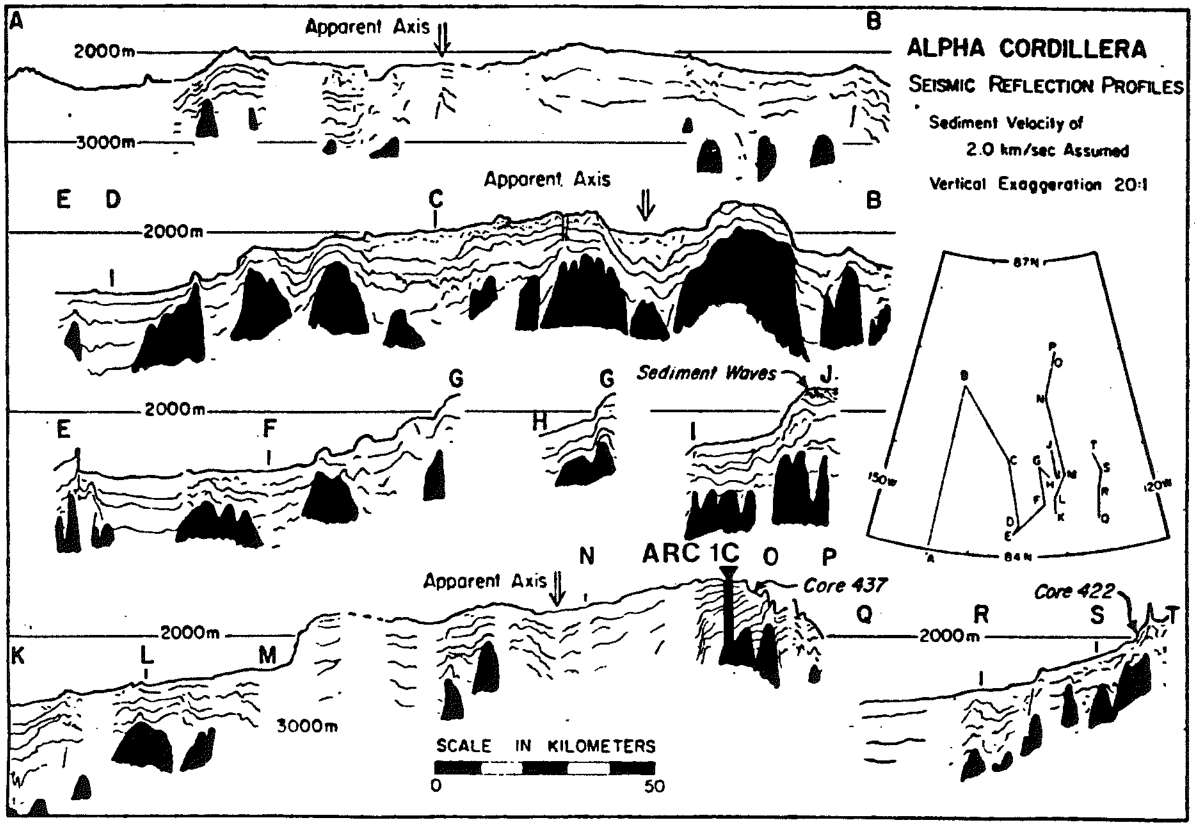
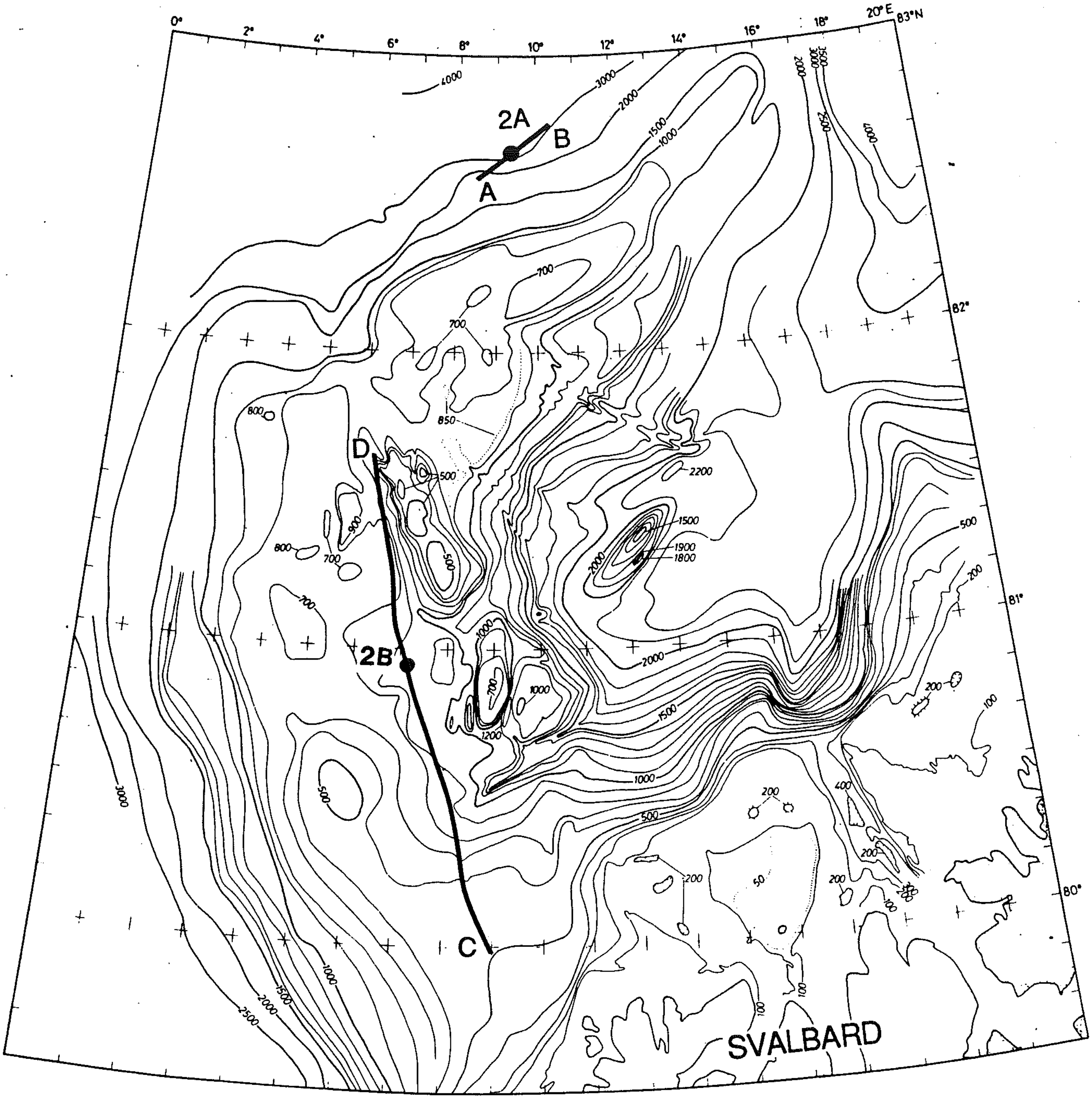

