Journal of Geophysical Research
Vol 86, NO. B7, Pages 6323-6333
July 10, 1981

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 86, NO. B7, PAGES 6323–6333, JULY 10, 1981

Detailed Aeromagnetic Investigation of the Arctic Basin, 2

P. T. TAYLOR

Geophysics Branch, Earth Survey Applications Division, NASA Goddard Space Flight Center Greenbelt, Maryland 20771

L. C. KOVACS AND P. R. VOGT

Naval Research Laboratory, Washington, D. C. 20375

G. L. JOHNSON

Office of Naval Research, Arlington, Virginia 22217

Over 150,000 line-kilometers of low-level (152 m) aeromagnetic data were recorded in the western Arctic Basin by the U.S. Navy during four field seasons (1975–1978); data from the first 2 years were presented by Vogt et al. (1979*a*), while the data from the last two years are described in this paper. These data (1977–1978) cover a swath from the north slope of Alaska to the north geographic pole. Flight lines were spaced between 10 and 24 km. The east-west oriented aeromagnetic profiles across the Canada Basin and the Beaufort Sea suggest that Alaska was moving away from the Queen Elizabeth Islands of the Canadian Arctic from 153 m.y. B.P. (anomaly M-25 time) to 127 m.y. B.P. (M-12), at an opening rate of 2.6 cm/yr. An extinct spreading center is defined by a positive free-air gravity anomaly, with the relic spreading axis generally paralleling the 150°W meridian. We are unable to recognize a coherent pattern of lineated anomalies over the Alpha Ridge; therefore its origin remains uncertain. A series of seafloor spreading type anomalies have been tentatively identified in the Fletcher (Makarov) Basin. Spreading began in the Upper Cretaceous (anomaly 34; 80 m.y. B.P.) and continued until mid-Eocene (anomaly 21; 53 m.y. B.P.); total opening rate was about 1.7 cm/yr. During the opening of the Fletcher Basin, rifting began in Baffin Bay and the Norwegian and Labrador seas and the Eurasian Basin. Our results suggest a tectonic coupling between these areas at this time, with the Nares Strait acting as a transform fault and serving as a connector with the Baffin Bay/Labrador Sea spreading centers.

INTRODUCTION

In order to determine the nature of the regional geologic and tectonic structure of the Arctic Basin it is necessary to employ remote sensing techniques. Magnetic measurements from aircraft are the most commonly used method. Since 1972 the U.S. Navy has been engaged in a long-term program of mapping, in relative detail, the earth's magnetic field over that portion of the Arctic Basin accessible to the P3 aircraft. Initially, flights were conducted over the eastern Arctic Basin, between the Lomonosov Ridge and the Eurasian continental margin [*Phillips et al.*, 1981; *Vogt et al.*, 1979*a*]. In 1977 and 1978, work was concentrated in the western region (Figures 1*a* and 1*b*), covering the Makarov Basin (Fletcher Abyssal Plain), Alpha Ridge, and Canada Basin [*Taylor*, 1978, *Taylor et al.*, 1979, 1980].

In this paper we will present and discuss the results of the 1977 and 1978 field efforts. As the manuscript's title suggests, this paper represents a continuation of the earlier work [*Vogt et al.*, 1979*a*]. Since the *Vogt et al.* [1979*a*] manuscript was written, a very comprehensive geophysical review of the Arctic has been published by the Earth Physics Branch of the Energy, Mines and Resources Canada group [*Sweeney*, 1978], and the GEBCO (general bathymetric chart of the ocean) sheet for the Arctic Ocean has become available [*Johnson et al.*, 1979]. For background review we will refer the reader to *Vogt and Avery* [1974], *Fujita* [1978], *Sweeney* [1978], and *Vogt et al.* [1979*a*]. The bathymetric and geographic base map for this paper (Figure 1*a*) will be the GEBCO sheet, which supersedes the earlier *American Geographical Society* [1975] map.

Paper number 1B0029.

Where physiographic features have two commonly used names, both are given, with the GEBCO name being usually preferred.

