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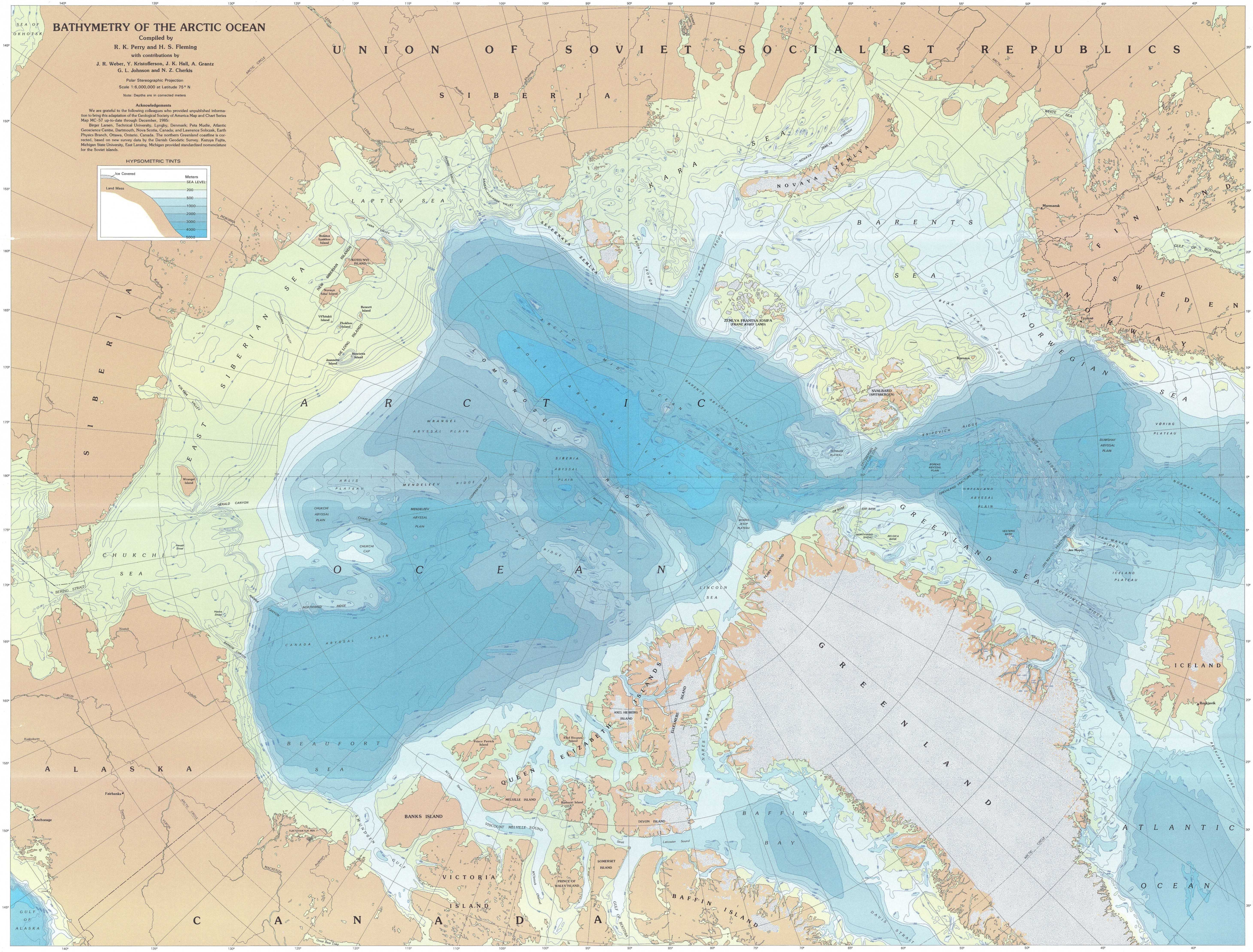

BATHYMETRY OF THE ARCTIC OCEAN

Compiled by
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Polar Stereographic Projection
Scale 1:6,000,000 at Latitude 75° N

Note: Depths are in corrected meters

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PLATE 1. Bathymetry of the Arctic Ocean
The Arctic Ocean Region
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SEISMICITY AND HEAT FLOW OF THE ARCTIC

Seismicity compiled by R.J. Wetmiller
Heat flow compiled by M.G. Langseth, B.V. Marshall and A.H. Lachenbruch

Polar Stereographic Projection
Scale 1:6,000,000 at Latitude 75°N

NOTES (SEISMICITY)

(i) Sources

Earthquakes plotted were taken from the data files for the Preliminary Determination of Epicenters (PDE) program and the regional earthquake catalog of the USSR as given in the 1981 NOAA-EDIS Earthquake Data File (EDF) tape. A more complete description of the EDF is given in Key to Geophysical Records No. 5, Earthquake Data File Summary by Meyers and von Hake (NOAA/EDIS, NGSDC, Boulder, Co. U.S.A.). Also plotted were earthquakes in the Canadian Earthquake Epicenter File of the Geological Survey of Canada (GSC).

All earthquakes listed in each of the sources with epicentral latitudes north of the Arctic Circle were considered for plotting. Known or suspected explosions were not plotted.

The PDE and GSC files were updated to the end of 1984 with data from the original sources. The USSR file on the EDF tape was complete only to the end of 1976 and could not be updated from the original source. However, the PDE file did contain data on earthquakes in the USSR portions of the Arctic for the period from 1977 to 1984, which were used instead. Thus the coverage is complete to the end of 1984 for all areas of the Arctic shown on the map.

Specific earthquakes discussed in Chapter 6 (Seismicity and Focal Mechanisms) and located in the Arctic Region are plotted according to the revised epicenters and magnitudes given in Table 6-1. These revised parameters, which have been taken from various reports in the current scientific literature, are more accurate determinations of these events' source parameters than were available in the original data sources.

(ii) Priorities

The Arctic Region was divided into three regions according to the data sources. The USSR file was used as the primary source for earthquakes in the USSR portion of the Region, specifically south of 80°N and from 30°E to 170°W. The GSC file was the primary source for earthquakes in the Canadian portion of the Arctic, from 40°W to 145°W. The PDE file was the primary source for earthquakes in the Arctic outside these two other regions. Thus, for the Arctic Mid-Ocean Ridge seismicity, PDE values are plotted for those parts of the ridge in the Arctic Ocean Basin, but USSR values are plotted for the seismicity associated with the extension of this feature onto the continental shelf in the Laptev Sea-Lena River Delta area of the USSR south of 80°N.

The earthquakes are plotted with values given in their primary source according to the area which they are located in. In seismically active areas along the boundaries of two data source regions, the earthquakes listed on both sides of the boundary in each source have been compared in overall completeness and accuracy in the time periods used and the more complete source used. Event-by-event comparisons were not done between data sources. There may be differences of up to 30 km in position and 0.5 units in magnitude for events in different sources.

(iii) Time-Periods

The total time period covered by the data sources was divided into three sub-periods for the purposes of plotting. The first period included earthquakes up to the end of 1961, which represents a period of generally incomplete coverage and relatively poor location accuracy of Arctic earthquakes. The second period covered the time interval from the start of 1962 to the end of 1971. This period featured a rapid expansion of world-wide earthquake coverage through the establishment of the World-Wide Standard Seismograph Network (WWSSN) and the advent of systematic computer processing of earthquake hypocenters. These two events significantly improved the coverage and location accuracy of earthquakes throughout the world including the Arctic. The third period represented a continuation of the previous phase, but with the number of seismograph stations located in the Arctic gradually increasing to provide more and better coverage of the seismic activity in the region.

On the map earthquakes in each time period are plotted by a distinct colour so that the most recent, more reliable data may be compared to the older data in each area.

(iv) Magnitudes

Magnitudes quoted for earthquakes in the data sources included long-period MS magnitudes, short-period mb magnitudes and a variety of local magnitude schemes including ML magnitudes as originally defined by Richter. mb and MS magnitudes have only been routinely computed by the PDE program since 1963 and 1968 respectively. Before these dates magnitude calculations were less systematic and included other magnitude schemes such as intermediate-period MB magnitudes. The data files are not always specific as to which type of magnitude has been calculated for earthquakes in the first period before 1962, and it has been assumed that the magnitudes for these older events are in general comparable to the mb or MS magnitudes calculated for the more recent events. No recalculation of magnitude values or comparison of values for the same event in different sources has been done for this map except in the case of those events discussed in Chapter 6.

In general, MS magnitudes were available for earthquakes of magnitude 6.0 or greater and these magnitudes have been used to plot the largest events. For events less than magnitude 6.0, mb magnitudes have been used when available, but otherwise local magnitude values are plotted. The data sources list some earthquakes with no calculated magnitudes. In general, these have been assumed to be small events around magnitude 3 and they have been plotted.

Three ranges of magnitudes have been distinguished on the map by different symbols: magnitude 6.0 and greater, magnitude 5.0 to 5.9 and magnitude less than 5.0. The largest events have the most tectonic significance and are the most completely recorded. The smallest events give some idea of the relative rate of activity in different parts of the Arctic but they are certainly not uniformly monitored in all parts of the region.

Note that events with magnitude less than 3.0 are reported for some time periods in some of the data sources, but have not been plotted. In the regions where they were reported, their distribution was in general very similar to that of the events of magnitude 3.0 to 4.9 and their ommission did not significantly change the map. Chapter 6 and Figures 6-5 to 6-8 specifically present additional information on small magnitude earthquake activity in the Baffin-Lincoln, Beaufort, Chukchi and Laptev-East Siberian Seas respectively taken from special studies of these areas published in the literature.

(v) Focal Depth

With very few exceptions all the earthquakes listed in the data sources were shallow events, with depths of 40 km or less. In general, depth is difficult to estimate accurately for Arctic earthquakes, and for many events it is not known at all. No distinction has been made as to focal depth in plotting the events.

(vi) Accuracy and Completeness

It is estimated that the information plotted on this map for the most recent time period (1972-1984) is generally accurate to at least ± 50 km and complete to at least magnitude 5.0 or greater for the Arctic Region considered as a whole. The accuracy and completeness of earthquake data are undoubtably better than this in some of the continental areas on the map which have regional seismic networks in them, but it is difficult to estimate what the appropriate values might be. On the other hand, some of the data presented in the earliest period (before 1962) are worse. See Chapter 6 for a more detailed discussion of the accuracy and completeness of Arctic earthquake data.

(vii) Focal Mechanisms

Plots of the lower focal sphere for any P-nodal solution available for Arctic earthquakes are shown on the map. The solutions are taken from Chapter 6 herein for the Arctic Basin, Canada, Greenland, Alaska and the USSR and from the Map of Seismicity and State of Stress in the North Atlantic Ocean Basin and Adjacent Areas compiled by S. Nishenko, P. Einarsson and M.L. Zoback (Plate 11, Seismicity and State of Stress, The Western North Atlantic Region, Volume M, The Geology of North America) for that part of the North Atlantic Basin between Svalbard and Iceland covered by this map. Compressional quadrants are shaded.

NOTES (HEAT FLOW)

Geothermal measurements on the map fall into four major categories; i) sea-floor measurements, ii) land heat flow values in North America, iii) boreholes instrumented for temperature observations, and iv) land heat flow values outside of North America. Full references to published data are given in Chapter 9 herein.

(i) Sea-floor measurements

Arctic Ocean:

General region	Date	Number	References
Queen Elizabeth Islands	1964	10	Law and others, 1965 Paterson and Law, 1966
Amerasia Basin	1964-1973	356	Lachenbruch and Marshall, 1966 Lachenbruch and Marshall, 1969
Arctic Mid-Ocean Ridge	1967	8	*Lubimova and others, 1976
Lomonosov Ridge	1967	23	*Lubimova and others, 1976
Mendeleev Ridge	1969	5	*Lubimova and others, 1976
Alpha Ridge	1983	10	Taylor and others, 1986
Lomonosov Ridge	1980	–	Judge, 1980

* This publication reviews Soviet data in the Arctic and contains references to original papers.

Amerasia Basin measurements were made by the U.S. Geological Survey from the ice island "T-3" using thermistors on a 2-4 m piston corer. Thermal conductivity was measured by the needle probe technique at many locations along each core. Groups of high quality measurements were taken within a small area shown by a circle. The mean value (given next to each circle) provides a highly reliable determination of the regional heat flow.

Measurements by Paterson and Law in McClure Strait and northwest of Prince Patrick Island were made using oceanographic probes at stations established and supported by aircraft on the pack ice.

Soviet measurements were made from air supported drifting ice stations using a Bullard type oceanographic probe. Sediment thermal conductivity was estimated from the water content.

Heat flow measurements were made on two recent Canadian expeditions (LOREX and CESAR) on the Lomonosov and Alpha ridges. The areas where measurements were made are shown as hatchured circles.

Norwegian-Greenland Sea:

General region	Date	Number	References
Norwegian-Greenland Sea	1974	55	Langseth and Zielinski, 1974
Denmark Strait	1974	9	Lachenbruch and Marshall, 1968
Norway Basin	1974	7	Haenel, 1974
Voring Plateau	1977	11	Zielinski, 1977
Yermak Plateau	1981	4	Jackson and others, 1984
Yermak Plateau	1980	16	Crane and others, 1982
Norwegian-Greenland Sea	1971	7	Lubimova and others, 1973
Knipovich Ridge	1985	40	Crane and others, 1987 (In prep.)

Except for the nine measurements made in the Denmark Strait from a drifting ice island the data listed above were obtained on research ships using oceanographic probes.

(ii) Published land heat flow measurements in North America

There are only four published land heat flow measurements on the North American continent shown as colored dots with the heat flow value next to it. The Prudhoe Bay value is the average of measurements in 9 boreholes.

Region	References
Resolute Bay	Misener and others, 1956, Lachenbruch and Brewer, 1959
Cape Thompson	Lachenbruch and others, 1966
Prudhoe Bay	Lachenbruch and others, 1982
Norman Wells	Garland and Lennox, 1972

(iii) Instrumented boreholes in North America

Locations of instrumented holes are shown as black squares. Thermistor cables or periodic measurements in these holes have monitored temperature for up to 10 years. Temperature data from these holes have been published in several reports and papers.

Region	References
Alaskan Sites	Misener and others, 1956, Lachenbruch and Brewer, 1959
Canadian Sites	Lachenbruch and others, 1966

(iv) Continental heat flow measurements outside of North America

Published values up to 1984 are shown as colored dots in the same way as the sea-floor values.

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PLATE 2. Seismicity and Heat Flow
The Arctic Ocean Region
Vol. L of The Geology of North America (GNA-L)

GRAVITY OF THE ARCTIC

Compiled by
L.W. Sobczak and D.B. Hearty
with contributions by
R. Forsberg, Y. Kristoffersen, O. Eldholm and S.D. May

Polar Stereographic Projection
Scale 1:6,000,000 at Latitude 75°N

Plate 3 (i) Measurements

Gravity map of the Arctic is based on surface observations; Free-air anomalies offshore and Bouguer anomalies onshore. Gravity anomalies are based on IGSN 1971 and GRS 1967 described below. Applicon colour discrimination is 5 mGal. Small dots are locations of gravity observations. Areas with station density greater than 1 per 3 km have been filtered in station dots in order to maintain colour discrimination such as the National Petroleum Reserve area of northern Alaska and the Amundsen Gulf area.

This map has been compiled from 353,195 observations. Of this number 19,365 observations (5 minute averages, EPB and AGC, 1986) are from Baffin Bay, 60,298 from the North Atlantic Ocean, 62,193 from the Arctic Ocean, 117,368 from continental areas and 93,971 digitized contoured values from Alaska.

The Arctic region was divided into a series of 1:1,000,000 map sheets as shown in Figure 7-1 (in text). A total of 57 map sheets were plotted on a polar stereographic projection where observed gravity data exist. For every sheet, gravity data from each source were plotted separately. As many as five overlays were required for some of the 1:1,000,000 sheets. After discrepancies were identified and resolved, the data were merged and hand-contoured at 10 mGal intervals. The individual sheets were then photo-reduced to 1:6,000,000 scale. A simplified figure of this map is shown in Figure 7-2 (in text).