ALPHA CORDILLERA
SEISMIC REFLECTION PROFILES
Sediment Velocity of
2.0 km/sec Assumed
Vertical Exaggeration 20:1
A
B
Apparent Axis
2000m
3000m
E
D
C
Apparent Axis
B
2000m
E
F
G
G
H
Sediment Waves
J
I
2000m
K
L
M
3000m
Apparent Axis
N
ARC 1C
O
P
Core 437
Q
R
S
T
Core 422
2000m
2000m
SCALE IN KILOMETERS
0
50
87N
84N
150W
120W

Figure A1-3b



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

Figure A2-1

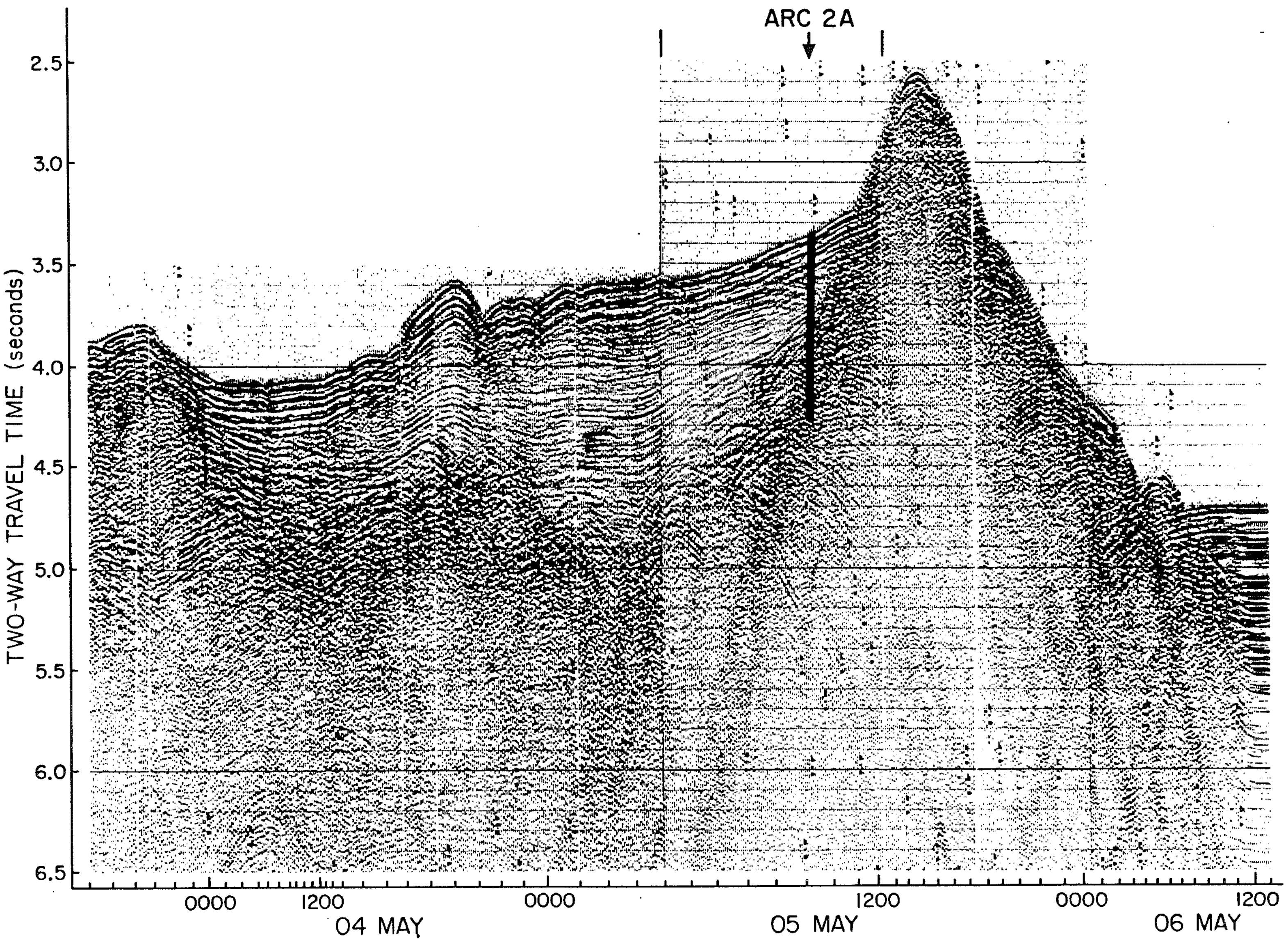

ARC 2A
TWO-WAY TRAVEL TIME (seconds)
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
0000
1200
04 MAY
0000
05 MAY
1200
0000
06 MAY
1200