Our recent efforts were directed towards understanding the nature, age, and origin of the major physiographic features of the western Arctic Basin. Specifically, we concentrated on the Canada and Makarov basins (Fletcher Abyssal Plain) and the Alpha Ridge. Several mutually exclusive hypotheses for these regions have been previously proposed. It has been suggested that the Alpha Ridge (1) is of a continental origin or nature [*Eardley*, 1961; *King et al.*, 1966], (2) is a former spreading center [*Vogt and Ostenso*, 1970], (3) results from a 'hot spot' like origin [*Sweeney et al.*, 1978; *Vogt et al.*, 1979*a*], or (4) is a former region of subduction [*Herron et al.*, 1974]. However, as early as 1958, *Carey* [1958] suggested that the Canada Basin was formed by a relative rotation between Alaska and the Queen Elizabeth Islands. While the detailed mechanism of this basin formation is not certain, this geometry of origin, however, has generally been accepted [*Sweeney et al.*, 1978]. The nature of the present uncertainty and disagreement is related to the time of formation of the Canada Basin. Proposed ages of opening vary from Early Jurassic (180 m.y. B.P.) to Early Cretaceous (130 m.y. B.P.), depending on the geological/geophysical data used; for a recent summary of this problem see *Grantz et al.* [1979]. In this paper we will interpret our aeromagnetic data with respect to the *Carey* [1958] theory of origin. Others, however, have proposed that the present geographic setting of the Canada Basin and the Beaufort Sea resulted from large-scale movements along transform faults throughout the western Arctic [*Jones*, 1980] or from northward movement of continental plates followed by circumpolar drift [*Churkin and Trexler*, 1980].

Fig. 1*a*. General bathymetric map of the Arctic [*Johnson et al.*, 1979]. Labelled contours are in kilometers.

Our objective is to date the initial opening of this basin and delineate the location of a possible extinct axis of seafloor spreading. In addition, we propose an age for the lineated anomalies in the Makarov Basin and suggest how the formation of this area relates to the overall plate tectonic framework of the Arctic.

Data Collection and Processing

During both the 1977 and the 1978 field season the same Navy P-3A aircraft, from squadron VXN-8, was used for these surveys. In 1977 the flights were from mid-September to mid-October, while in 1978 they were from mid-July to mid-August. Flight elevation was 152 m (500 feet), similar to that used during the earlier field work [*Vogt et al.*, 1979*a*]. Survey line separation varied from 10 to 24 km. Figure 1*b* indicates the track lines obtained during the last two field seasons. Since an inertial navigation system was used in these surveys, the positioning error was less than 5 km. For additional details about the data processing the reader is referred to *Vogt et al.* [1979*a*].

It is not possible to remove temporal magnetic field variations from the survey data by filtering, since the exact spectral separation between spatial and temporal measurements is unknown. In practice, however, we did not fly during periods of significant temporal field variations. During the 1977 field season, time variations were monitored by referring to the magnetograms at the U.S. Geological Survey magnetic observatory in College, Alaska. Unfortunately, we had no knowledge of the temporal field variations in our immediate survey area. In 1978, however, we were able to utilize, in addition, station