The coloured map was produced from the above random data points by first forming a 10 km grid by linear interpolation to a maximum point separation of 200 km. (J. Halpenny, personal communication, 1986). Each grid cell was further refined using quadratic interpolation to define each 0.1 mm plotter colour pixel (0.6 km on the map).

Gravity data for this map were made available by the Earth Physics Branch (EPB) and Atlantic Geoscience Centre (AGC) of the Department of Energy, Mines and Resources, Ottawa, Canada; the Defense Mapping Agency Aerospace Centre (DMAAC), St. Louis Missouri, United States of America (USA); United States Geological Survey (USGS), Menlo Park, California, USA; Geodetic Institute, Copenhagen, Denmark; and the Finnish Geodetic Institute, Helsinki, Finland via the International Gravity Bureau, Toulouse, France. Before the data from these diverse sources could be directly compared and the map (Plate 3) compiled, differences in survey techniques and in the formulas used to derive anomaly values had to be identified. Problems included the use of different ellipsoids, datums, control station values, cross-over ties and ice-cap thicknesses. Besides collaborating with the above institutions some of these differences were identified by contacting the original sources such as Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA; Atlantic Geoscience Centre (AGC), Dartmouth, Nova Scotia, Canada; National Geophysical and Solar - Terrestrial Data Centre (NGDC), Boulder, Colorado, USA; Lamont-Doherty Geological Observatory (L-DGO) of Columbia University, Palisades, New York, USA; and the University of Wisconsin, Milwaukee, Wisconsin, USA. The differences were then eliminated by recomputing all gravity anomaly values using the method described below.

(ii) Method of reduction

Gravity anomalies were calculated from the following relationship: $g_o = \gamma_o - Fe + Be$ where g_o = observed gravity; γ_o = theoretical gravity; Fe = Free-air effect; Be = Bouguer effect. The Free-air anomaly $FA = g_o - \gamma_o + Fe$ and Bouguer Anomaly $BA = FA - Be$. The observed gravity (g_o) is the value of gravity determined at some field station with respect to a control station. The control station values are based on the International Gravity Standardization Net 1971 (IGSN 71, Morelli et al. 1974). Theoretical gravity (γ_o) *which is a function of latitude* (φ) *is based* on the Geodetic Reference System 1967 (GRS67, 1971) reference ellipsoid where $\gamma_o = 978.03185 (1 + 0.005278895 \sin^2 \varphi + 0.000023462 \sin^4 \varphi)$ Gal. One Gal is a unit of acceleration equal to 1 cm/s^2. One mGal is a thousandth of a Gal or equal to 10 μm/s^2. The Free-air effect (Fe) is a function of the elevation or depth of the observed station above or below the reference ellipsoid which is taken here as mean sea level. $Fe = (dg/dz)\,h - (dg/dz - 4\pi G p_w)\,d_w$ where dg/dz is the vertical gradient of gravity equal to 0.30861 mGal/m, h is the station elevation in meters, G the universal constant of gravitation (6.67), p_w the density of water (1.0 Mg/m^3), and d_w the depth of water. The Bouguer effect (Be) is a function of the mass above or below the reference ellipsoid. The usual correction for mass, a semi-infinite flat slab, is $Be = 2\pi G p_c h + 2\pi G (p_c - p_w)\, d_w + 2\pi G (p_c - p_i)\, d_i$ where $2\pi G = 0.04187$ m^3/Mgs^2, p_c is the assumed surface crustal density (2.67 Mg/m^3), p_i is the assumed density of ice (0.9 Mg/m^3) and d_i is the thickness of ice in meters. Corrections for terrain (topographic relief not included in the slab approximation) were not made.

(iii) Accuracy of Anomalies

The accuracy of the gravity anomalies is dependent on the variables in the above equation. Stations over glaciers such as on Greenland and northern Ellesmere Island have been corrected for the thickness of ice; these corrections are usually in excess of 100 mGal. In mountainous areas, such as Ellesmere and Baffin islands, terrain corrections of up to 30 mGal can be expected. Accuracy of the anomalies varies generally from about 0.2 mGal for detailed surveys such as along a line between Melville Island and Axel Heiberg Island to about 2 mGal for most regional surveys over relatively flat areas. (Sobczak and Weber, 1970; Sobczak and Overton, 1984). Stations over the continental margin of the Arctic Ocean where Decca Lambda navigation, echo sounding and land control were used, anomalies have an accuracy of about 2 mGal (Sobczak and Weber, 1970). Seaward of this, the accuracy drops to about 5 to 10 mGal for various reasons. In the late 1960's and early 1970's measurements were made on the sea ice north of Alaska by the University of Wisconsin using a ski-plane for transportation with navigational uncertainties of up to 15 km and this resulted in gravity anomaly uncertainties of over 5 mGal (Wold et al. 1970, Wold, 1973). In the navigable part of the Chukchi Sea region there were course changes due to floating ice and there were a lack of harbours which prevented dockside ties to land control stations. Dehlinger et al. (1972) and Barnes (1977) estimated a root-mean square of uncertainty of about 5 mGal for these shipborne surveys. Accuracy of gravity anomalies from shipborne surveys in areas of good data control such as the Greenland – Norwegian Seas is probably about 5 mGal (Gronlie and Talwani, 1982; Faleide et al., 1984). In Davis Strait and Baffin Bay the estimated accuracy is ±3 mGal (EPB and AGC, 1986). In areas of the North Atlantic where shipborne surveys have very few crossovers, datum errors in the 10 to 20 mGal range may be common, (McConnell, personal communications, 1986). The DMAAC gravity file for the North Atlantic Ocean lists 54 sources of information of which 37 provide accuracy estimates; the accuracy of the anomalies varies between 1 and 14 mGal with a root mean square of 5.65 mGal.

(iv) Discussion of anomalies

Gravity anomalies can indicate the mass distribution, shape, and equilibrium conditions of the Earth. In topographically high regions, where the Bouguer gravity effect becomes large, Bouguer anomalies are generally negative, sometimes exceeding −200 mGal. A contributing cause of Bouguer anomaly lows in such areas is thickened continental crust, the so-called "crustal root", that commonly underlies mountain belts and compensates isostatically their high elevations. Mean Free-air anomalies in mountainous regions are usually small, which indicates that near-equilibrium conditions are common in such areas. The large Bouguer anomaly lows in mountainous areas, however, tend to obscure smaller anomalous features. Similarly where Bouguer anomalies over oceanic areas are strongly positive, because the Bouguer effect replaces seawater with rock, anomalous features such as the belt of prominent elliptically-shaped Free-air anomaly highs along the Canadian Arctic shelf break are obscured (compare Gravity Map of Canada, 1980 with Bouguer Anomaly Map of Canada, 1974). On land, excluding mountainous areas, Bouguer anomalies depict anomalous mass distributions better than Free-air anomalies and in marine areas the reverse is generally true.

Isostasy or isostatic equilibrium may be expressed by taking the average Free-air anomalies over a large relatively flat area such as the Queen Elizabeth Islands. If this average is near zero then as a first approximation, the region can be considered to be in isostatic equilibrium; that is, mass differences at or near the surface are compensated by mass differences at depth.

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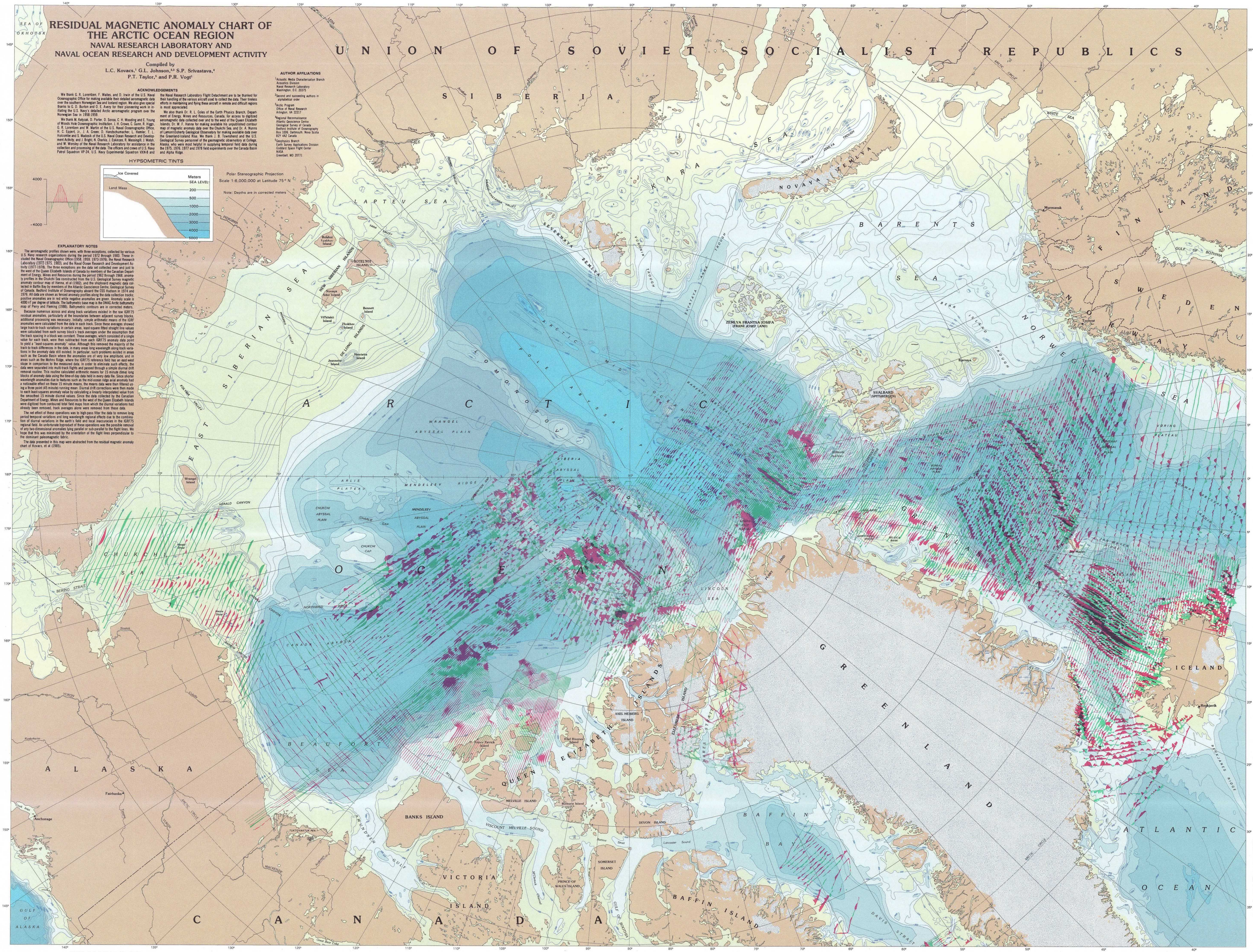
PLATE 3. Gravity of the Arctic
Vol. L of The Geology of North America



RESIDUAL MAGNETIC ANOMALY CHART OF THE ARCTIC OCEAN REGION

NAVAL RESEARCH LABORATORY AND NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY

Compiled by
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P.T. Taylor,[5] and P.R. Vogt[1]

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We also thank Dr. R. L. Coles of the Earth Physics Branch, Department of Energy, Mines and Resources, Canada, for access to digitized aeromagnetic data collected over and to the west of the Queen Elizabeth Islands, Dr. W. F. Hanna for making available his unpublished contour map of magnetic anomaly data over the Chukchi Sea, and Dr. A. Nunns of Lamont-Doherty Geological Observatory for making available data over the Greenland-Iceland Rise. We thank J. B. Townshend and the U.S. Geological Survey personnel of the geomagnetic observatory at College, Alaska, who were most helpful in supplying temporal field data during the 1975, 1976, 1977 and 1978 field experiments over the Canada Basin and Alpha Ridge.

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EXPLANATORY NOTES

The aeromagnetic profiles shown were, with three exceptions, collected by various U.S. Navy research organizations during the period 1972 through 1983. These included the Naval Oceanographic Office (1958, 1959, 1973-1976), the Naval Research Laboratory (1972-1975, 1983), and the Naval Ocean Research and Development Activity (1977-1978). The three exceptions are the data set collected over and just to the west of the Queen Elizabeth Islands of Canada by members of the Canadian Department of Energy, Mines and Resources during the period 1962 through 1968, anomaly profiles in the Chukchi Sea constructed from the U.S. Geological Survey magnetic anomaly contour map of Hanna, et al (1982), and the shipboard magnetic data collected in Baffin Bay by members of the Atlantic Geoscience Centre, Geological Survey of Canada, Bedford Institute of Oceanography aboard the CSS Hudson in 1974 and 1976. All data are shown as fenced anomaly profiles along the data collection tracks; positive anomalies are in red while negative anomalies are green. Anomaly scale is 4000 nT per degree of latitude. The bathymetric base map is the DNAG Arctic bathymetry map of Perry and Fleming (1986). Bathymetric contours are in corrected meters.

Because numerous across and along track variations existed in the raw IGRF75 residual anomalies, particularly at the boundaries between adjacent survey blocks, additional processing was necessary. Initially, simple arithmetic means of the IGRF anomalies were calculated from the data in each track. Since these averages showed large track-to-track variations in certain areas, least-square fitted straight line values were calculated from each survey block's track averages under the assumption that the track spacing in a block was constant. These averages, which consisted of a single value for each track, were then subtracted from each IGRF75 anomaly data point to yield a "least-squares anomaly" value. Although this removed the majority of the track-to-track differences in the data, in many areas long wavelength along-track variations in the anomaly data still existed. In particular, such problems existed in areas such as the Canada Basin where the anomalies are of very low amplitude, and in areas such as the Mohns Ridge, where the IGRF75 reference field has an east-west slope in comparison to the measured data. In order to eliminate such effects, the data were separated into multi-track flights and passed through a simple diurnal drift removal routine. This routine calculated arithmetic means for 15 minute (time) long blocks of anomaly data using the time-of-day data held in every data file. Since shorter wavelength anomalies due to features such as the mid-ocean ridge axial anomaly had a noticeable effect on these 15 minute means, the means data were then filtered using a three point (45 minute) running mean. Diurnal drift corrections were then made to each least-squares anomaly value by calculating a linearly interpolated value from the smoothed 15 minute diurnal values. Since the data collected by the Canadian Department of Energy, Mines and Resources to the west of the Queen Elizabeth Islands were digitized from contoured total field maps from which the diurnal variations had already been removed, track averages alone were removed from these data.

The net effect of these operations was to high-pass filter the data to remove long period temporal variations and long wavelength regional effects due to the combination of diurnal variations in the earth's field and local inaccuracies in the IGRF75 regional field. An unfortunate byproduct of these operations was the possible removal of any two-dimensional anomalies lying parallel or sub-parallel to the flight lines. We hope that this was minimized by the orientation of the flight lines perpendicular to the dominant paleomagnetic fabric.

The data presented in this map were abstracted from the residual magnetic anomaly chart of Kovacs, et al (1985).

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PLATE 4. Residual magnetic anomaly chart of the Arctic Ocean region
The Arctic Ocean Region
Vol. L of The Geology of North America

SEDIMENTARY THICKNESS MAP OF THE ARCTIC OCEAN

Compiled by H. R. Jackson and G. N. Oakey

This contoured sedimentary thickness map has been synthesized from a variety of data sources. The primary data set consists of seismic reflection profiles in pink and seismic refraction profiles in grey, but the limited number of lines and the fact that few of them penetrated basement (Jackson and others, this volume) precluded a chart based on these lines alone. Three Soviet maps (Anonymous, 1978[41]; Anonymous, 1983{43}; and Pogrebitskii and others, 1984[44]) that showed sedimentary thickness contours were used as a basis for contouring vast regions (Numbers are keyed to the Index Map).