Figure A2-2

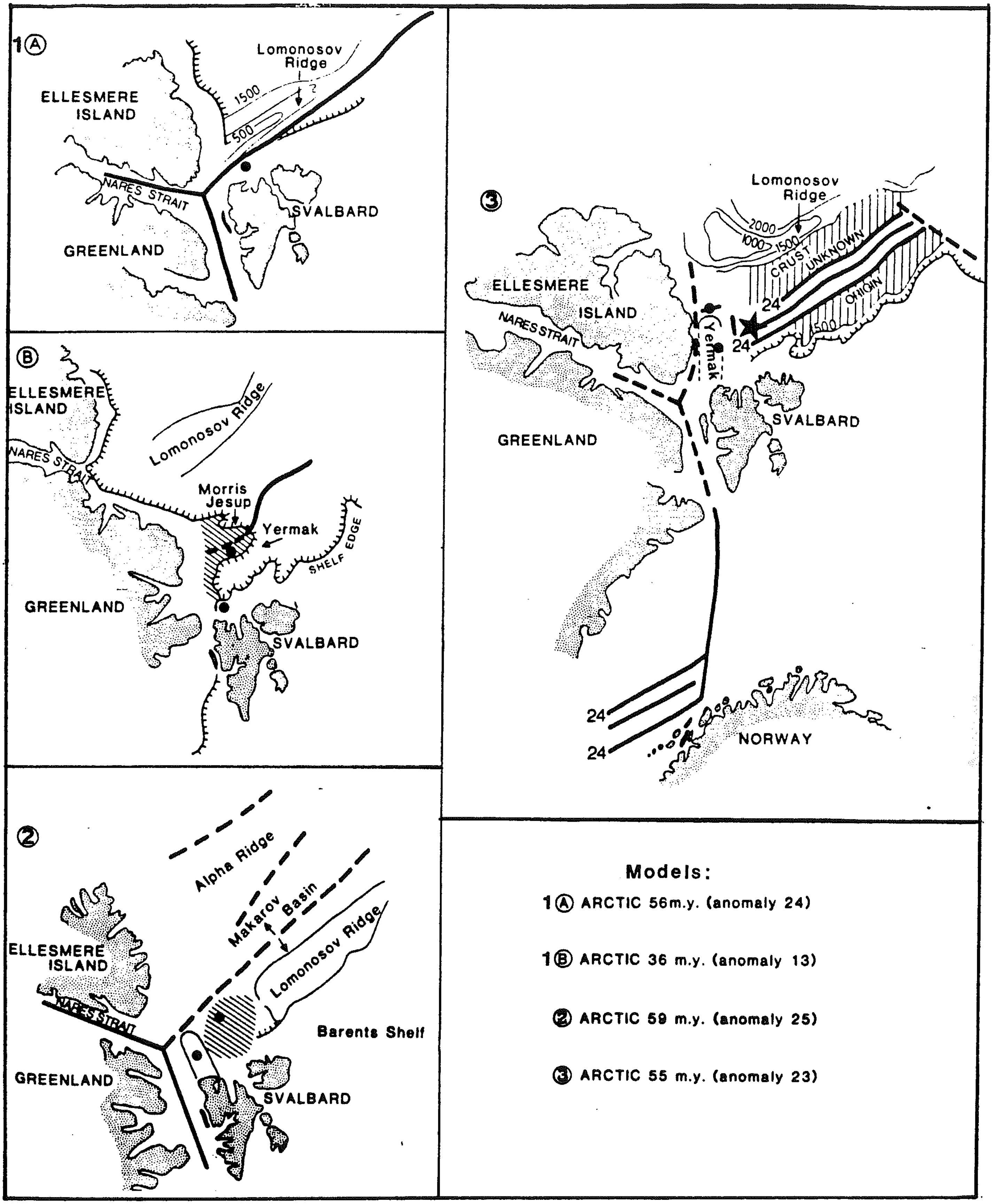

1Ⓐ
Lomonosov Ridge
1500
500
?
ELLESMERE ISLAND
NARES STRAIT
GREENLAND
SVALBARD
Ⓑ
ELLESMERE ISLAND
NARES STRAIT
Lomonosov Ridge
Morris Jesup
Yermak
SHELF EDGE
GREENLAND
SVALBARD
②
Alpha Ridge
Makarov Basin
Lomonosov Ridge
ELLESMERE ISLAND
NARES STRAIT
Barents Shelf
GREENLAND
SVALBARD
③
Lomonosov Ridge
2000
1000
1500
500
CRUST UNKNOWN ORIGIN
24
24
24
24
ELLESMERE ISLAND
NARES STRAIT
Yermak
GREENLAND
SVALBARD
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

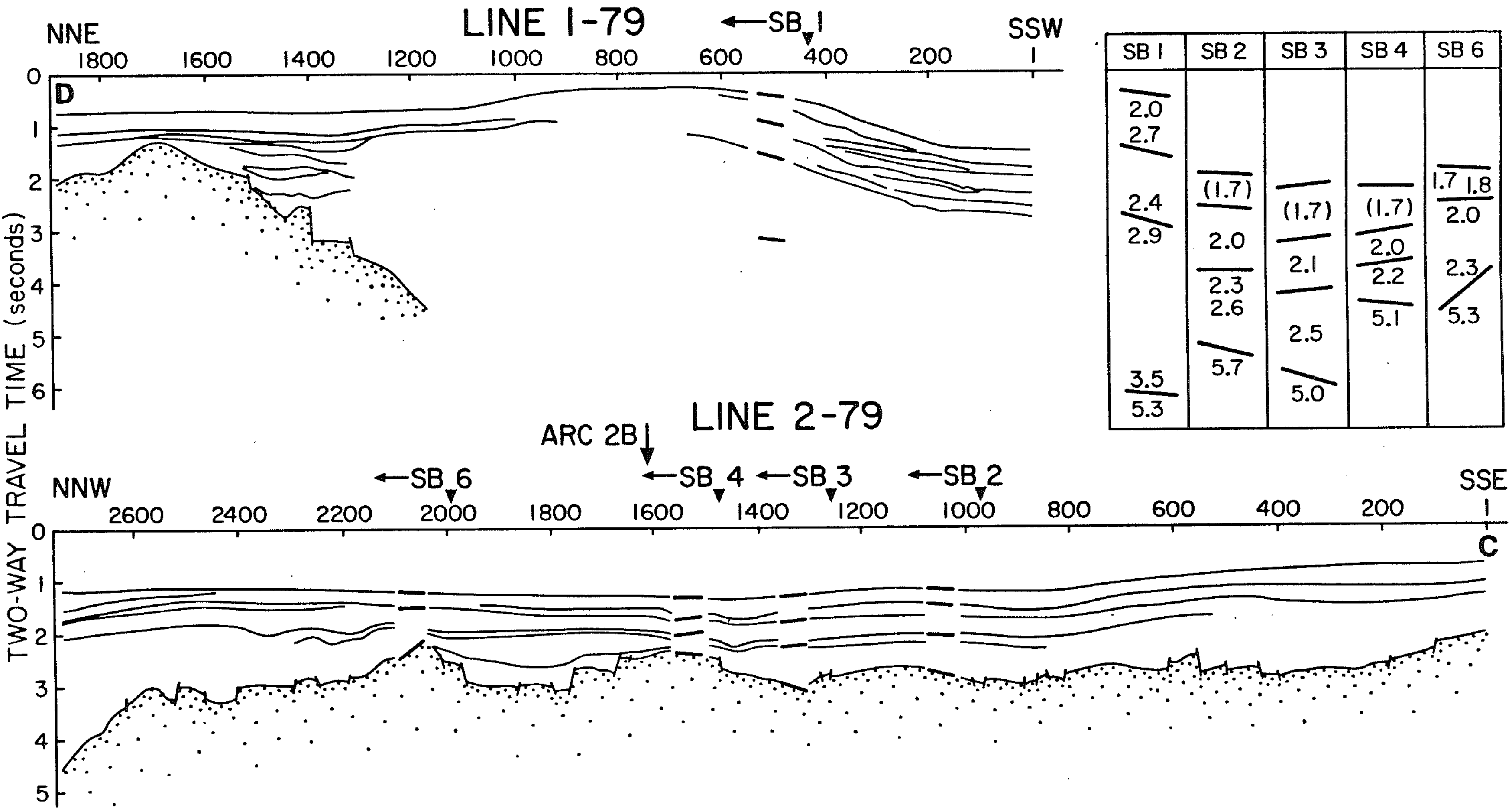
LINE 1-79
NNE
SSW
←SB 1
1800
1600
1400
1200
1000
800
600
400
200
1
D
0
1
2
3
4
5
6
TWO-WAY TRAVEL TIME (seconds)
SB 1
2.0
2.7
2.4
2.9
3.5
5.3
SB 2
(1.7)
2.0
2.3
2.6
5.7
SB 3
(1.7)
2.1
2.5
5.0
SB 4
(1.7)
2.0
2.2
5.1
SB 6
1.7 1.8
2.0
2.3
5.3
LINE 2-79
ARC 2B
NNW
SSE
←SB 6
←SB 4
←SB 3
←SB 2
2600
2400
2200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