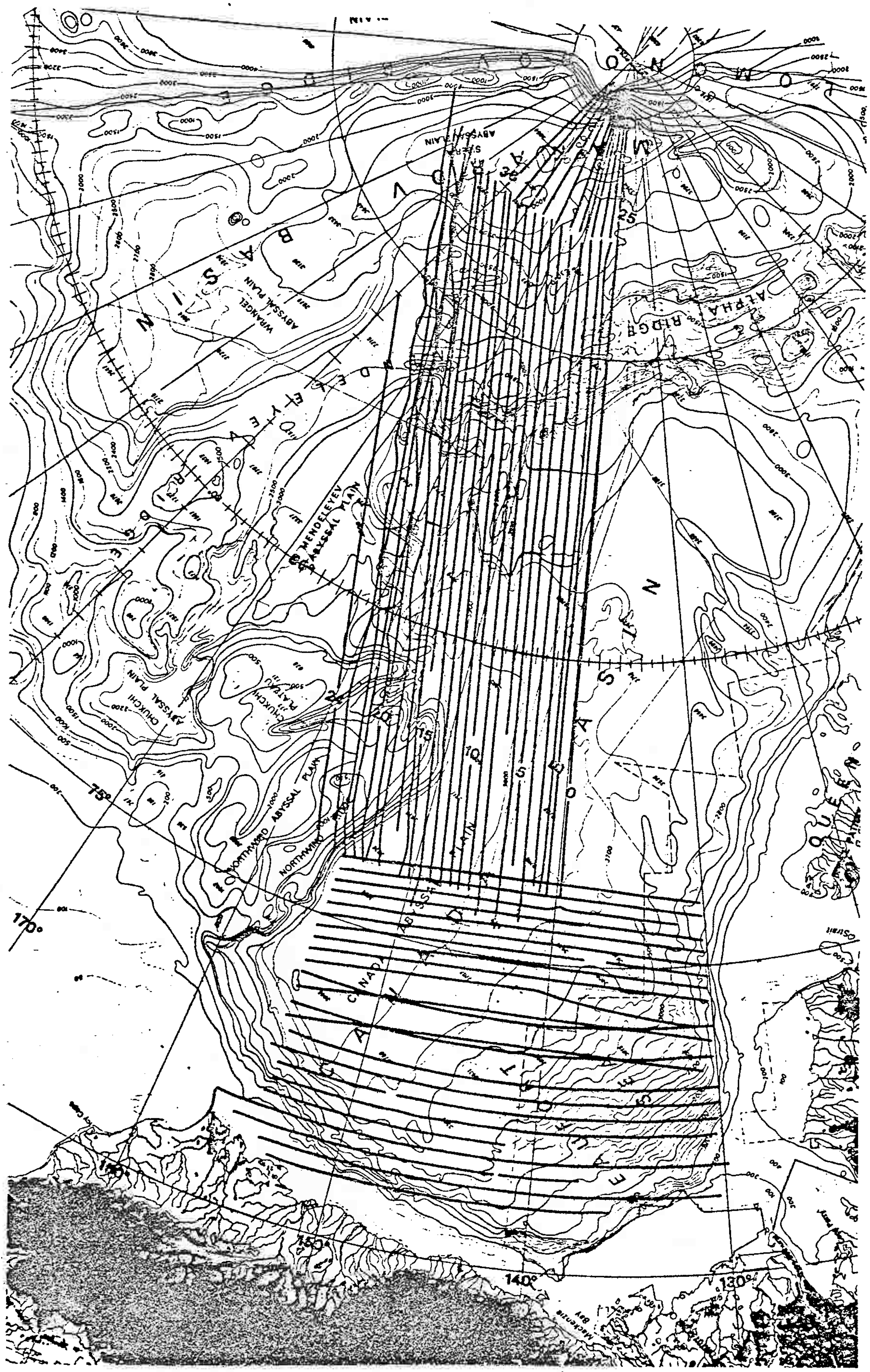

Fig. 1*b*. Track lines of aeromagnetic investigations discussed in the text, superimposed on the Arctic GEBCO bathymetric map [*Johnson et al.*, 1979]. Numbered tracks over the Alpha Ridge (0–24) and Makarov Basin (25–36) correspond to profiles in Figures 4 and 6. Unnumbered tracks across Canada Basin are shown in Figure 2.

data from the network of remotely operated magnetic observatories monitored by the University of Alaska. These stations extended between Fairbanks, Alaska, and Thule, Greenland. Several of the stations were very close to our operation area. On the basis of the results from this chain of magnetic stations we changed our early morning to midafternoon operations schedule to a late afternoon to early morning schedule. This procedure enabled us to avoid the auroral ring of magnetic field disturbance which moved into our operational area during local noon. Evidence of the presence of time variation in the 1977 data can be seen in the long-wavelength variations in some of the profiles (Figure 2, lines 2–4 from bottom).

DATA PRESENTATION

We will discuss the western Arctic magnetic measurements presented in this paper by geographic province and relate them to the data from the eastern Arctic [*Vogt et al.*, 1979*a*; *Phillips et al.*, 1981]. There are three regions where recent data have been gathered: (1) Canada Basin, (2) Alpha Ridge, and (3) Makarov Basin (Fletcher Abyssal Plain). Initially, the areas are discussed separately, and in the summary they will be related to one another.