The data sources for these maps are often unknown, and the contours are not always consistent from one map to the other. The chart that was used to supply data in a particular region had the most detailed information and was supported by independent information. For example, the refraction line in the Barents Sea [31] supported the information published on the Progrebitskii and others (1984 [44]) map. Furthermore, the reports of Ulmishek (1982, 1985 [44]) verified the structures in the Barents and Kara Seas. Most of the information in the Barents and Kara Seas is based on gravity and magnetic surveys and extrapolation of geology from onshore and the many islands; limited seismic data and one onshore well are available. The review of Meyerhoff (1982 [44]) was used to modify contours in the Kara Sea.

On the continental margin of Alaska, the Beaufort Sea, the Mackenzie Delta, and western Barents Sea, sedimentary thickness information is based on multichannel reflection seismic lines. The basement for the Alaskan and Beaufort margin survey is the early paleozoic Franklinian sequence, while on the western Barents shelf it is Paleozoic strata. In the western Barents Sea, where sonobuoy data were used to derive sedimentary thickness, the base of the Devonian is basement. In other regions of the map where contours are based on seismic data, acoustic basement is used with no stratigraphic significance implied. The terms sedimentary rocks and sedimentary deposits are used here to describe everything from the sea floor to basement.

Basement in the Canada Basin, where little information is available, is based on an algorithm of Grantz and May (1987 [46]) that uses a bathymetric chart and refraction data to estimate sedimentary thickness. Sedimentary thickness was determined north of Ellesmere Island and over parts of the Lomonosov and Alpha Ridges by subtracting water depths from magnetic depth to source calculations of Kovacs and Vogt (1982 [45]). Contouring on the shelf of northeast Greenland was constructed from aeromagnetic lines and stratigraphic comparisons with basins in East Greenland and the Norwegian shelves. In the Norwegian-Greenland Sea, maps with sedimentary thickness in time units are available (Eldholm and others, this volume [39]). Using sonobuoy velocities averaged by region, more generalized thickness contours in kilometers have been drawn in this region.

Additional information for the map is available principally from Soviet sources. The data sources for the following information are not clearly presented nor are their locations accurately known. These data have been used to modify contours derived from other references. For example, on the Wrangel Abyssal Plain, Gramberg and Kulakov (1975 [43]) report a sedimentary sequence of 5 to 6 km that thickens to 7 to 8 km on the East Siberian continental slope. The 8 km contour interval was extended between the Lomonosov Ridge and the shelf because Demenitskaya and Hunkins (1970 [43]) indicated a deep sediment-filled trough in this area. In the Laptev Sea the shape of the contour intervals based on Soviet charts was retained, but the thicknesses have been increased because Demenitskaya and others (1973 [43]) suggested there are between 2 and 8 km of sedimentary rocks in this area. This thickness is supported by the refraction line in Grachev (1982 [30]). Furthermore, in the region of the Chukchi Borderland, Gramberg and Kulakov (1975 [43] described troughs bordering the Chukchi Borderland which contain thick clastic sections. Between the Northwind Ridge and Chukchi Borderland 5 to 7 km of sedimentary rocks are observed on seismic records.

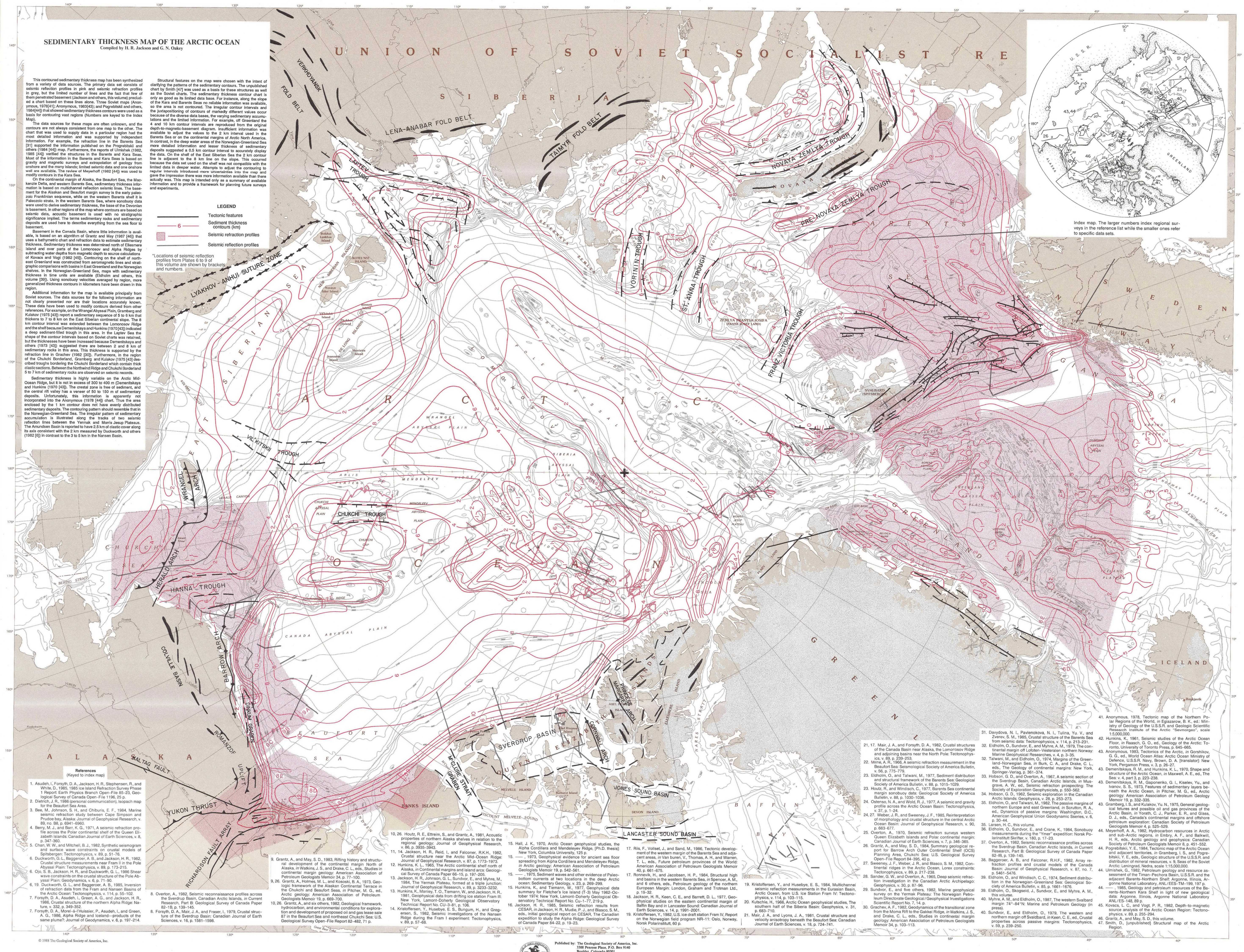
Sedimentary thickness is highly variable on the Arctic Mid-Ocean Ridge, but it is not in excess of 300 to 400 m (Demenitskaya and Hunkins (1970 [43]). The crestal zone is free of sediment, and the central rift valley has a veneer of 50 to 150 m of sedimentary deposits. Unfortunately, this information is apparently not incorporated into the Anonymous (1978 [44]) chart. Thus the area enclosed by the 1 km contour does not have evenly distributed sedimentary deposits. The contouring pattern should resemble that in the Norwegian-Greenland Sea. The irregular pattern of sedimentary accumulation is illustrated along the tracks of two seismic reflection lines between the Yermak and Morris Jesup Plateaus. The Amundsen Basin is reported to have 2.5 km of clastic cover along its axis consistent with the 2 km measured by Duckworth and others (1982 [6]) in contrast to the 3 to 5 km in the Nansen Basin.

Structural features on the map were chosen with the intent of clarifying the patterns of the sedimentary contours. The unpublished chart by Smith [47] was used as a basis for these structures as well as the Soviet charts. The sedimentary thickness contour chart is only as good as its limited data base. For instance, along the slope of the Kara and Barents Seas no reliable information was available, so the area is not contoured. The irregular contour intervals and the juxtapositioning of contours of markedly different values occur because of the diverse data bases, the varying sedimentary accumulations and the limited information. For example, off Greenland the 4 and 10 km contour intervals are reproduced from the original depth-to-magnetic-basement diagram. Insufficient information was available to adjust the values to the 2 km interval used in the Barents Sea or on the continental margins of Arctic North America. In contrast, in the deep water areas of the Norwegian-Greenland Sea more detailed information and lesser thickness of sedimentary deposits suggested a 0.5 km contour interval to accurately display the data. On the shelf of the East Siberian Sea the 2 km contour line is adjacent to the 8 km line on the slope. This occurred because the data set used on the shelf was not compatible with the limited data in deeper water. Attempts to adjust the contouring to regular intervals introduced more uncertainties into the map and gave the impression there was more information available than there actually was. This map is intended only as a summary of available information and to provide a framework for planning future surveys and experiments.

LEGEND

- Tectonic features
- 6 Sediment thickness contours (km)
- ▨ Seismic refraction profiles
- Seismic reflection profiles

*Locations of seismic reflection profiles from Plates 6 to 9 of this volume are shown by brackets and numbers.



Index map. The larger numbers index regional surveys in the reference list while the smaller ones refer to specific data sets.

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PLATE 5. Sedimentary thickness map
The Arctic Ocean Region
Vol. L of The Geology of North America (GNA-L)

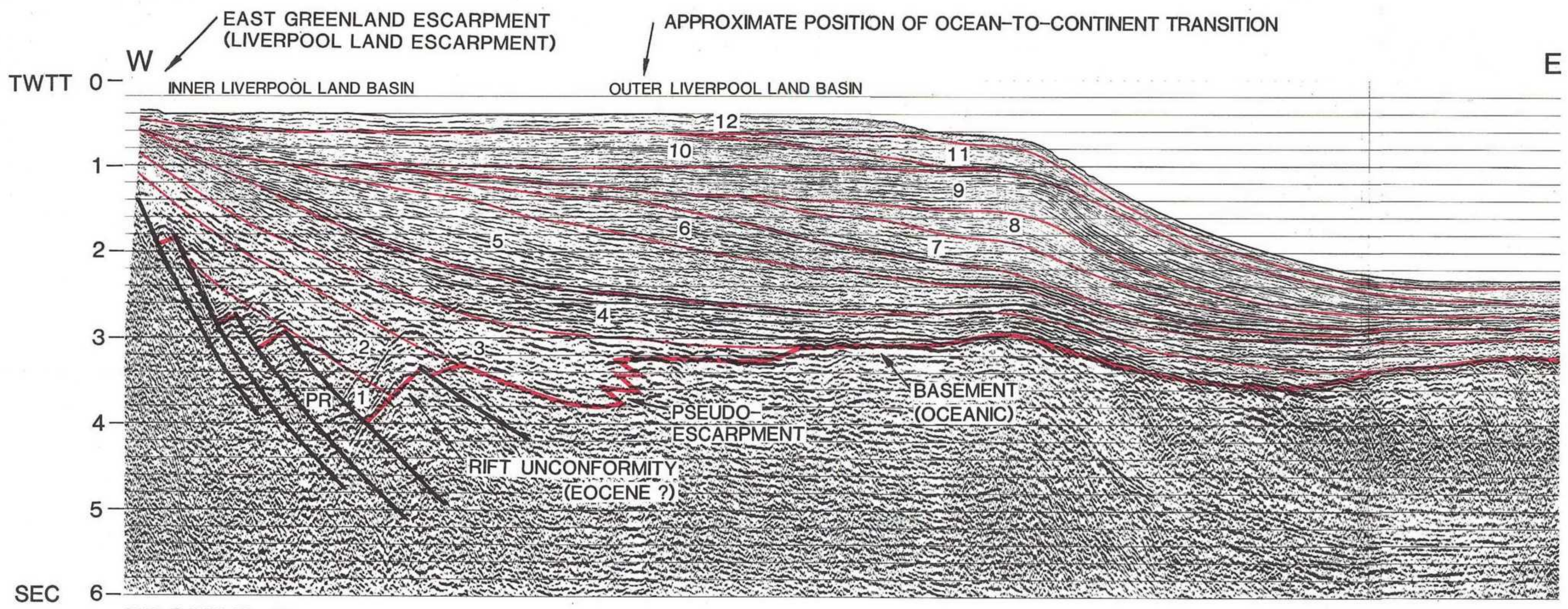
PLATE 6. Seismic reflection profiles across the
continental margin off East Greenland
The Arctic Ocean Region
Vol. L of The Geology of North America (GNA-L)

SEISMIC REFLECTION PROFILES ACROSS THE CONTINENTAL MARGIN OFF EAST GREENLAND

Compiled by H.C. Larsen

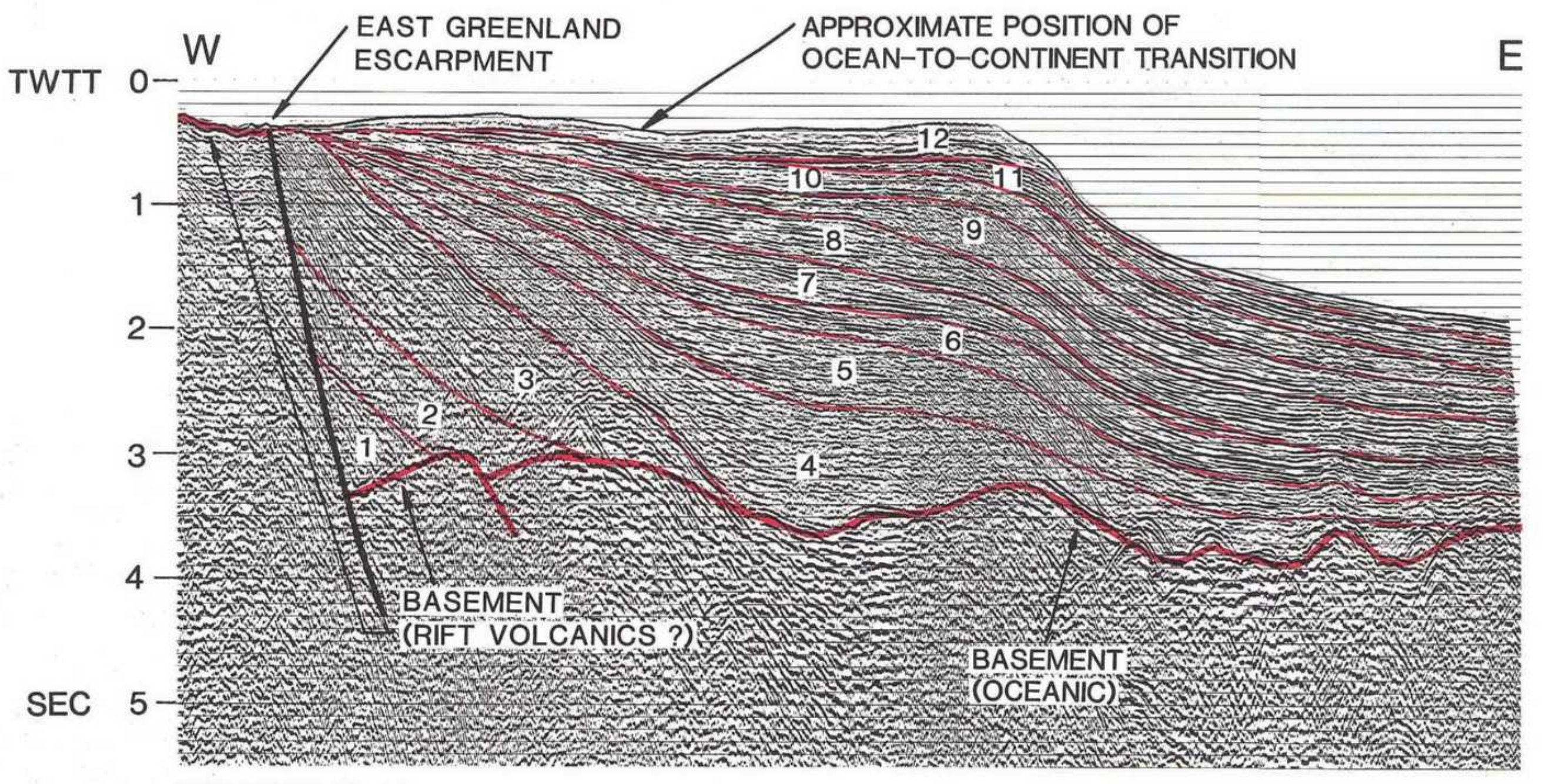
The Geological Survey of Greenland
Copenhagen. January 1988