Figure A2-4

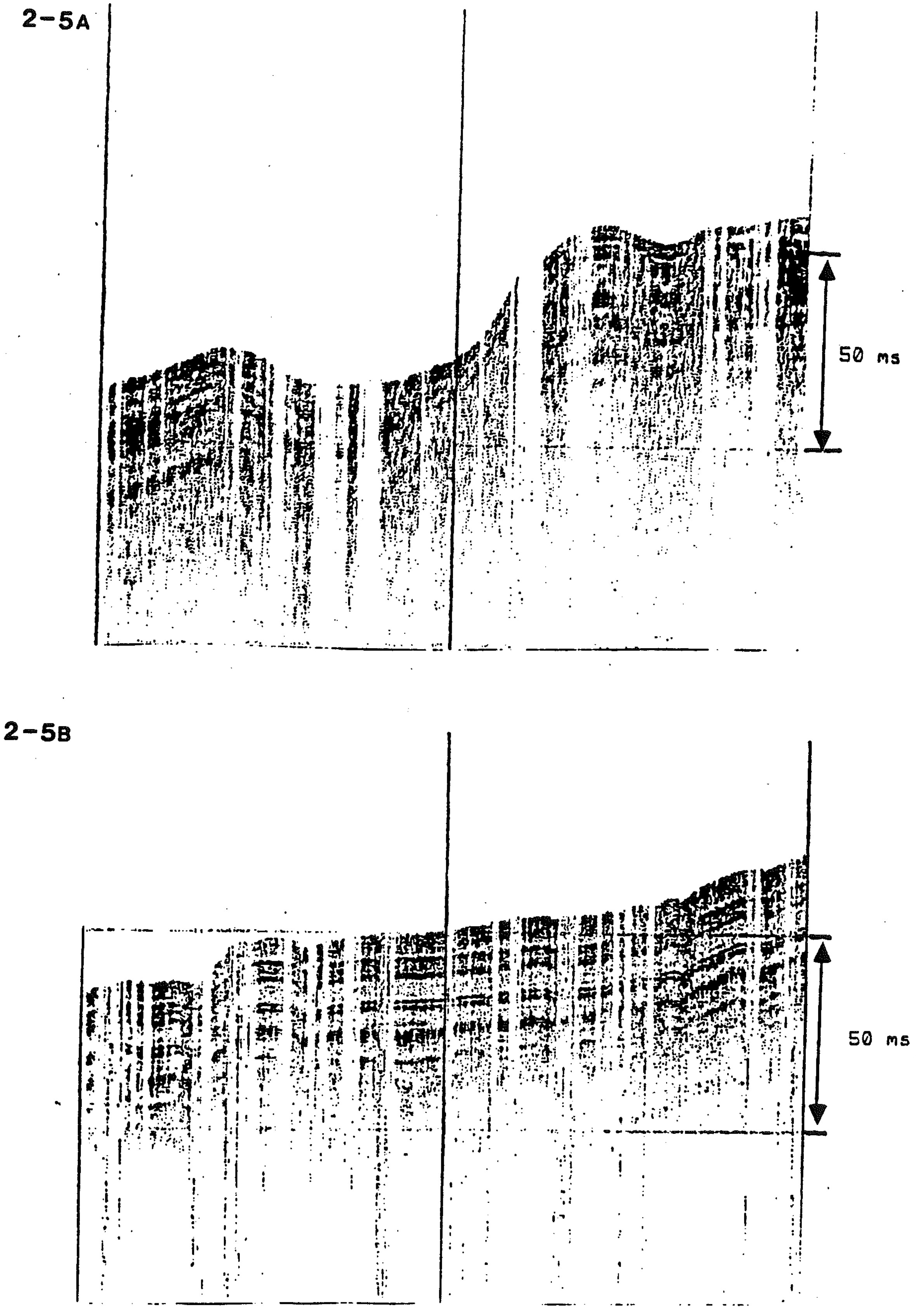


Figure A2-5

Sea Ice Distribution 1971 - 1980

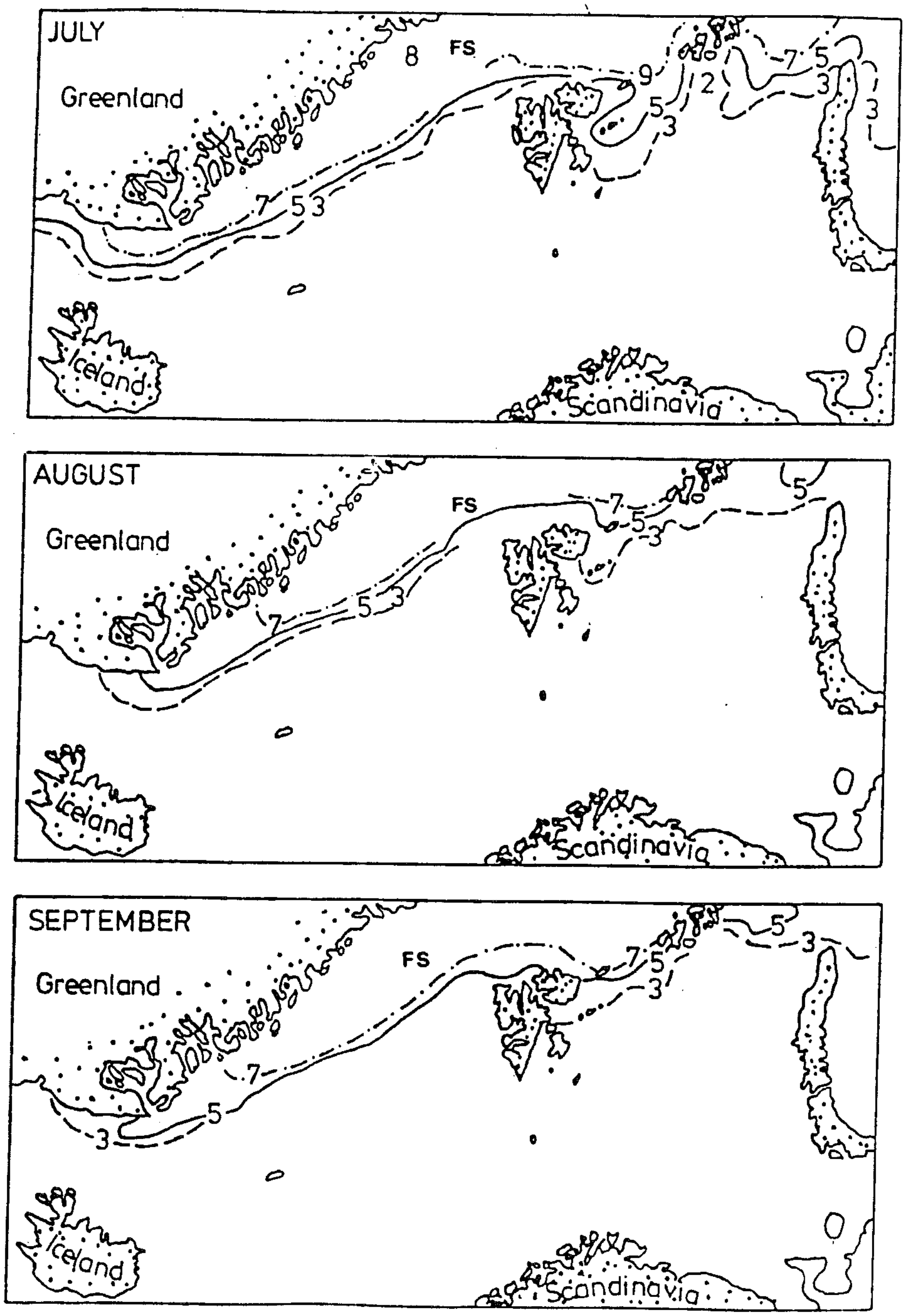


Figure A2-6

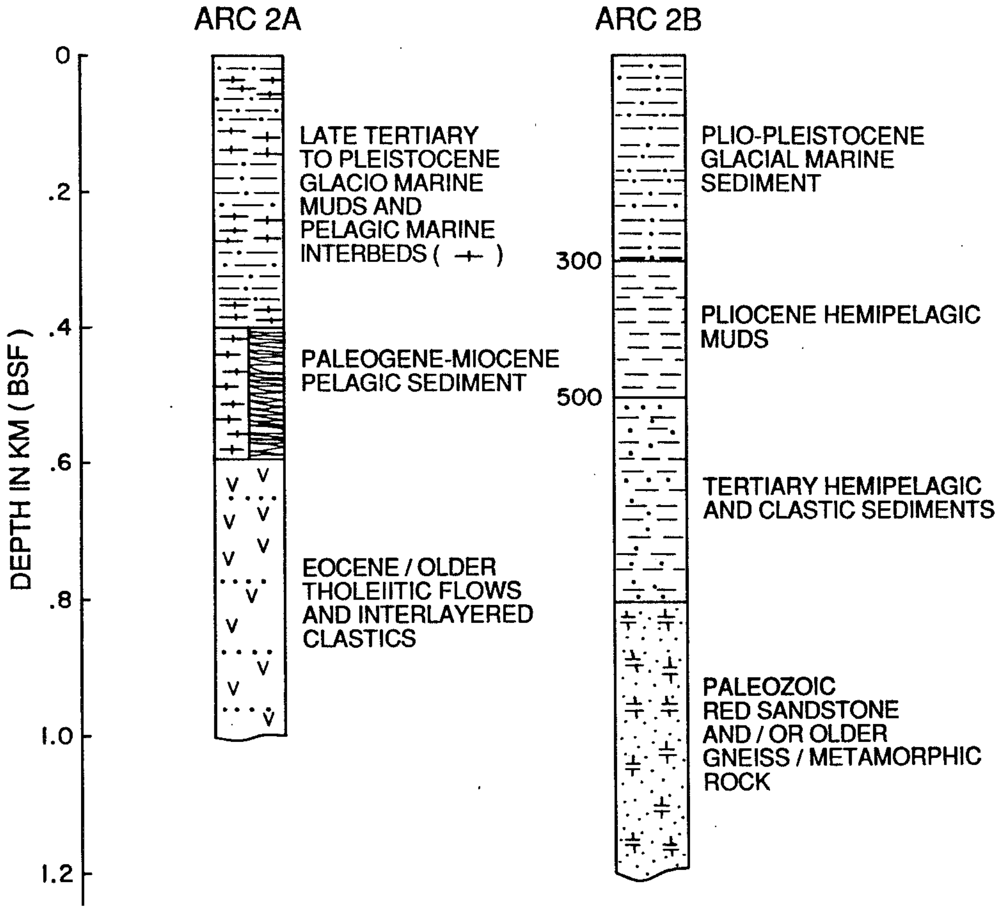
ARC 2A
ARC 2B
0
.2
.4
.6
.8
1.0
1.2
DEPTH IN KM (BSF)
LATE TERTIARY TO PLEISTOCENE GLACIO MARINE MUDS AND PELAGIC MARINE INTERBEDS (—+—)
PALEOGENE-MIOCENE PELAGIC SEDIMENT
EOCENE / OLDER THOLEIITIC FLOWS AND INTERLAYERED CLASTICS
300
500
PLIO-PLEISTOCENE GLACIAL MARINE SEDIMENT
PLIOCENE HEMIPELAGIC MUDS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