CANADA BASIN

The Canada Basin extends in a north-south direction some 1330 km from the Alpha ridge to the north slope of Alaska. It is bounded on the east by the Queen Elizabeth Islands and on the west by the Northwind Ridge and the 160°W meridian (Figure 1*a*). At its maximum, this basin extends about 890 km in an east-west direction, along the 74° north parallel. Depths range to over 3900 m, the most common value ranging from 3500 to 3800 m.

Our profiles over the Canada Basin extend in two directions, 14 in a north-south (these consist of the southern ends of profiles extending over the Alpha Ridge) and 23 in an east-west (Figure 1*b*) direction. The latter are the most important and will be discussed first. These flights extend from 130°W to 155°W longitude and from 71°N to 76°N latitude and are, on the average, 24 km apart (Figure 2). The data north of 76°N will be discussed in the section on the Alpha Ridge.

Anomalies across the southern Canada Basin are of relatively low amplitude, with peak to trough values ranging only to about 325 nT but generally averaging around 200 nT. Anomaly half-wavelengths vary from 55 km to 22 km, the longer half-wavelengths being south of 73°N. This broadening of the anomalies to the south reflects, no doubt, the proximity of the Alaska continental shelf with its large sediment influx and the resulting greater depth to the magnetic basement.

The orientation of the flight lines was chosen to maximize the detection of north-south lineated anomalies which might have been produced by a generally east-west process of seafloor creation. This idea, that the Canada Basin was formed by a relative rotation of northern Alaska away from the Queen Elizabeth Islands, was first proposed by *Carey* [1958] and *Tailleur* [1969]. Our work in this region sought to investigate this hypothesis and describe, if possible, the details of the mode for seafloor formation in this area.

Figure 2 illustrates our interpretation of the anomalies over the southern Canada Basin and the Beaufort Sea. We have adopted a seafloor spreading model for this region. The low amplitude of these magnetic anomalies does not permit us to assign reliable ages by using the known magnetic polarity time scales. Our identifications for these anomalies should only be considered to be a first approximation and therefore could be used as a guide in future work.

Our inferred extinct spreading center strikes 350°T, from a point at 72°N and 143°W (Figure 3). The youngest anomaly at this former ridge is M-12, or 127 m.y. B.P., Valanginian of the Early Cretaceous. (The time scale used in this paper is that of *Vogt and Einwich* [1979] and is similar to that of *Larson and Hilde* [1975]). The oldest datable anomaly is M-25 (153 m.y. B.P., or Oxfordian). Our model would suggest that all of the rotation occurred from the Late Jurassic to the Early Cretaceous. This is similar to the results of *Newman et al.* [1977], who proposed, on the basis of paleomagnetic data, that the rotation occurred in the Early Cretaceous; for a summary see *Sweeney et al.* [1978]. Recently, A. Baggeraer and R. Falconer (manuscript in preparation, 1981), utilizing refraction data for depth to oceanic basement, suggested a Lower Cretaceous age for the Canada Basin. The maximum distance between the oldest and youngest anomalies is 292 km, which implies a half-spreading rate of 1.3 cm/yr, or a total opening rate of 2.6 cm/yr.

Although we do not detect a bathymetric expression for this former spreading center, it does, however, lie on a large positive free-air gravity anomaly (Figure 3). One might speculate that this positive free-air gravity anomaly indicates the position of the former spreading center or ridge crest topography.

In any case, the low amplitude of these magnetic anomalies, together with the general paucity of geological data in this region, relegates any hypothesis to little more than speculation.

ALPHA RIDGE

The Arctic Ocean Basin is a deep oceanic area segmented by long positive topographic features. The Nansen-Gakkel Ridge separates the Eurasia Basin, while the Lomonosov Ridge divides the Eurasia and the Makarov basins. The Makarov and Canada basins are separated by the Alpha Ridge (Alpha-Mendeleyev ridges, Figure 1*a*). The Nansen-Gakkel Ridge is a part of the worldwide midoceanic system of ridges, representing the center of seafloor spreading. The Lomonosov Ridge, however, is believed to be a sliver of the Eurasian continent which split away from Eurasia when the Nansen-Gakkel Ridge formed [*Sweeney et al.*, 1978]. The origin of the Alpha Ridge remains highly speculative [e.g., *Sweeney*, 1978]. For this reason, we flew a series of aeromagnetic profiles over the Alpha Ridge and part of the Mendeleyev Ridge in an effort to help determine the origin of these features.