25 Km



PROFILE E

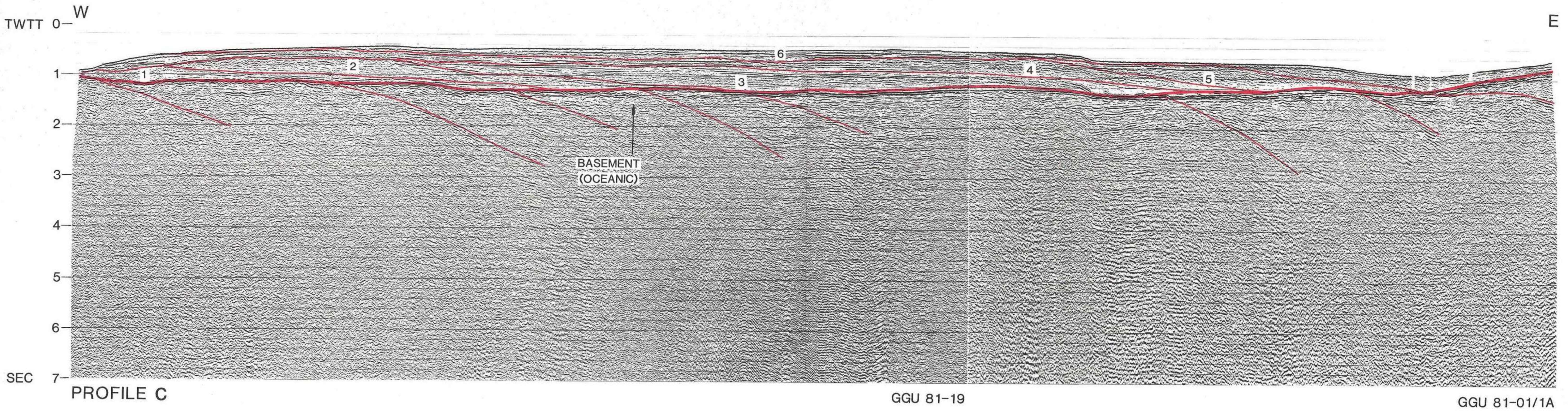
PROFILE E: Approximate age of oceanic basement: anomaly 6 to 5A.
Sequence 1 – 2: Eocene to Early Oligocene.
Sequence 3: Late Oligocene to Early Miocene.
Sequence 4: Early Miocene to Middle Miocene.
Sequence 5 – 6: Middle to Late Miocene.
Sequence 7 – 8: Late Miocene.
Sequence 9 – 11: Late Miocene to Pliocene.
Sequence 12: Pleistocene.
Sequence PR: Pre-drift sequence, Mesozoic or older.



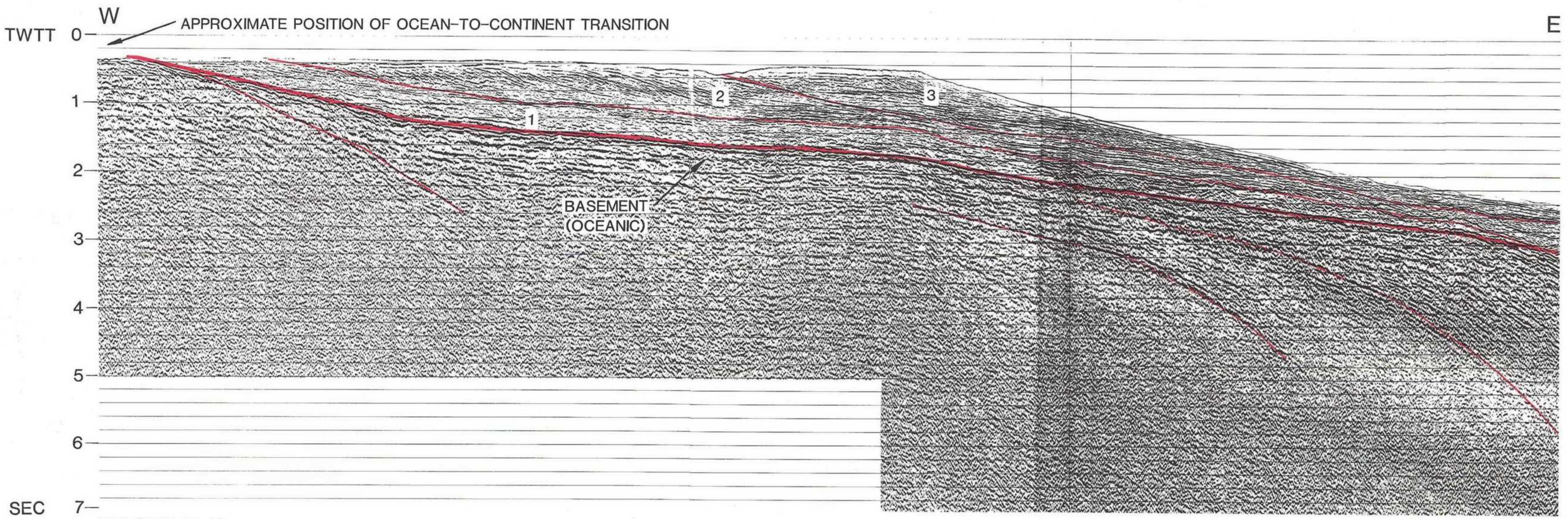
PROFILE D

PROFILE D: Approximate age of oceanic basement: anomaly 9 to 7.
Sequence 1 – 3: Eocene to Early Oligocene.
Sequence 4: Late Oligocene to Early Miocene.
Sequence 5 – 6: Early to Middle Miocene.
Sequence 7 – 8: Middle to Late Miocene.
Sequence 9 – 11: Late Miocene to Pliocene.
Sequence 12: Pleistocene.

PROFILE C: Presumed ocean-to-continent transition located west of profile.
Approximate age of basement: anomaly 22 to 13.
Note minor reversals in the seaward dip of intra-basement reflectors interpreted as a consequence of minor axial jumps.
Sequence 1: Middle Miocene or younger.
Sequence 2 – 6: Middle Miocene to Plio-Pleistocene.

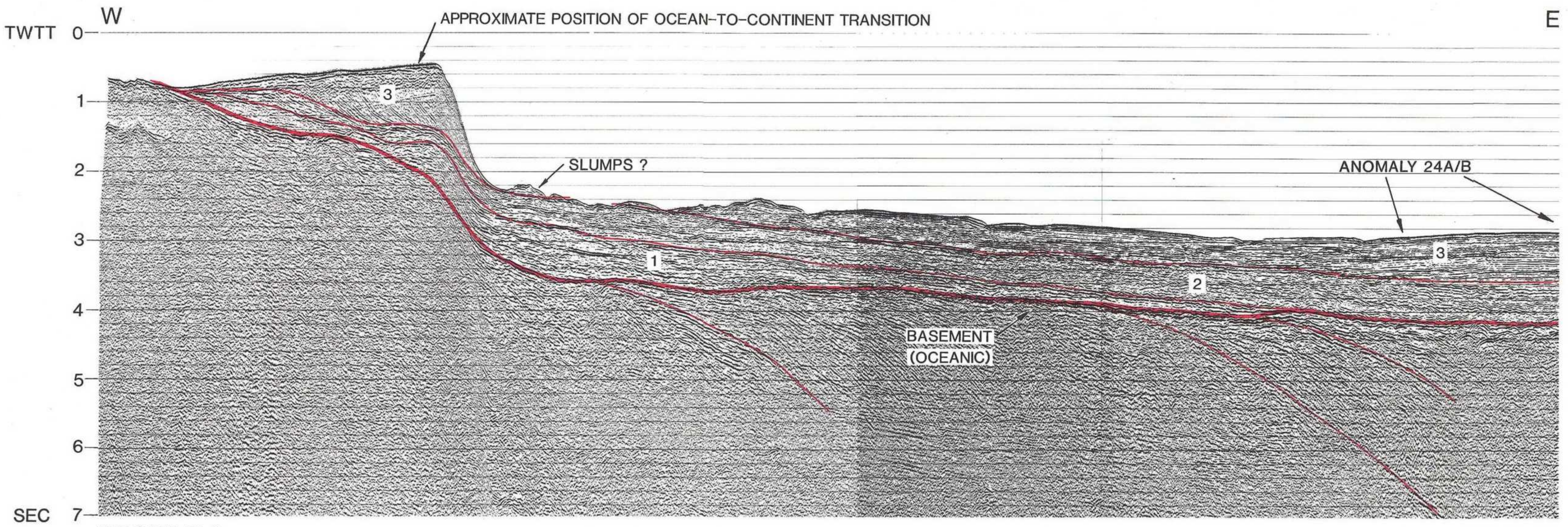


PROFILE C



PROFILE B

PROFILE B: Approximate age of oceanic basement: anomaly 24 to 22.
Dating of seismic sequences 1 through 3 as in profile 1.



PROFILE A

PROFILE A: Note presence of seaward dipping reflectors within the basement.
Landward edge of the dipping volcanic sequence outcrops on sea bed.
Sequence 1: Late Paleocene to Eocene.
Sequence 2: Eocene to Early Oligocene ?
Sequence 3: Miocene to Plio-Pleistocene ?

NOTE: Ages of seismic sequences inferred from seismic stratigraphy assisted by ages from sea-floor spreading anomalies; no well control.

All profiles at same scale.

Vertical exaggeration approximately 4.5.

Positions of profiles shown on Plates 5 & 10.

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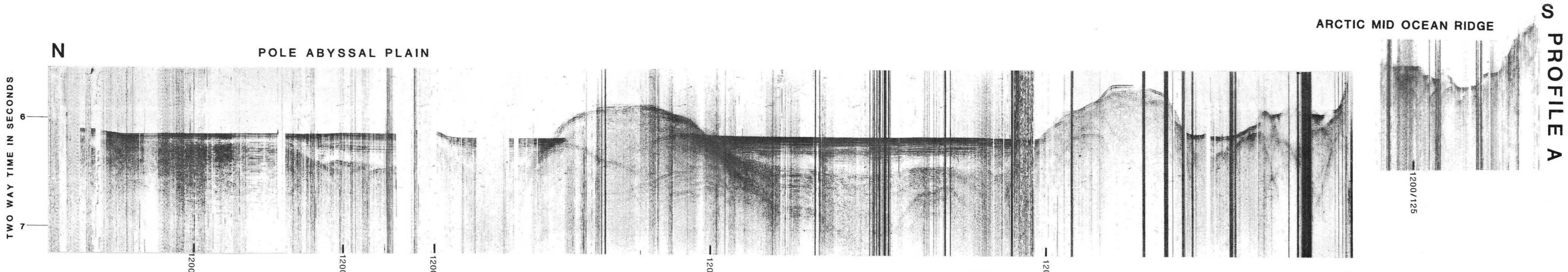
SINGLE CHANNEL SEISMIC REFLECTION PROFILES