FIGURE A2-7

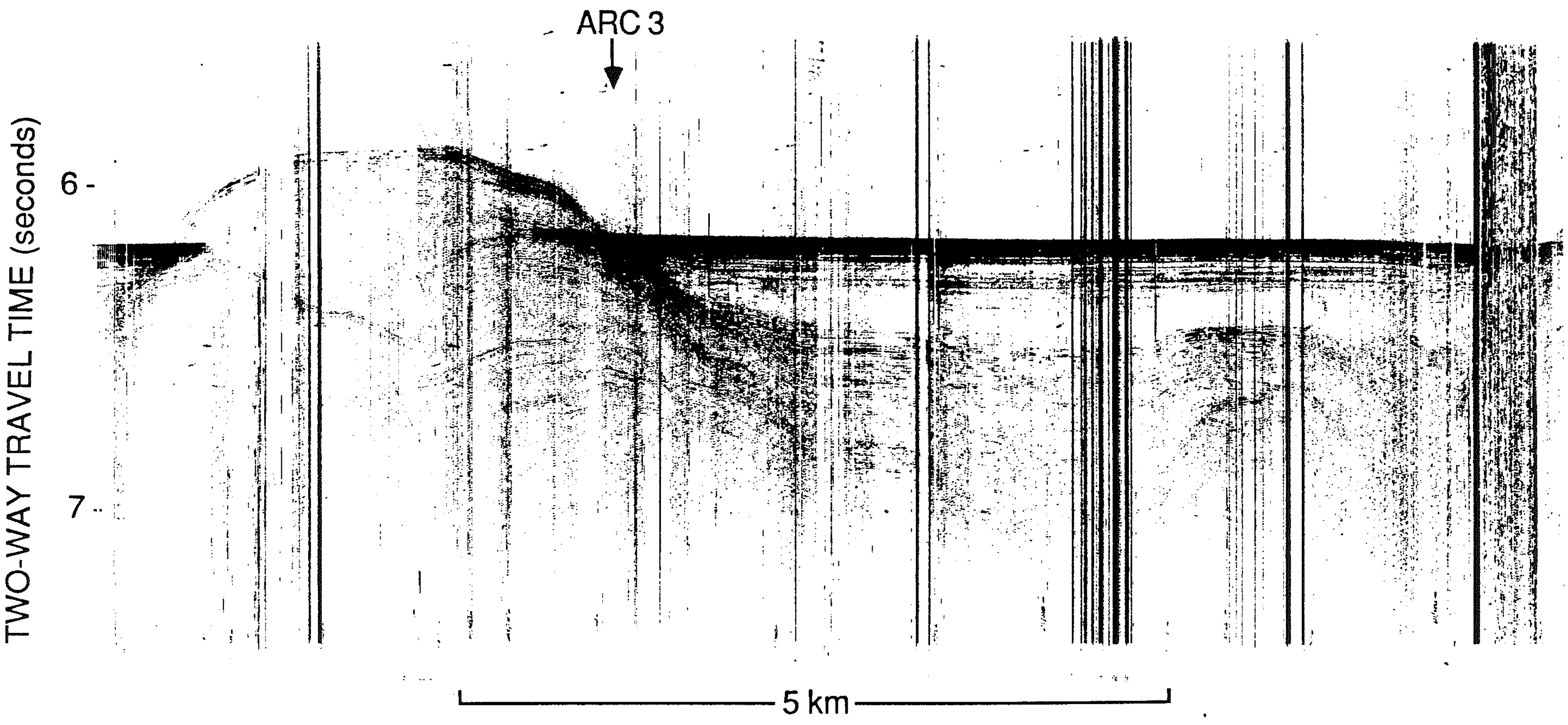


Figure A3-1

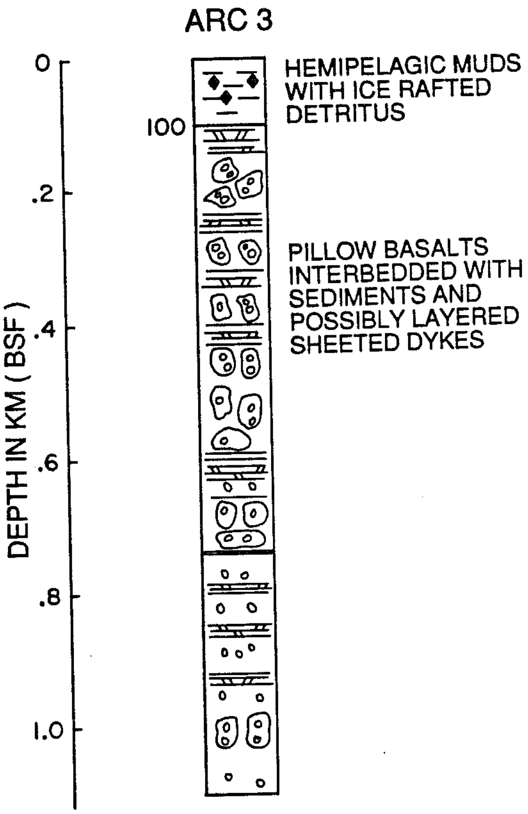

ARC 3
0
.2
.4
.6
.8
1.0
DEPTH IN KM (BSF)
100
HEMIPELAGIC MUDS WITH ICE RAFTED DETRITUS
PILLOW BASALTS INTERBEDDED WITH SEDIMENTS AND POSSIBLY LAYERED SHEETED DYKES