Morphologically, Alpha Ridge is the most complex of the three large Arctic ocean ridges. It has a variable width, averaging around 360 km, and is some 1000 km long. This ridge connects Ellesmere Island with the continental margin of Siberia in the vicinity of Wrangel Island (Figure 1*a*). It is not known if the Alpha-Mendeleyev ridges represent a complex single-ridge system or if they are two differing but contiguous structures (Figure 1*a*). A significant part of the problem is the lack of bathymetric and/or geologic data over these regions, due, of course, to the ice cover.

The shallowest point on the Alpha Ridge is 1169 m (640 fm); the ridge has a predominantly east-west strike (Figure 1*a*). Superimposed on the main structure are a series or chain of topographic highs and depressions.

The aeromagnetic profiles across this feature extend from 76°N to 87°N latitude. Flight line orientation was 350°T (Figure 1*b*). This orientation was established in order to cross the

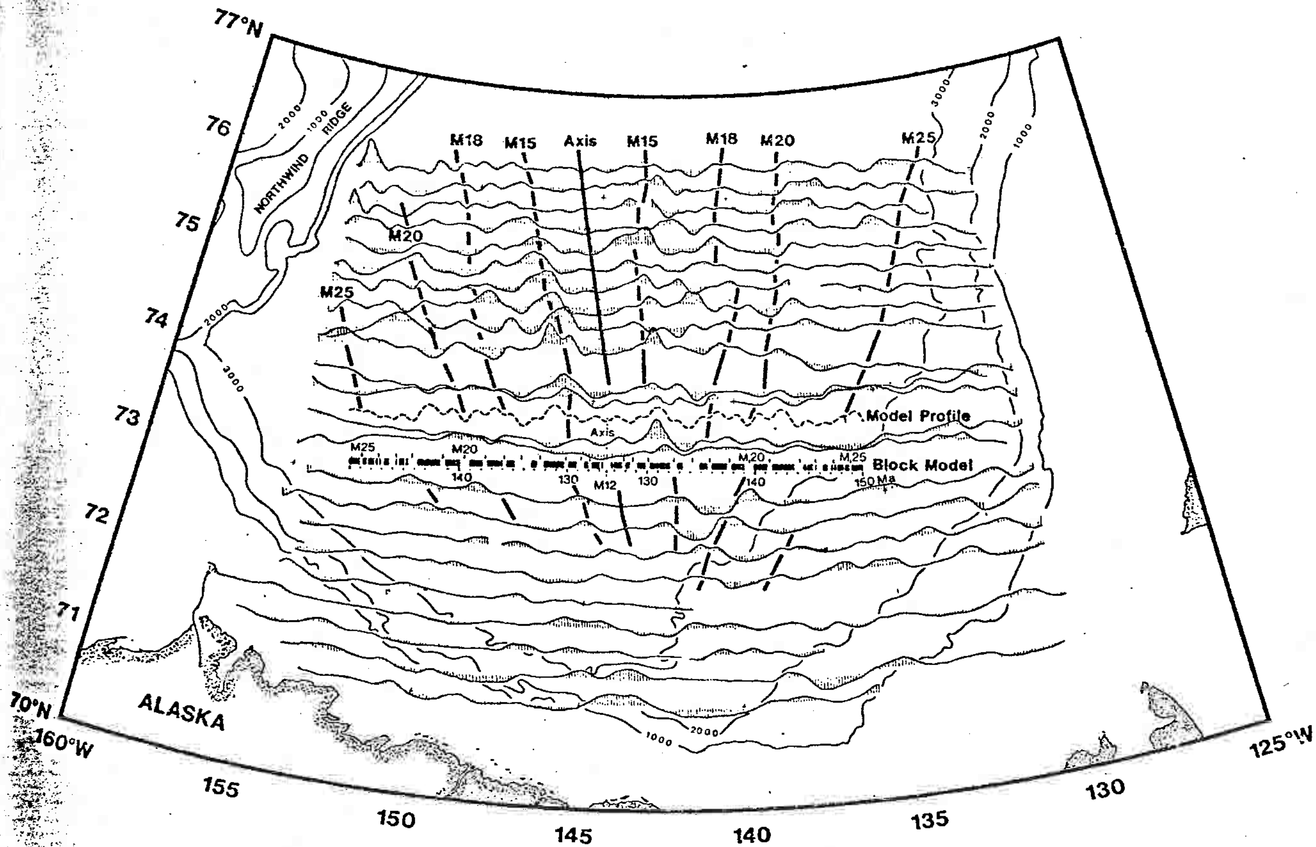

Fig. 2. Aeromagnetic profiles across the Canada Basin. Model is dashed profile computed from reversal sequence of *Larson and Hilde* [1975] and *Vogt and Einwich* [1979]. Regional field removed is composite of the International magnetic reference field (IGRF) [*IAGA Division 1 Study Group,* 1975] and a baseline shift equal to the arithmetic mean of the anomaly values along each track. Possible anomaly correlations are indicated by thin lines.

Alpha Ridge perpendicular to its structural trend (Figure 1*a*). Anomaly amplitude and wavelength are extremely variable over this feature. The largest anomaly, peak to trough, is some 1500 nT, while the smallest are less than 100 nT (Figure 4). Anomaly wavelengths are also quite variable, from 20 to 75 km to an essentially flat field (Figure 4). This extreme change in anomaly character represents, we believe, the transition from the Alpha Ridge to the Canada Basin. That is, the shorter wavelength anomalies represent the variable topographic expression of the Alpha Ridge, while the smooth magnetic field expresses the bathymetrically featureless Canada Basin. If this is true, then the Alpha Ridge extends beneath the sediments of the Canada basin further to the south than is indicated by its bathymetric expression (Figure 1*a*).