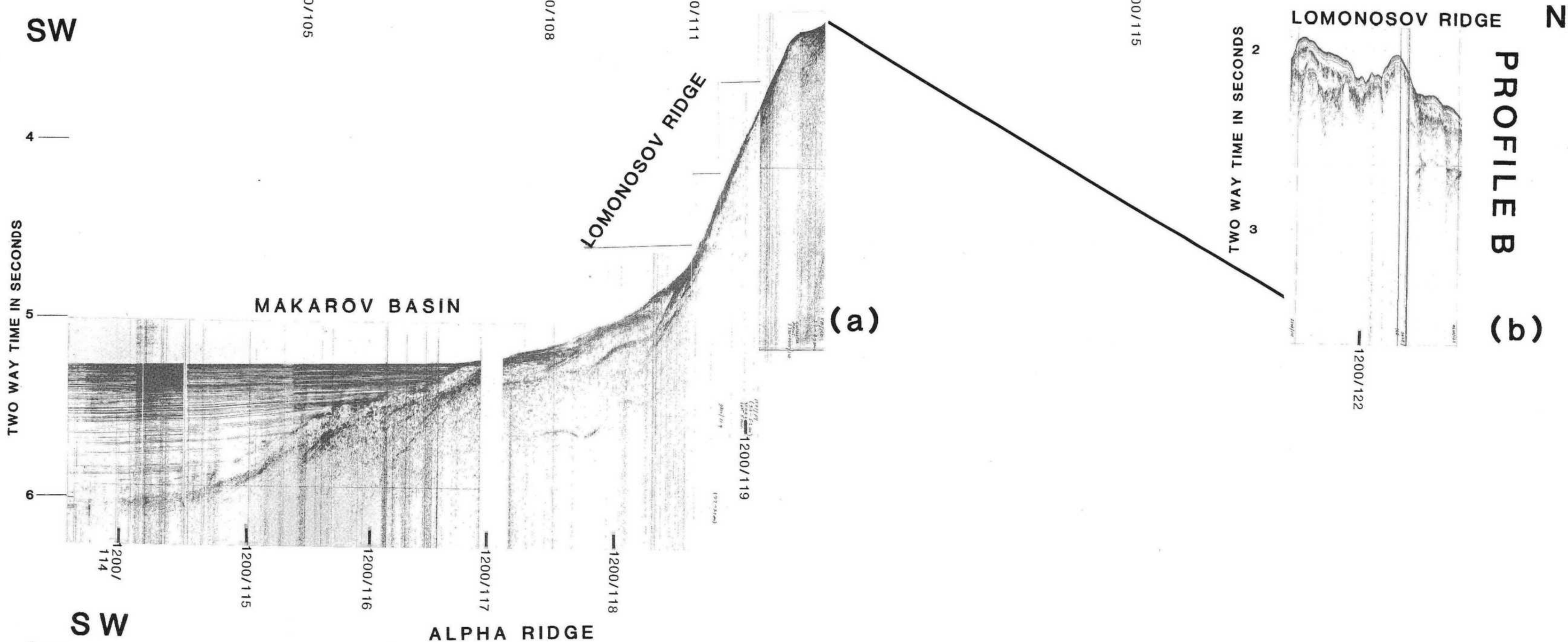
FROM THE

ARCTIC BASIN

Contributed By

Marcus G. Langseth, Kenneth L. Hunkins, H. Ruth Jackson, and Steven M. Blasco

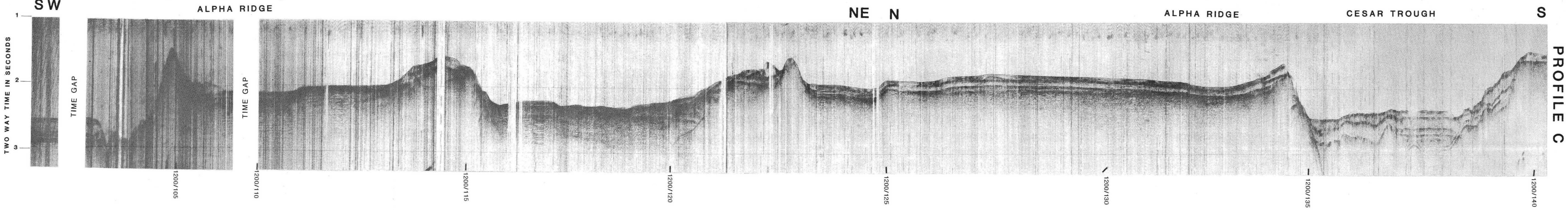


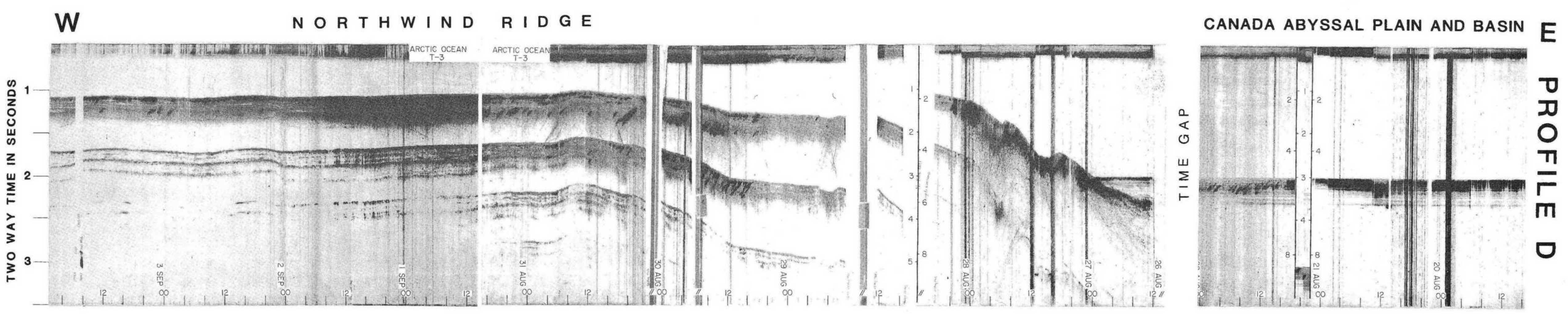


PROFILE A. Seismic reflection profile recorded from floating ice station FRAM I, 1979, using a 40 in^3 airgun and a single omnidirectional hydrophone receiver. Airgun was fired once every five minutes and the distance between shots varied with the drift rate of the ice station. The profile crosses the Eurasia Basin between the Morris Jesup Plateau and the Arctic Mid-Ocean Ridge. The rugged topography of the ridge is apparent. Sediments are thick and flat-lying, and thin rapidly to zero toward the ridge. The thickest observed sediments have a two-way travel time of 0.7s, corresponding to a thickness of about 1 km, using an assumed average velocity of 3 km s^{-1}. This high sediment concentration in deeper areas suggests a predominantly turbiditic origin from the nearby Greenland continental shelf. Time scale at bottom indicates Julian Day at 1200 hours. Location of profile shown on Plate 5. Material contributed by H. R. Jackson, Geological Survey of Canada.

PROFILE B. Seismic reflection profiles across (a) Makarov Basin and (b) top of Lomonosov Ridge. Profile (a) shows 1,100 m of horizontally stratified and undeformed unconsolidated sediments (turbidites?) of the Makarov Basin unconformably abutting the rising flanks of Lomonosov Ridge. The Makarov (western) flank of the ridge is formed by a steep fault scarp. The flank rises steeply, with slopes of 12°, from a bathymetric depth of 3,950 m in the Makarov Basin to a minimum crest elevation of 1,400 m below sea level. The Lomonosov Ridge (b) appears to consist of imbricated normal fault blocks composed of sedimentary rocks as much as 6 km thick resting on a crustal root of intermediate to basic crystalline rocks approximately 20 km thick. Geophysical evidence suggests the ridge is a linear fragment of the Barents and Kara continental shelves which was broken away at the inception of spreading along the Arctic Mid-Ocean (Nansen-Gakkel) Ridge in Late Cretaceous to early Tertiary time. The ridge crest is covered with a thin veneer of less than 40 m of unconsolidated to semiconsolidated sediments whose internal stratigraphy is conformable to the irregular morphology of the ridge crest bedrock. Shooting parameters as in Profile A. Time scale at bottom indicates Julian Day at 1200 hours. Location of profile shown on Plate 5. Material contributed by Steven M. Blasco, Geological Survey of Canada.

PROFILE C. Seismic reflection profile across Alpha Ridge recorded from floating ice station CESAR, 1983 (Canadian Expedition to Study the Alpha Ridge). Profile shows from 0.2 to 0.5 s of layered, generally flat-lying and internally conformable sediment overlying acoustic basement. Where basement is irregular the sedimentary horizons follow the irregular trend, as at J.D. (Julian Day) 134. A bottom-simulating reflector, believed to be caused by a gas hydrate zone, obscures the sediment-basement interface at 0.15 s. In some locations the bottom is offset in a step-like fashion (J.D. 111 and J.D. 125) that is probably fault controlled. Faults with greater offsets occur at J.D. 120 to J.D. 122. At these locations sedimentary reflectors terminate against basement and suggest that the faults postdate the deposition of the sediments. On top of the uplifted block, the sediments conform to basement and dip gently. The major valley crossed at J.D. 135 to J.D. 140 shows a rugged basement topography. The valley has a graben-shaped cross section with less sediment deposited along the north than along the south scarp. The sedimentary reflectors adjacent to the northern scarp suggest an onlap sequence. The sediment on the southern wall and beneath the valley appears to be slumped. Between J.D. 137 and 139, the flat-lying section is an artifact of the abrupt slowing of the drift rate. Shooting parameters as in Profile A. Time scale at bottom indicates J.D. at 1200 hours. Location of profile shown on Plate 5. Material contributed by H. R. Jackson, Geological Survey of Canada.

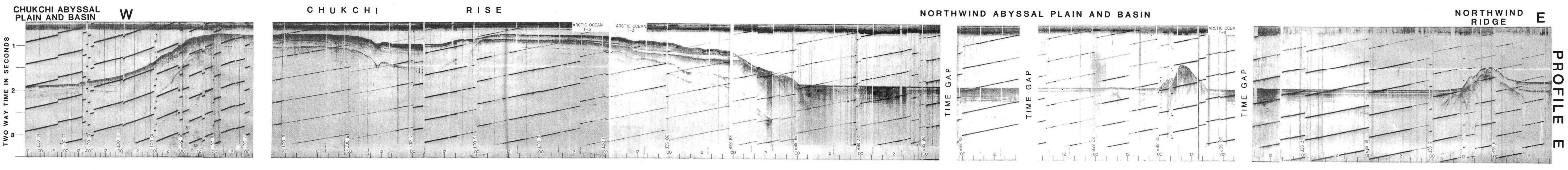




PROFILE D. Seismic reflection profile recorded from Fletcher's Ice Island (T-3), August 19 to September 3, 1966. The profile, obtained with a 9000 joule speaker and two hydrophones 30 m apart suspended 4 m beneath the sea ice, crosses the Northwind Ridge of the Chukchi Borderland. The Northwind Ridge rises to depths of about 900 m on the west side of this profile. On the east side is the Canada Abyssal Plain at a constant depth of 3,840 m. The flat-lying sediments beneath the Abyssal Plain onlap the eastern escarpment of the Northwind Ridge. Location of profile shown on Plate 5. Material contributed by Marcus G. Langseth and Kenneth L. Hunkins, Lamont-Doherty Geological Observatory.

PROFILE E. Seismic reflection (sparker) profile recorded from Fletcher's Ice Island (T-3), September 13 to October 14, 1966. Profile crosses Chukchi Abyssal Plain, Chukchi Rise, Northwind Abyssal Plain and west flank of Northwind Ridge. This crossing of the Chukchi Borderland lies south of the Chukchi Cap and the minimum depth encountered was 384 m. The floor of the Chukchi Abyssal Plain is at 2,200 m. The floor of the Northwind Abyssal Plain, which is perched between the Chukchi Rise and Cap and Northwind Ridge, lies at 2,100 m. Note the extensional faults on the Chukchi Rise and the almost flat-lying sediments beneath the Northwind and Chukchi Abyssal Plains. The sediments of the Northwind Abyssal Plain appear in part to onlap and in part to be faulted against the adjacent ridges. Shooting parameters as in Profile D. Location of profile shown on Plate 5. Material contributed by Marcus G. Langseth and Kenneth L. Hunkins, Lamont-Doherty Geological Observatory.

PROFILE F. Seismic reflection (sparker) profile recorded from Fletcher's Ice Island (T-3), March 19 to May 9, 1967. Profile crosses the north end of Arlis Plateau and the southeast flank of the Mendeleev Ridge along a primarily north-south zig-zag track. The sediment cover is relatively thick but highly variable. Steep slopes and rough, probably fault-produced topography within the basement are reflected in the surface topography even though large volumes of sediment have partially filled some valleys. Shooting parameters as in Profile D. Location of profile shown on Plate 5. Material contributed by Marcus G. Langseth and Kenneth L. Hunkins, Lamont-Doherty Geological Observatory.



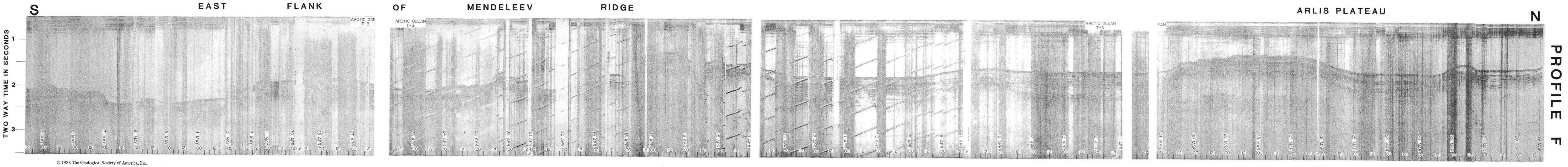


PLATE 7. Single channel seismic reflection profiles
Arctic Basin
The Arctic Ocean Region
Vol. L of The Geology of North America (GNA-L)

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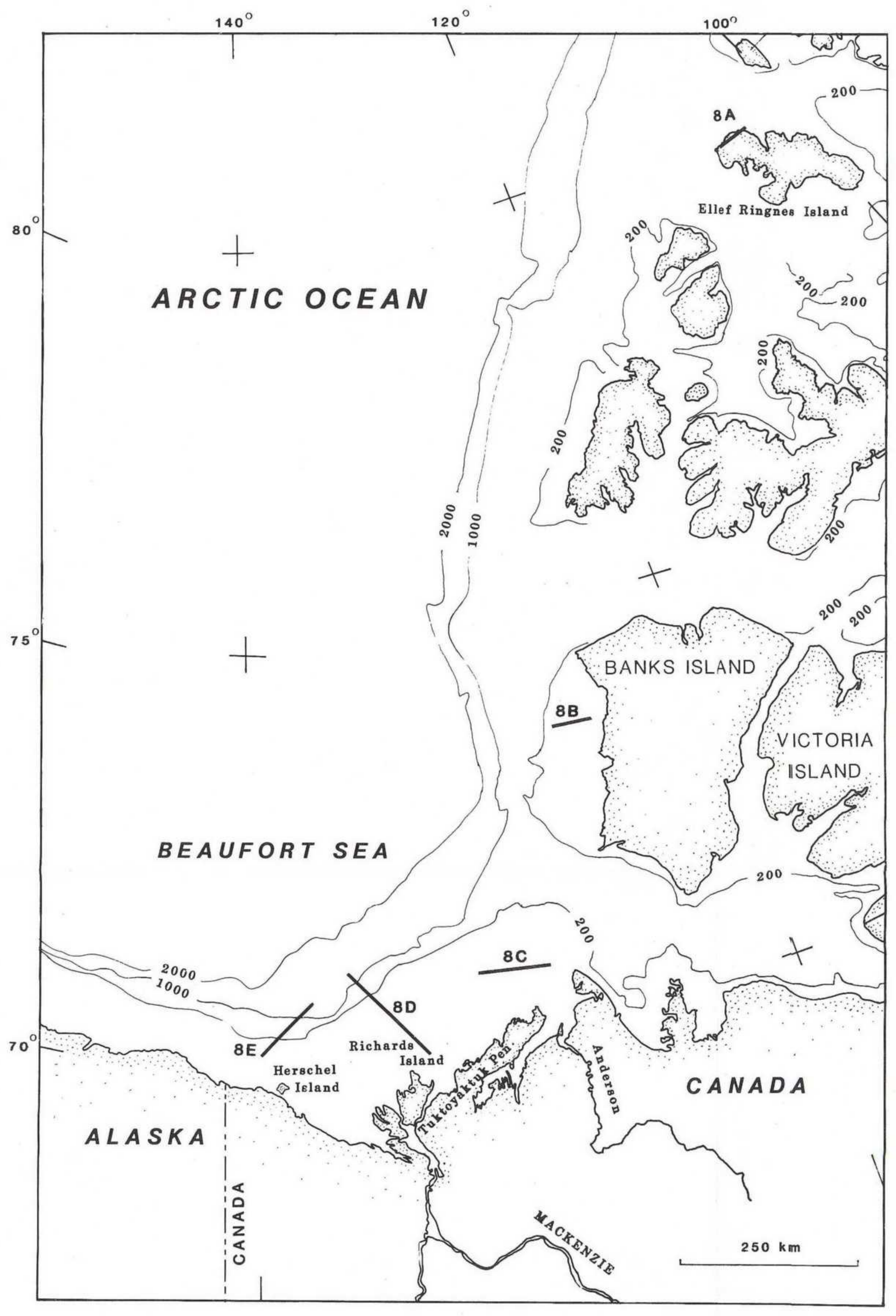
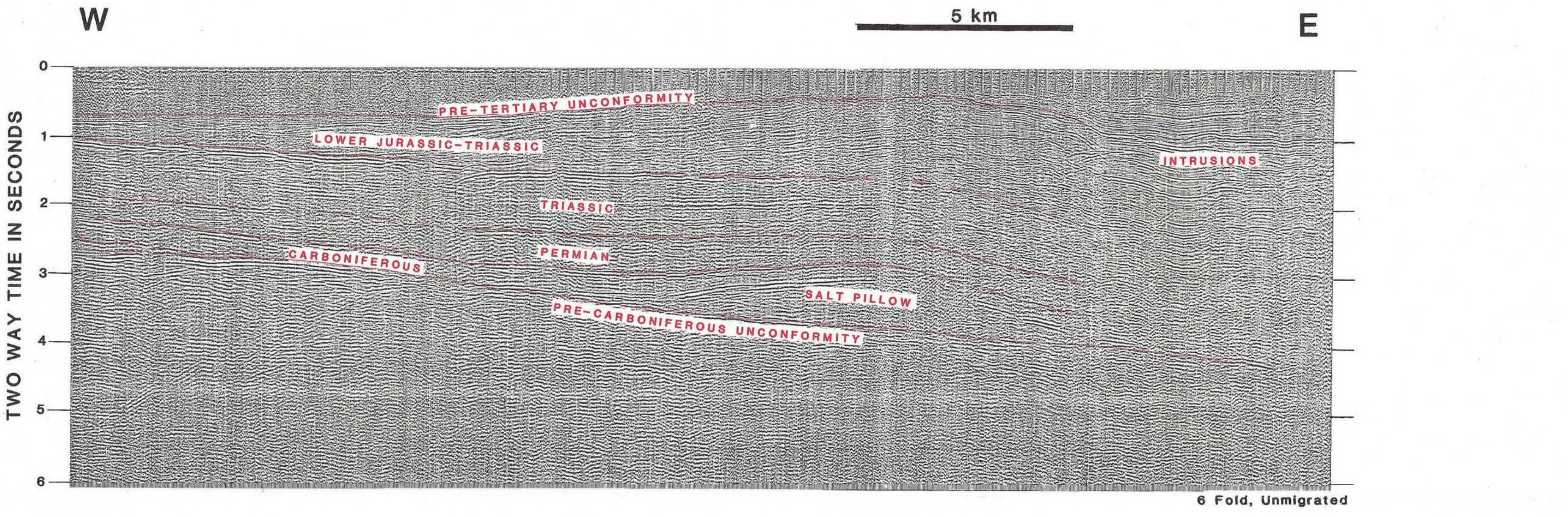
PLATE 8. Multichannel seismic reflection profiles
Canadian margin of the Canada Basin
The Arctic Ocean Region
Vol. L of The Geology of North America (GNA-L)