FIGURE A3-2

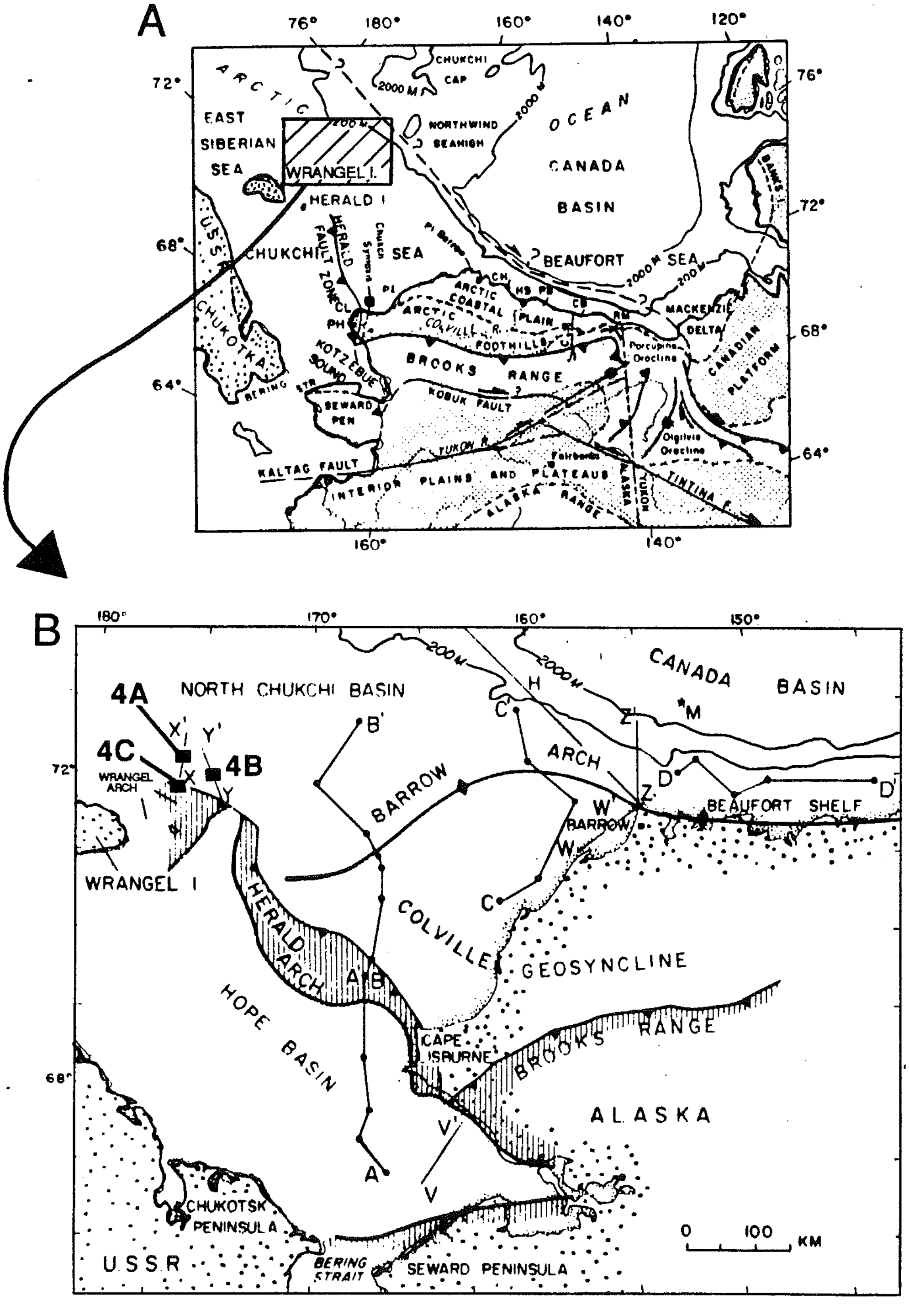

A
76°
180°
160°
140°
120°
72°
76°
68°
64°
72°
68°
64°
ARCTIC
OCEAN
CHUKCHI CAP
2000 M
NORTHWIND SEAHIGH
EAST SIBERIAN SEA
200 M
WRANGEL I.
HERALD I
CANADA BASIN
BANKS I.
U.S.S.R.
CHUKCHI SEA
HERALD FAULT ZONE
Chukchi Syntaxis
Pt Barrow
BEAUFORT SEA
2000 M
200 M
CH
HS
PB
CB
RM
PL
CL
PH
ARCTIC COASTAL PLAIN
ARCTIC FOOTHILLS
COLVILLE R.
MACKENZIE DELTA
CANADIAN PLATFORM
CHUKOTKA
KOTZEBUE SOUND
BROOKS RANGE
Porcupine Orocline
BERING STR
SEWARD PEN
KOBUK FAULT
YUKON R.
Fairbanks
Ogilvie Orocline
KALTAG FAULT
INTERIOR PLAINS AND PLATEAUS
ALASKA RANGE
ALASKA
YUKON
TINTINA F.
160°
140°
B
180°
170°
160°
150°
72°
68°
NORTH CHUKCHI BASIN
CANADA BASIN
200 M
2000 M
4A
4B
4C
X'
Y'
X
Y
WRANGEL ARCH
WRANGEL I
B'
C'
H
Z'
M
ARCH
BARROW
D
D'
Z
W'
BARROW
W
BEAUFORT SHELF
C
COLVILLE
GEOSYNCLINE
HERALD ARCH
A'
B
HOPE BASIN
CAPE LISBURNE
BROOKS RANGE
ALASKA
V'
V
A
CHUKOTSK PENINSULA
U S S R
BERING STRAIT
SEWARD PENINSULA
0
100
KM

Figure A4-1

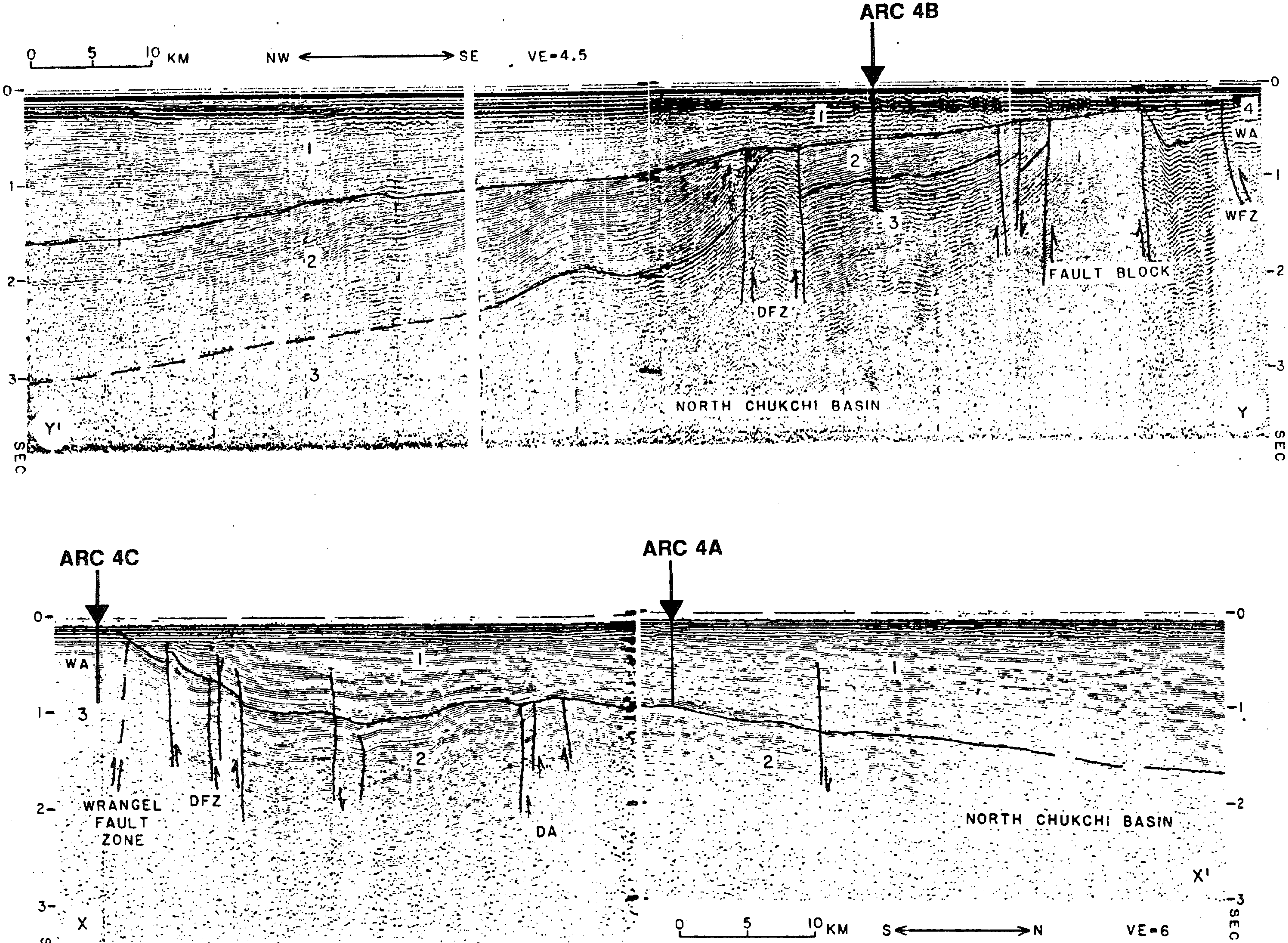

ARC 4B
0 5 10 KM
NW ⟷ SE
VE=4.5
0
1
2
3
SEC
1
2
3
4
WA
WFZ
FAULT BLOCK
DFZ
NORTH CHUKCHI BASIN
Y'
Y
ARC 4C
ARC 4A
WA
3
WRANGEL FAULT ZONE
DFZ
DA
NORTH CHUKCHI BASIN
X
X'
0 5 10 KM
S ⟷ N
VE=6