While some anomalies along the Alpha Ridge exhibit short lineated segments, these magnetic data do not reveal a consistent pattern of lineations, such as would be expected for a normal midocean spreading center, whether active or dormant (Figure 5). For this reason, we did not attempt to match these magnetic profiles with any of the magnetic anomaly time scales. This does not preclude the possibility, however, that the magnetic profiles could have been produced by a now dormant process of seafloor spreading, which has since been obscured by volcanic/tectonic processes. Another possibility is anomalous spreading such as occurs in the Iceland area, where anomalies are also known to be highly irregular in amplitude and wavelength. Thus the new magnetic data do not rule out any of the proposed modes of origin except normal ocean floor spreading with no subsequent modification.

MAKAROV BASIN

The smallest bathymetrically distinct basin in the Arctic Ocean is Makarov Basin (Fletcher Abyssal Plain); its long axis (north-south) is 830 km, and the basin is 330 km wide (these dimensions are defined by the 3000-m isobath, [*Johnson et al.,* 1979]. The deepest point is approximately 4007 m (2190 fm) [*Johnson et al.,* 1979]; the Lomonosov and Alpha ridges establish the northern and southern boundaries (Figure 1*a*).

Twelve magnetic profiles, some 275 km long, were recorded across this region (Figure 6). These flights traversed the entire basin and extended onto the Lomonosov Ridge. Maximum peak-to-trough anomaly amplitudes extend to over 700 nT, while wavelengths vary between 20 and 60 km (Figure 6). We have matched these anomalies with a Cenozoic seafloor spreading time scale [*La Brecque et al.,* 1977]. The youngest anomaly is number 21 (53 m.y. B.P.), while the oldest is 34 (approximately 80 m.y. B.P.). These dates would indicate that this basin was opening from the Late Cretaceous through the Paleocene. We postulated an axis of symmetry approximately coincident with the 87° north parallel of latitude. If our identifications are accurate, then the total opening rate for the Makarov Basin would be 1.7 cm/yr (Figure 6).

The age-depth relationship for the Makarov Basin is not consistent with the model presented by *Sclater et al.* [1971].