MULTICHANNEL SEISMIC REFLECTION PROFILES
FROM THE
CANADIAN MARGIN OF THE CANADA BASIN

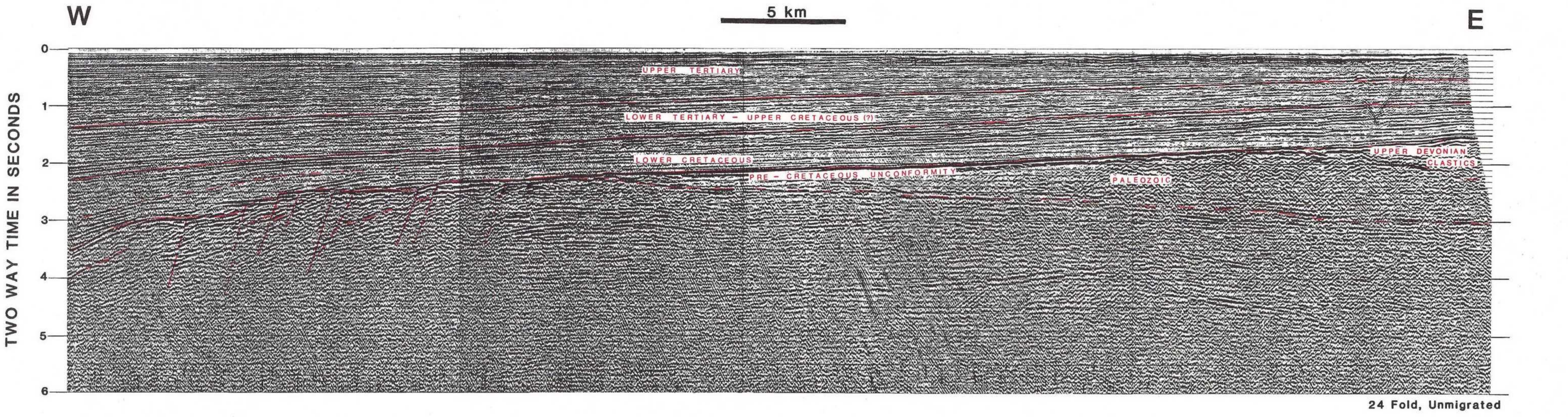
Contributed by

James Dixon, James Dietrich, and Norman E. Haimila

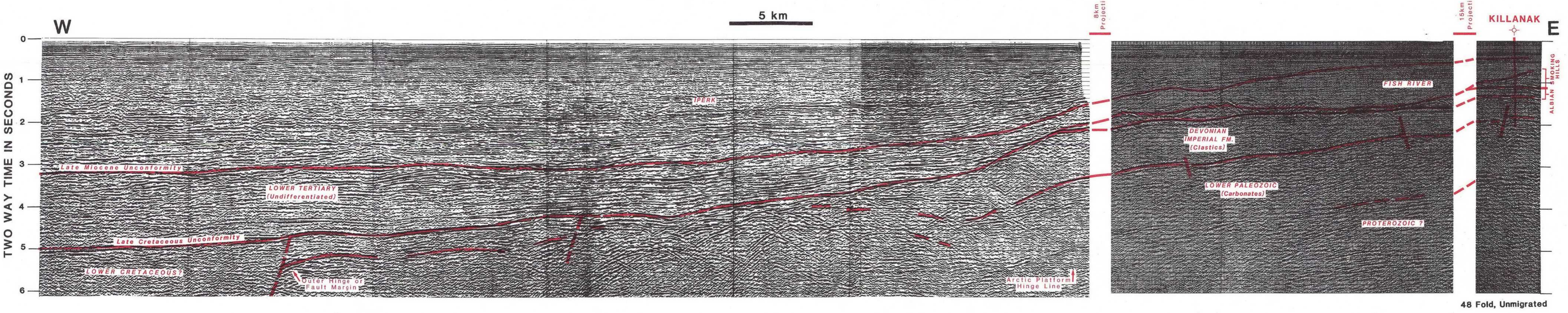




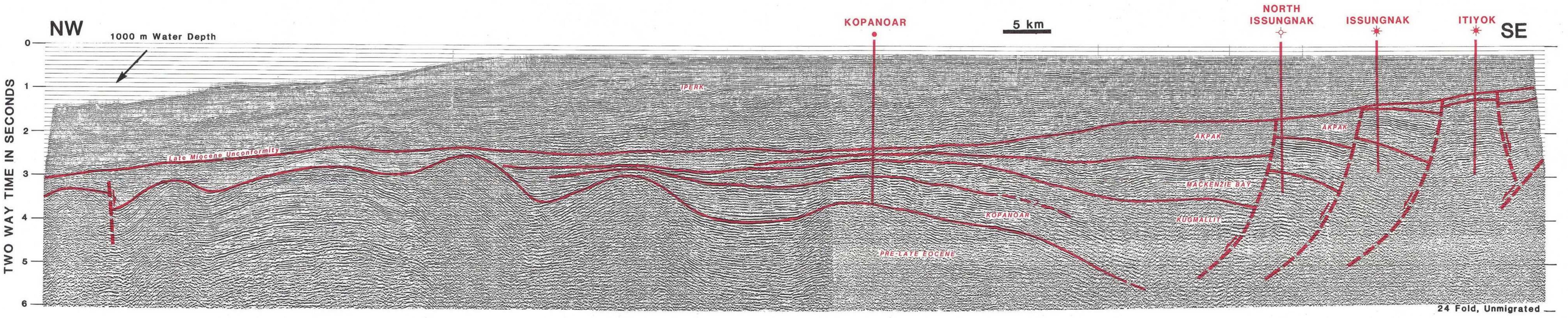
PROFILE 8A. Interpreted marine reflection seismic profile across northern Ellef Rignes Island demonstrating the transition from platform sedimentation at the Arctic rim in the west to basinal facies in Sverdrup Basin in the east during the upper Paleozoic. Evaporites deposited at the edge of the platform during the Carboniferous were mobilized in a salt pillow during the Permian and Triassic. Mesozoic sediments thicken to the east, where they are intruded by numerous sills and dykes that obscure reflections in the area labelled "intrusions". It has been suggested by Embry and Wall (1985) that these intrusions may be related in origin to the volcanic events that formed Alpha Ridge. For location of profile see plate 5. Material contributed by Norman E. Haimila, Geological Survey of Canada.



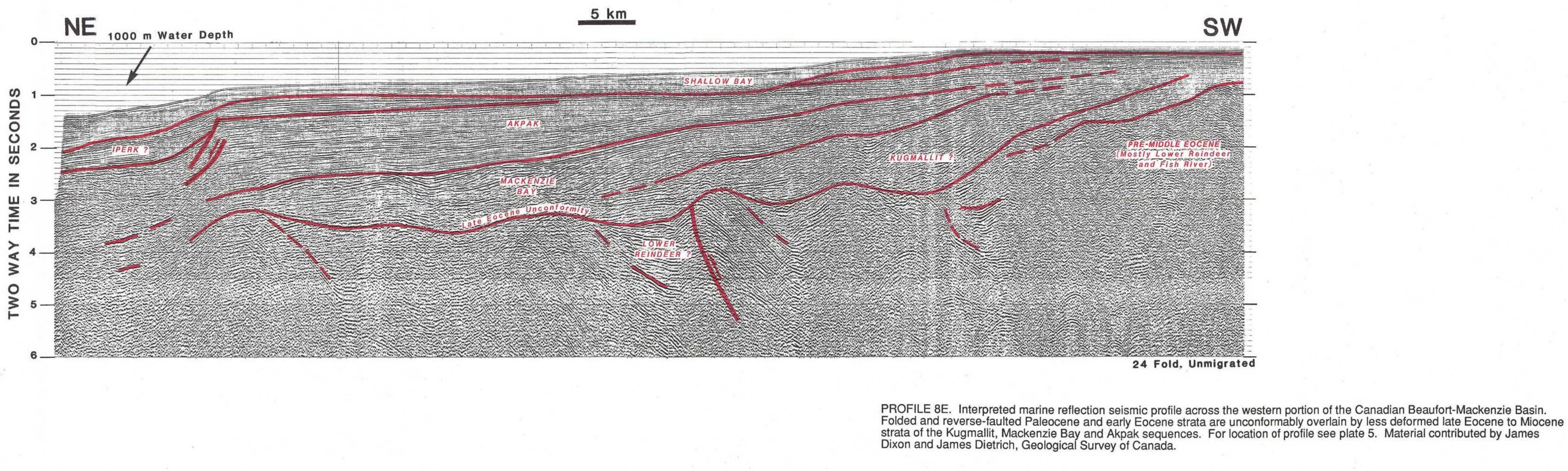
PROFILE 8B. Interpreted marine reflection seismic profile across Canadian Beaufort Sea shelf off Banks Island. The Devonian and older sedimentary section rises and is down-faulted to the west. An Early Cretaceous unconformity truncates the Paleozoic sequences and is onlapped by Cretaceous and Tertiary sedimentary strata that thicken westward into the Arctic Ocean. For location of profile see plate 5. Material contributed by Norman E. Haimila, Geological Survey of Canada.



PROFILE 8C. Interpreted marine reflection seismic profile across the Arctic Platform hingeline and eastern portion of the Canadian Beaufort-Mackenzie Basin. Basinward of the inner platform hingeline Paleozoic strata are onlapped by thick sections of Cretaceous and early Tertiary strata. The Tertiary section contains a major Late Miocene unconformity at the base of the Iperk sequence. For location of profile see plate 5. Material contributed by James Dixon and James Dietrich, Geological Survey of Canada.



PROFILE 8D. Interpreted marine reflection seismic profile across the central portion of the Canadian Beaufort-Mackenzie Basin. Strata of the Akpak and older sequences (Miocene to Paleocene) are disrupted by listric normal faults at the south end of the section and deformed by shale-cored diapiric folds to the north. The structurally deformed Tertiary sequences are unconformably overlain and truncated by the Late Miocene-Pleistocene Iperk sequence. For location of profile see plate 5. Material contributed by James Dixon and James Dietrich, Geological Survey of Canada.



PROFILE 8E. Interpreted marine reflection seismic profile across the western portion of the Canadian Beaufort-Mackenzie Basin. Folded and reverse-faulted Paleocene and early Eocene strata are unconformably overlain by less deformed late Eocene to Miocene strata of the Kugmallit, Mackenzie Bay and Akpak sequences. For location of profile see plate 5. Material contributed by James Dixon and James Dietrich, Geological Survey of Canada.

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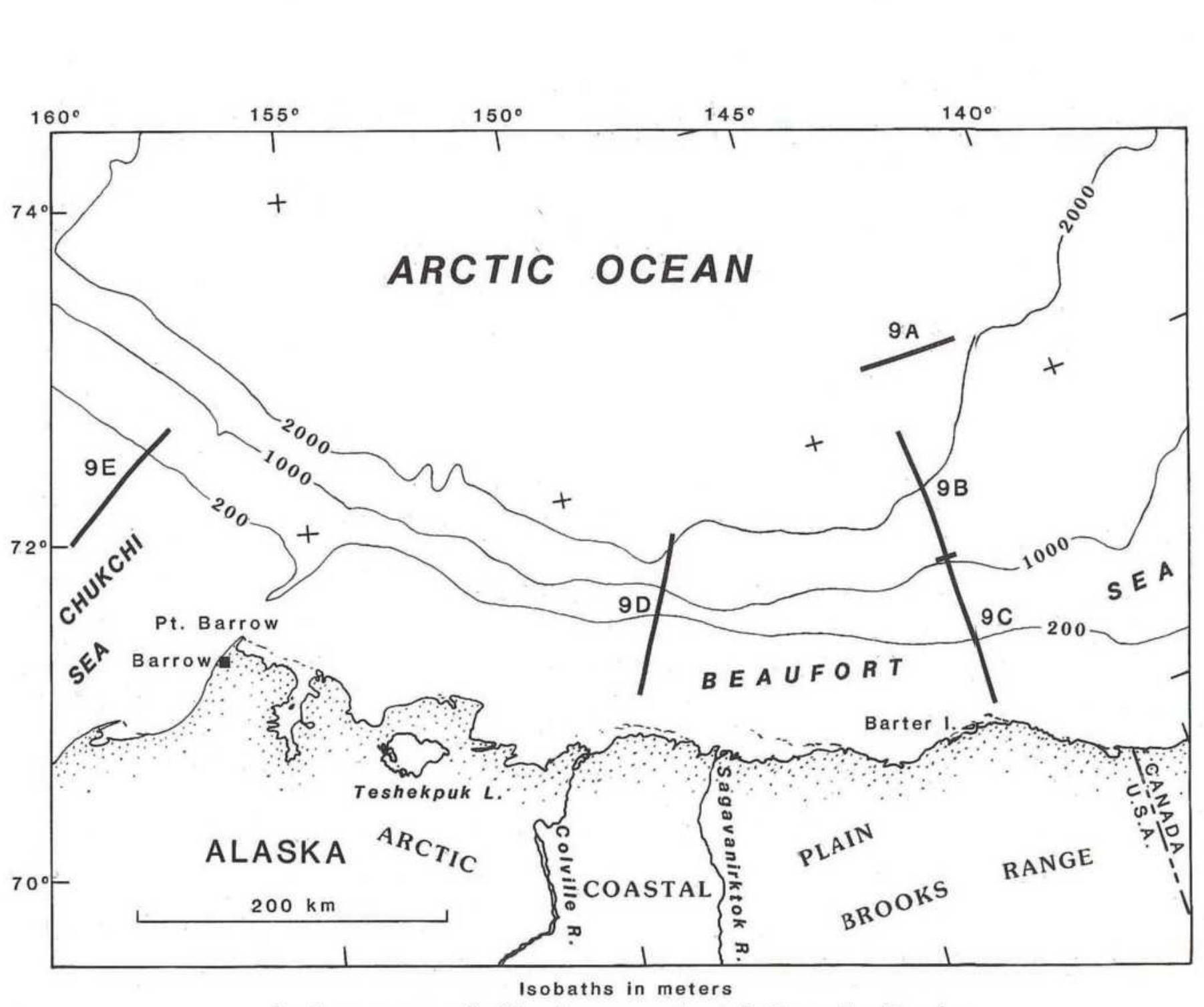
MULTICHANNEL SEISMIC REFLECTION PROFILES
FROM THE
ALASKA MARGIN OF THE CANADA BASIN

Compiled by

Arthur Grantz, S. D. May, and P. E. Hart

U.S. Geological Survey



Index map of Alaska margin of Canada Basin, showing location of seismic reflection profiles

All profiles are 24 fold, unmigrated, and at the same scale

Vertical exaggeration approximately X2

See inset map and plate 5 for location of profiles

0 5 10 15 20 25 km

EXPLANATION

(Approximate ages of seismic reflection units inferred from their reflection character and superposition and from extrapolation of geologic data from outcrops, test wells, and seismic reflection profiles in northern Alaska and the Canadian Beaufort shelf (Dixon and Deitrich, this volume). Offshore well control was not available.)