Figure A4-2

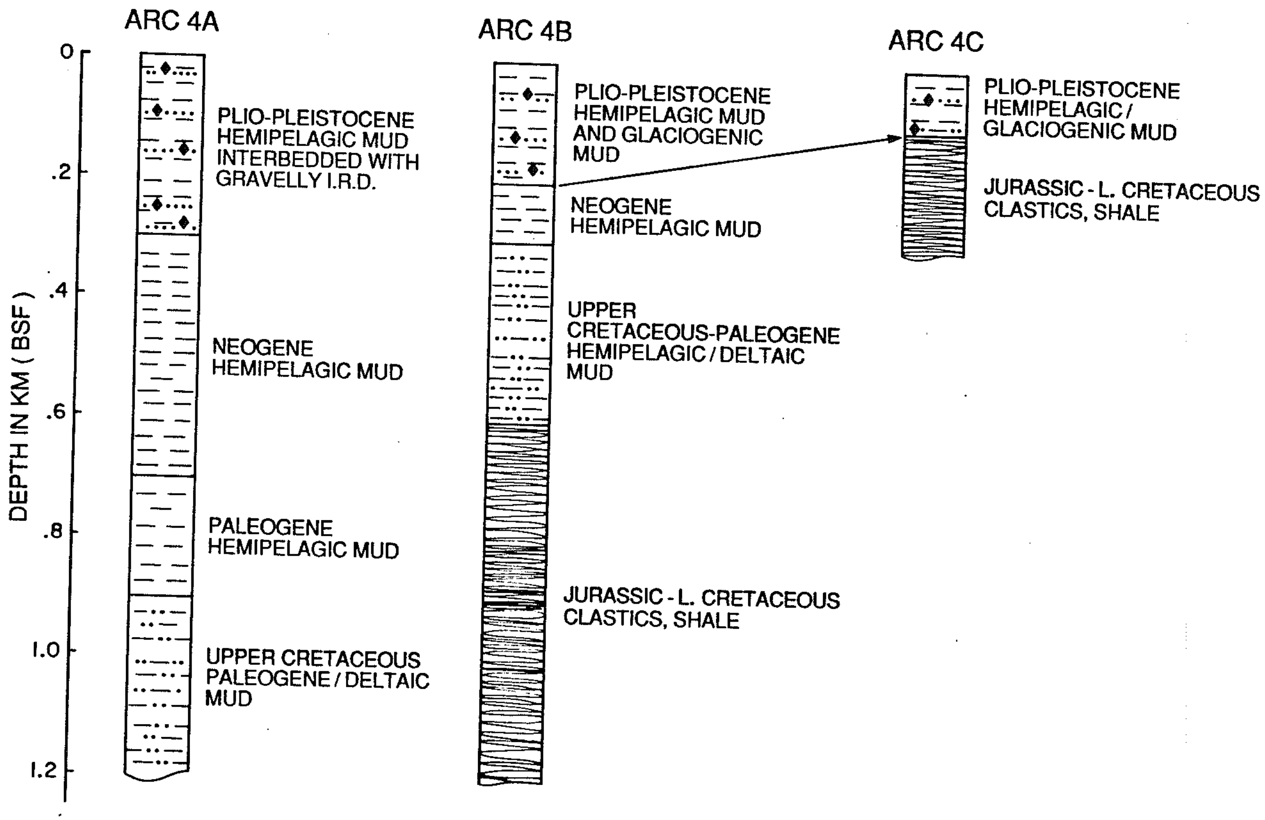

ARC 4A
ARC 4B
ARC 4C
DEPTH IN KM (BSF)
0
.2
.4
.6
.8
1.0
1.2
PLIO-PLEISTOCENE HEMIPELAGIC MUD INTERBEDDED WITH GRAVELLY I.R.D.
NEOGENE HEMIPELAGIC MUD
PALEOGENE HEMIPELAGIC MUD
UPPER CRETACEOUS PALEOGENE / DELTAIC MUD
PLIO-PLEISTOCENE HEMIPELAGIC MUD AND GLACIOGENIC MUD
NEOGENE HEMIPELAGIC MUD
UPPER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

FIGURE A4-3

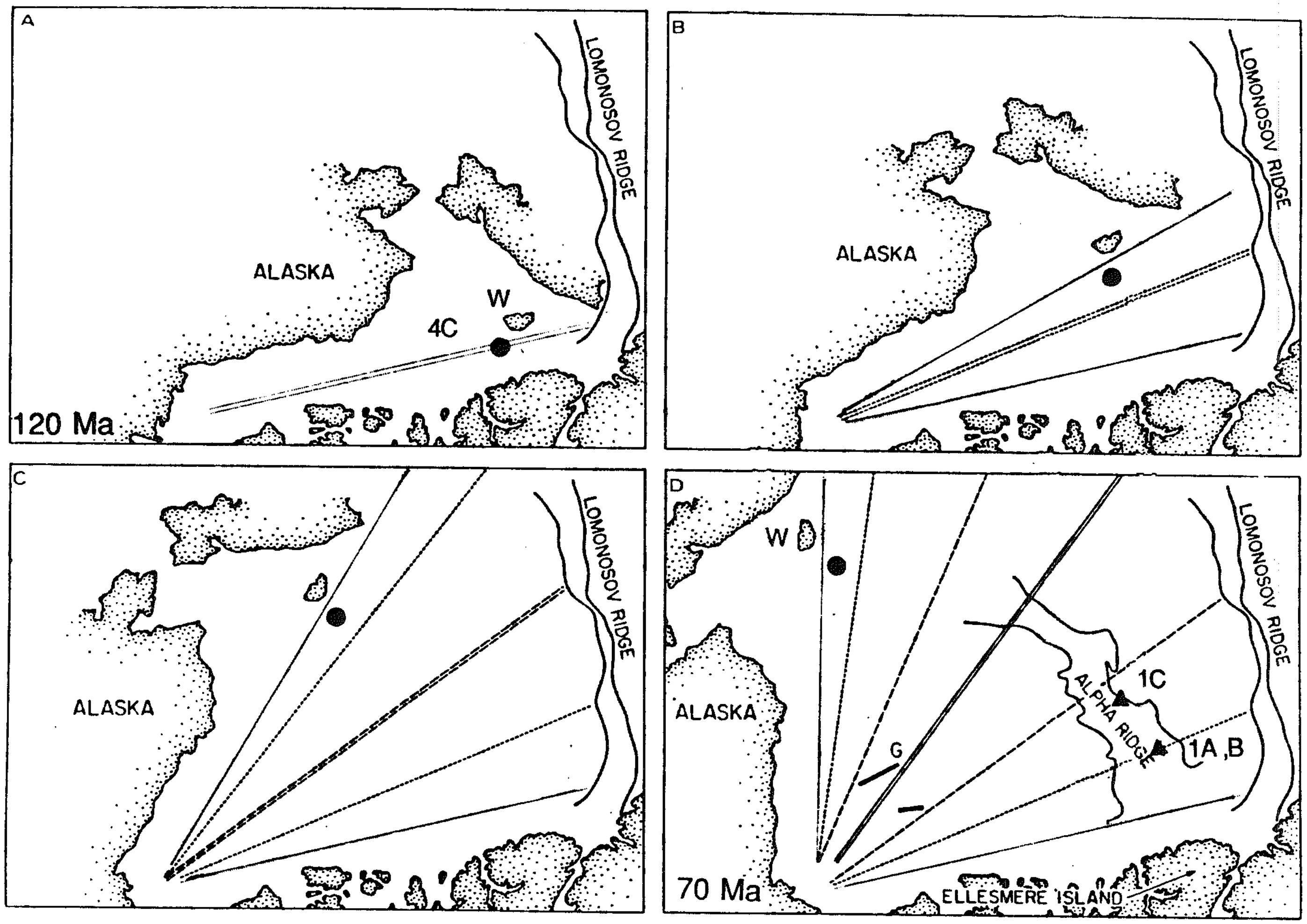

A
LOMONOSOV RIDGE
ALASKA
W
4C
120 Ma
B
LOMONOSOV RIDGE
ALASKA
C
LOMONOSOV RIDGE
ALASKA
D
W
LOMONOSOV RIDGE
ALASKA
1C
ALPHA RIDGE
1A,B
G
70 Ma
ELLESMERE ISLAND

Figure A4-4