SURFICIAL DEPOSITS

Qls	Quaternary landslide deposits

BEDDED ROCKS

Paralic to Deep-Marine Sedimentary Rocks of Brookian Sequence (Southerly Provenance)

QT	Quaternary and upper Tertiary
T	Upper and lower Tertiary, undivided. Locally divided provisionally into upper Tertiary - Tu and lower Tertiary - Tl
SU-Teu	Upper Eocene syntectonic unconformity
TlK	Lower Tertiary and Cretaceous
K	Upper and Lower Cretaceous, undivided
Kl	Lower Cretaceous
BU	Breakup unconformity of Barremian age

Marine Sedimentary Rocks of Dinkum Aulacogen and Adjacent Shelf

KJ	Cretaceous and post-Lower Jurassic, undivided

Paralic to Stable Shelf Deposits of Ellesmerian Sequence (Northerly Provenance)

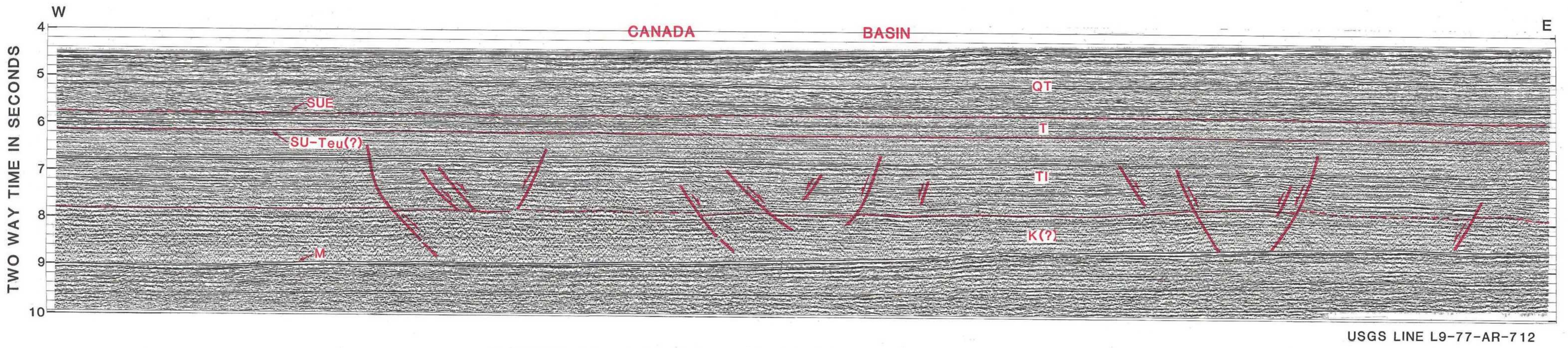
JlM	Lower Jurassic to Mississippian

Mildly Metamorphosed Marine Sedimentary Rocks of Franklinian Sequence

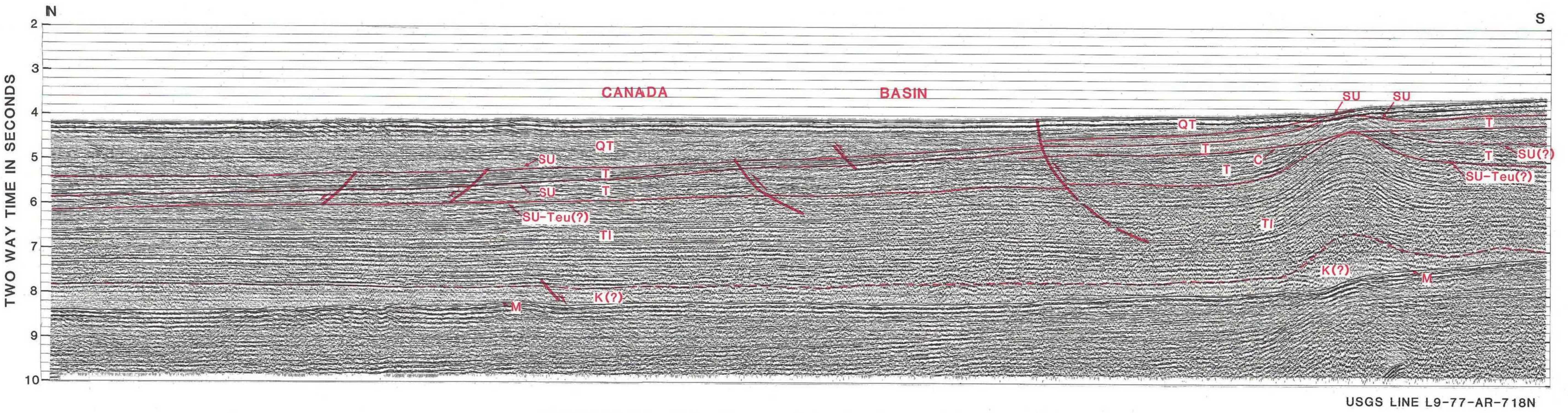
Pz	Paleozoic--Ordovician and Silurian
Pzp€	Lower Paleozoic and Precambrian(?)

OTHER SYMBOLS

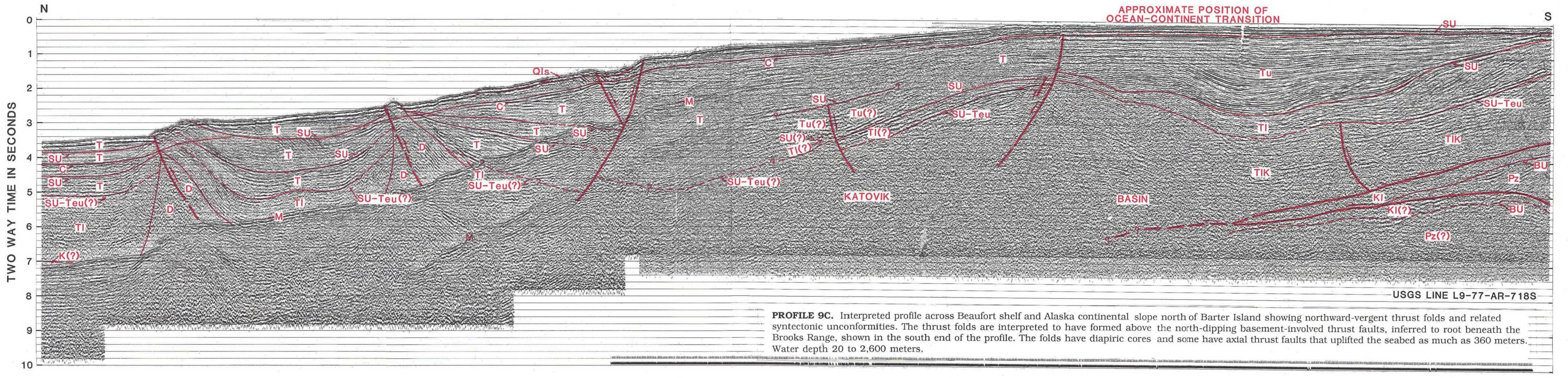
C	Base of clathrate (solid gas hydrate) zone
SU	Syntectonic unconformity
SUE	Projected extension of syntectonic unconformity across data gap
D	Structurally disrupted, locally diapiric core of thrust fold
M	Water-bottom multiple reflection
— – –	Seismic reflection horizon, dashed where inferred
⇄	Fault, dashed where approximately located. Arrow indicates direction of relative movement



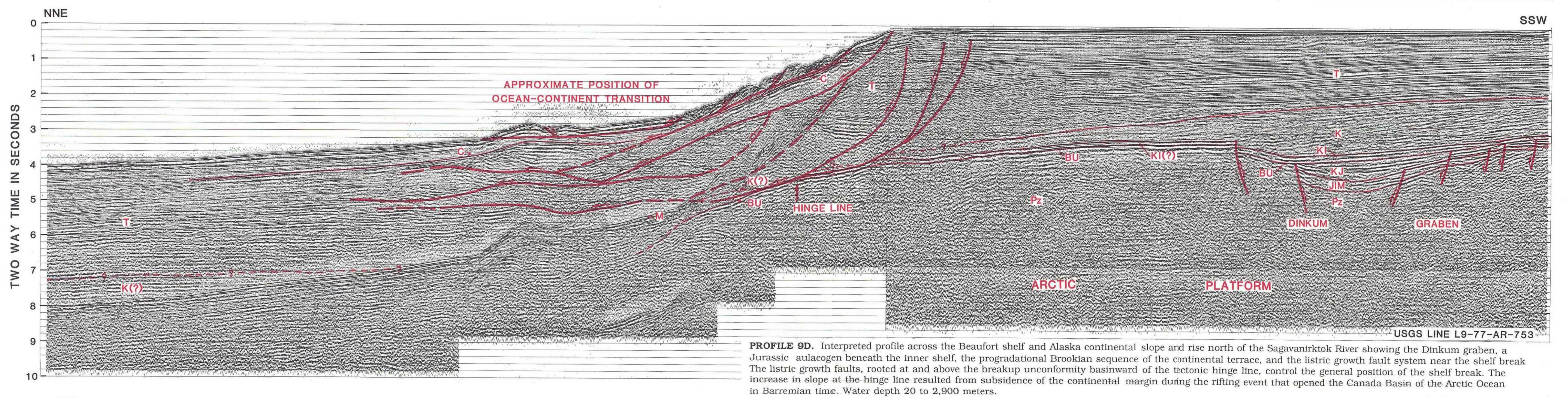
PROFILE 9A. Interpreted profile from southeast Canada Basin showing projected extensions (from profile 9B) of two syntectonic unconformities near 6 seconds and an extensive zone of small-displacement normal faults mainly below 6.8 seconds. Position of Cretaceous-Tertiary boundary based on a combined interpretation of seismic refraction and seismic reflection data. Water depth 3,100 to 3,300 meters.



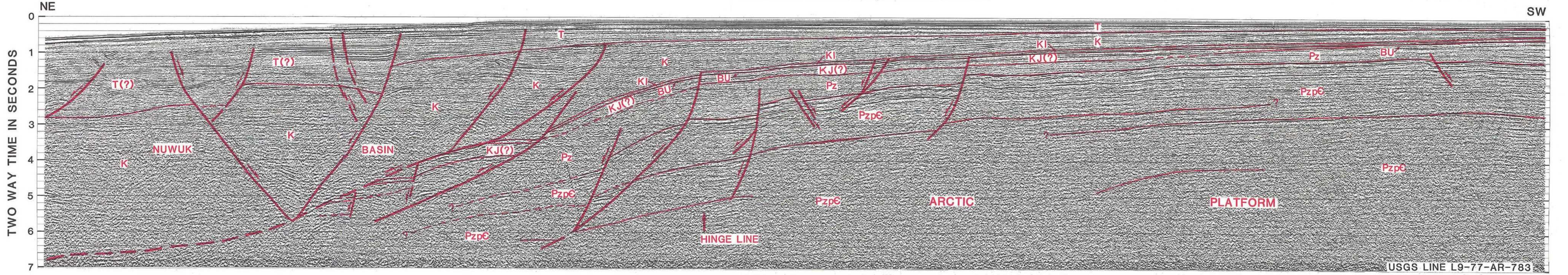
PROFILE 9B. Interpreted profile across transition from foot of Alaska continental slope north of Barter Island to southern part of Canada Basin showing northermost thrust fold of northeast Brooks Range fold belt, small teletectonic thrust faults in front (north) of the thrust fold, and syntectonic unconformities formed in response to northward tectonic advance and uplift of the thrust fold belt. Water depth 2,600 to 3,100 meters.



PROFILE 9C. Interpreted profile across Beaufort shelf and Alaska continental slope north of Barter Island showing northward-vergent thrust folds and related syntectonic unconformities. The thrust folds are interpreted to have formed above the north-dipping basement-involved thrust faults, inferred to root beneath the Brooks Range, shown in the south end of the profile. The folds have diapiric cores and some have axial thrust faults that uplifted the seabed as much as 360 meters. Water depth 20 to 2,600 meters.



PROFILE 9D. Interpreted profile across the Beaufort shelf and Alaska continental slope and rise north of the Sagavanirktok River showing the Dinkum graben, a Jurassic aulacogen beneath the inner shelf, the progradational Brookian sequence of the continental terrace, and the listric growth fault system near the shelf break The listric growth faults, rooted at and above the breakup unconformity basinward of the tectonic hinge line, control the general position of the shelf break. The increase in slope at the hinge line resulted from subsidence of the continental margin during the rifting event that opened the Canada Basin of the Arctic Ocean in Barremian time. Water depth 20 to 2,900 meters.



PROFILE 9E. Interpreted profile across the northern Chukchi shelf almost to the shelf break showing the structural transition from the Arctic Platform to the Nuwuk Basin of the continental margin. The tectonic hinge line at the transition was produced by the rifting event that opened the Canada Basin. Note that the listric growth faults root at the breakup unconformity seaward of the hinge line and that the faults associated with the hinge line do not extend much above the breakup unconformity and its overlying thin unit of condensed Lower Cretaceous strata. The unit of inferred Jurassic and Cretaceous age beneath the south flank of the Nuwuk Basin may be an extension of the Dinkum graben sequence from profile 9D. Water depth 40 to 450 meters.

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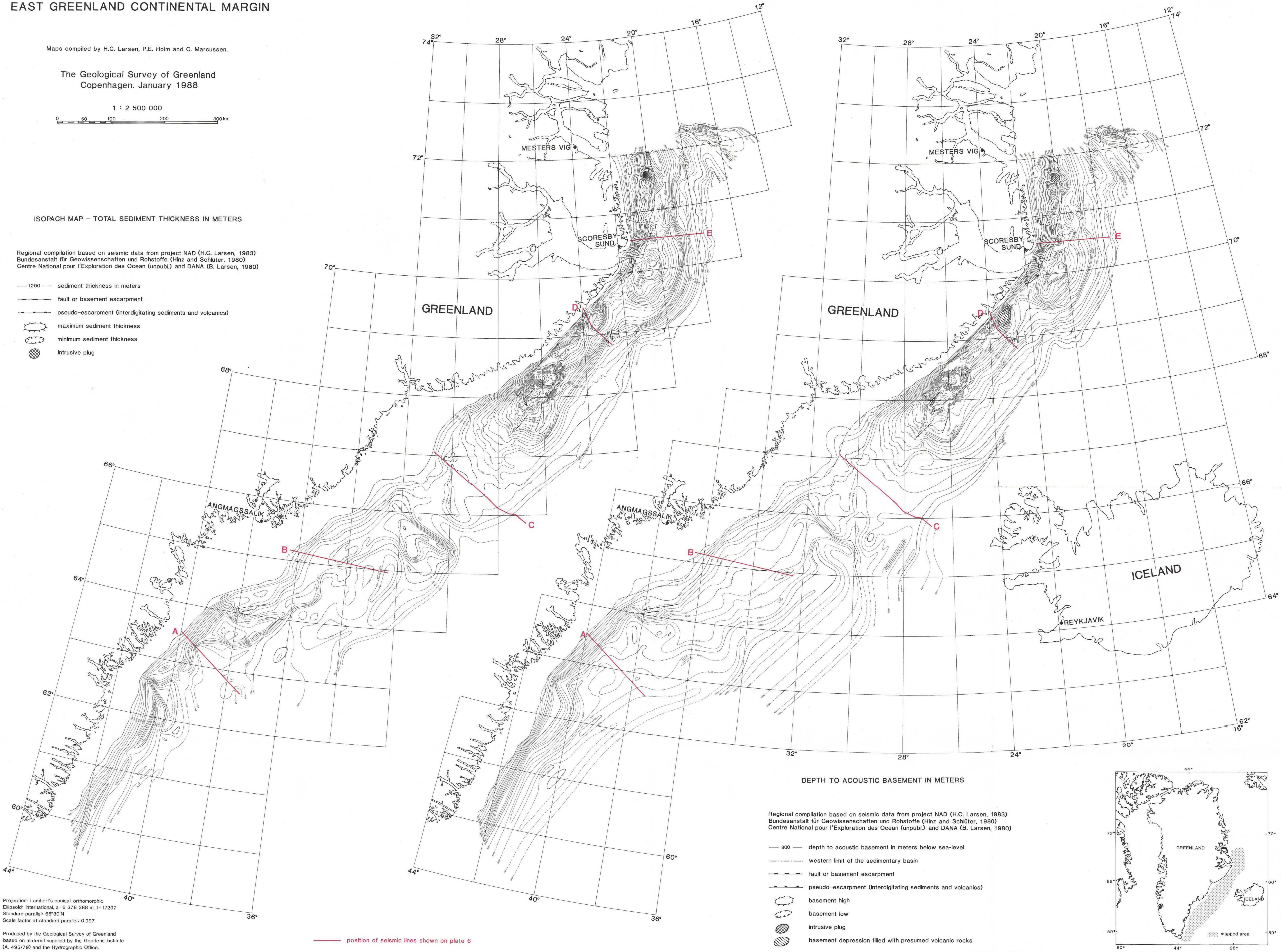
EAST GREENLAND CONTINENTAL MARGIN

Maps compiled by H.C. Larsen, P.E. Holm and C. Marcussen.

The Geological Survey of Greenland
Copenhagen. January 1988

1 : 2 500 000

0 50 100 200 300 km



ISOPACH MAP - TOTAL SEDIMENT THICKNESS IN METERS

Regional compilation based on seismic data from project NAD (H.C. Larsen, 1983)
Bundesanstalt für Geowissenschaften und Rohstoffe (Hinz and Schlüter, 1980)
Centre National pour l'Exploration des Ocean (unpubl.) and DANA (B. Larsen, 1980)

- —1200— sediment thickness in meters
- fault or basement escarpment
- pseudo-escarpment (interdigitating sediments and volcanics)
- maximum sediment thickness
- minimum sediment thickness
- intrusive plug

Projection: Lambert's conical orthomorphic
Ellipsoid: International, a = 6 378 388 m, f = 1/297
Standard parallel: 66°30'N
Scale factor at standard parallel: 0.997

Produced by the Geological Survey of Greenland
based on material supplied by the Geodetic Institute
(A. 495/79) and the Hydrographic Office.

position of seismic lines shown on plate 6

DEPTH TO ACOUSTIC BASEMENT IN METERS

Regional compilation based on seismic data from project NAD (H.C. Larsen, 1983)
Bundesanstalt für Geowissenschaften und Rohstoffe (Hinz and Schlüter, 1980)
Centre National pour l'Exploration des Ocean (unpubl.) and DANA (B. Larsen, 1980)

- —800— depth to acoustic basement in meters below sea-level
- western limit of the sedimentary basin
- fault or basement escarpment
- pseudo-escarpment (interdigitating sediments and volcanics)
- basement high
- basement low
- intrusive plug
- basement depression filled with presumed volcanic rocks

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PLATE 10. Isopach and depth to basement map
for East Greenland continental margin
The Arctic Ocean Region
Vol. L of The Geology of North America (GNA-L)

MAJOR PHANEROZOIC TECTONIC FEATURES OF THE ARCTIC OCEAN REGION

By

Arthur Grantz[1], A.R. Green[2], D.G. Smith[3], J.C. Lahr[1], and Kazuya Fujita[4]

This map shows the location and general age of major Phanerozoic tectonic and structural features of the Arctic Ocean region and their spatial relation to relatively undeformed sedimentary rock provinces and basins, sea-floor magnetic anomalies, and earthquakes with magnitudes greater than 4.0. The tectonic and structural features are interpreted mainly from outcrop data and seismic-reflection profiles, and as a result most of the features shown are of Antler (Late Devonian and Early Mississippian) or younger age. In some areas, especially in the Soviet Union, the structure is also based on potential field data.

The map was compiled by Arthur Grantz and A.R. Green from an unpublished map showing Arctic tectonic features by A.R. Green, B.L. Collot[2], I.O. Morton[2], S.R. May[2], and N.A. Woutas[2]; an unpublished map entitled "Major post-Devonian tectonic features of the Arctic" by D.G. Smith; unpublished maps showing tectonic features of northeast Siberia by Kazuya Fujita and of northern Alaska by Arthur Grantz; and other sources cited below. Earthquake epicenters were compiled by J.C. Lahr, and sedimentary provinces and basins by Arthur Grantz and R.S. Frisch[1] from references cited under Sources of Data.

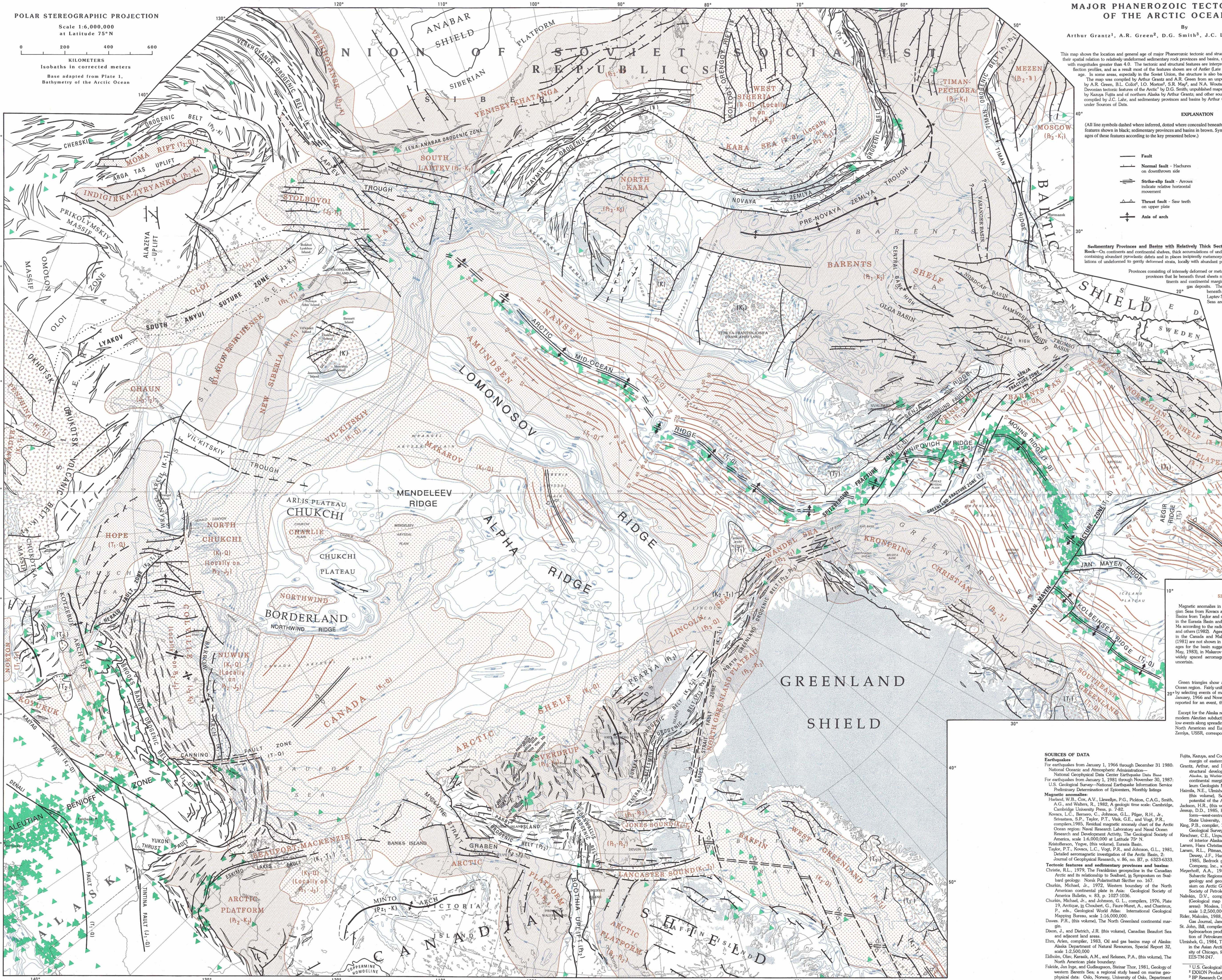
POLAR STEREOGRAPHIC PROJECTION

Scale 1:6,000,000
at Latitude 75° N

0 200 400 600
KILOMETERS

Isobaths in corrected meters

Base adapted from Plate 1,
Bathymetry of the Arctic Ocean



EXPLANATION

(All line symbols dashed where inferred, dotted where concealed beneath younger deposits. Names of tectonic features shown in black; sedimentary provinces and basins in brown. Symbols in parentheses give the provisional ages of these features according to the key presented below.)

- **Fault**
- **Normal fault** - Hachures on downthrown side
- **Strike-slip fault** - Arrows indicate relative horizontal movement
- **Thrust fault** - Saw teeth on upper plate
- **Axis of arch**
- **Axis of active spreading ridge**
- **Axis of dormant spreading ridge**
- **Major fold trend**
- **Volcanic field**
- **Mafic dikes** - possibly related to breakup of continents; in part interpreted from magnetic anomalies

Sedimentary Provinces and Basins with Relatively Thick Sections of Unmetamorphosed Sedimentary Rock—On continents and continental shelves, thick accumulations of undeformed to moderately deformed strata, locally containing abundant pyroclastic debris and in places incipiently metamorphosed. In ocean basins, thin to thick accumulations of undeformed to gently deformed strata, locally with abundant pyroclasts.

Provinces consisting of intensely deformed or metamorphosed sedimentary rocks and portions of provinces that lie beneath thrust sheets not shown. Many of the provinces on the continents and continental margins are petroliferous or prospective for oil and gas deposits. The extent of the sedimentary provinces shown beneath the north Greenland shelf, East Siberian and Laptev Seas, and outer shelves of the Kara and Barents Seas are speculative.

▨ Provinces consisting of primarily Cenozoic, and rare latest Cretaceous sedimentary rock

▨ Provinces consisting of Mesozoic and Cenozoic sedimentary rock

▨ Provinces consisting of Paleozoic, Mesozoic, and commonly Cenozoic sedimentary rocks. Provinces of this age in North America and Greenland are post-Caledonian

Key to Age Symbols Appended to Tectonic Feature and Sedimentary Province and Basin Names

Q	Quaternary
T	Undifferentiated Tertiary
T_2	Late Tertiary
T_1	Early Tertiary
K	Undifferentiated Cretaceous
K_2	Late Cretaceous
K_1	Early Cretaceous
J_3	Late Jurassic
J_2	Middle Jurassic
J_1	Early Jurassic
T̄R	Triassic
Pz_3	Late Paleozoic (Pennsylvanian, Permian)
Pz_2	Middle Paleozoic (Devonian, Mississippian)
Pz_1	Early Paleozoic (Cambrian, Ordovician, Silurian)

53 —— **Sea-floor Magnetic Anomalies**

Magnetic anomalies in the Eurasia Basin and Greenland and Norwegian Seas from Kovacs and others (1985); in the Makarov and Canada Basins from Taylor and others (1981). Approximate ages of anomalies in the Eurasia Basin and the Greenland and Norwegian Seas shown in Ma according to the radiometrically based polarity time scale of Harland and others (1982). Ages of low-amplitude sea-floor magnetic anomalies in the Canada and Makarov Basins suggested by Taylor and others (1981) are not shown in Canada Basin because these predate the oldest ages for the basin suggested by basin-margin stratigraphy (Grantz and May, 1983), in Makarov Basin because rough sea-floor topography and widely spaced aeromagnetic profiles make dating of the anomalies uncertain.

▲ **Earthquake Epicenters**

Green triangles show areal distribution of earthquakes in the Arctic Ocean region. Fairly uniform coverage of the entire region was achieved by selecting events of magnitude 4.0 or greater that occurred between January, 1966 and November, 1987. If more than one magnitude was reported for an event, the largest was considered for selection.

Except for the Alaska region, which includes the eastern portion of the modern Aleutian subduction zone, seismic activity is dominated by shallow events along spreading centers and transform faults that separate the North American and Eurasian plates. The two clusters near Novaya Zemlya, USSR, correspond to Russian nuclear test sites.

SOURCES OF DATA

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Plate 11. Major Phanerozoic tectonic features
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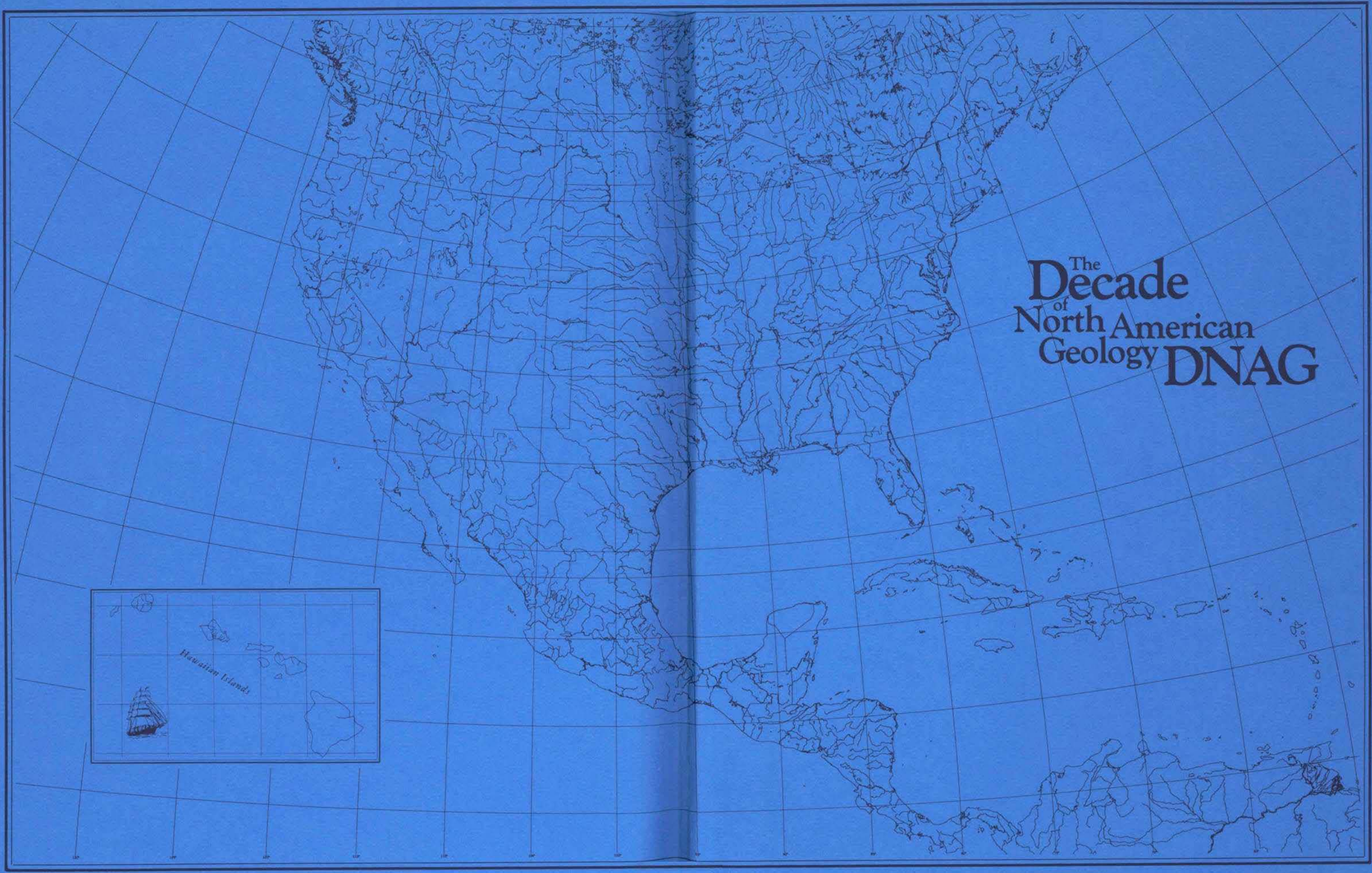
[1] U.S. Geological Survey, Menlo Park, CA
[2] EXXON Production Research, Houston, TX
[3] BP Research Centre, Sunbury-on-Thames, UK
[4] Michigan State University, East Lansing, MI



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