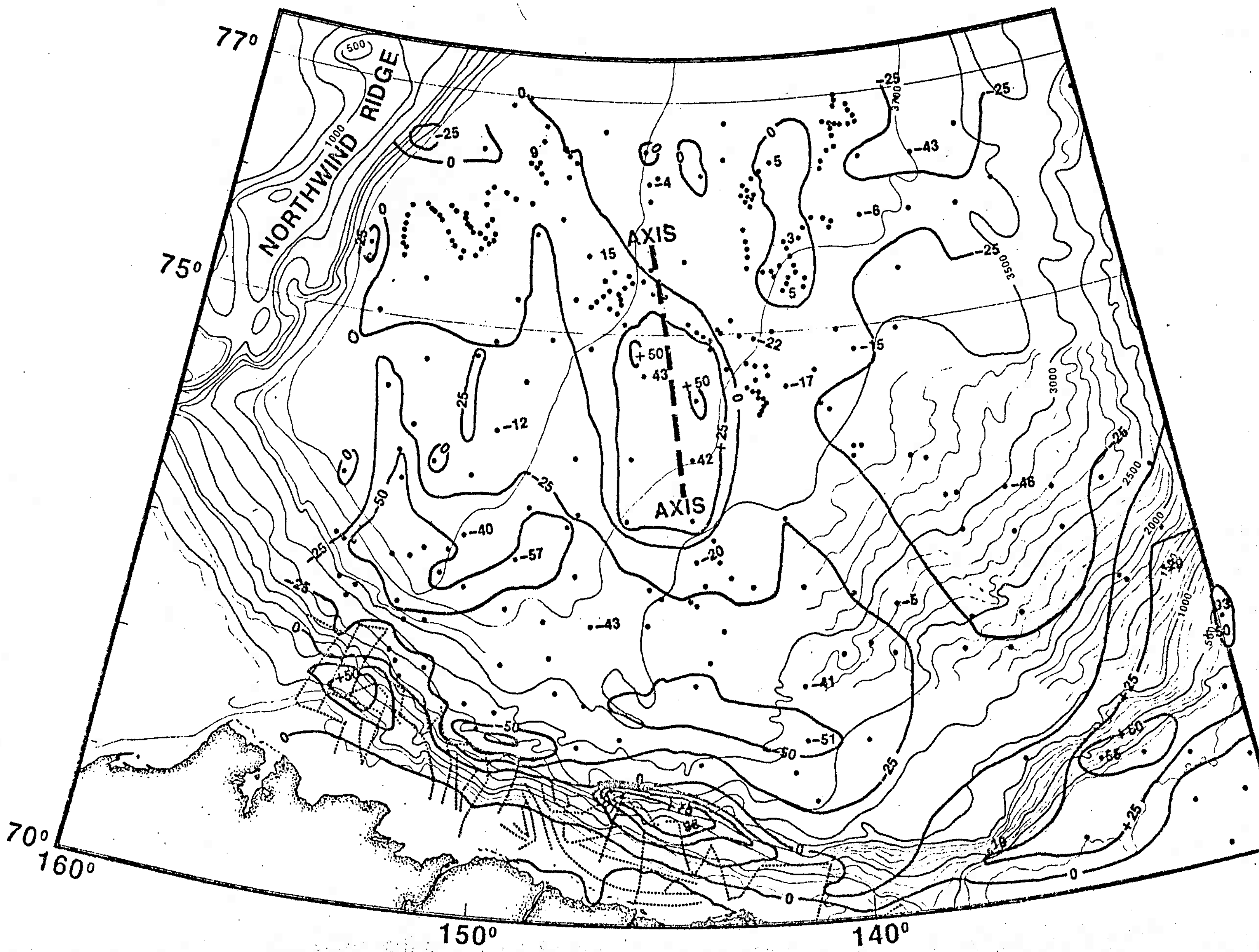

Fig. 3. Free-air anomaly chart of the Canada Basin. Closely spaced dotted lines near north slope of Alsaka represent track data from *Ruppel and McHendric* [1976], while larger dots represent point data from the Defense Mapping Agency gravity data bank and AIDJEX data (courtesy of H. Weber). Bold dashed line labelled Axis indicates position of anomaly M-12 (Figure 2).

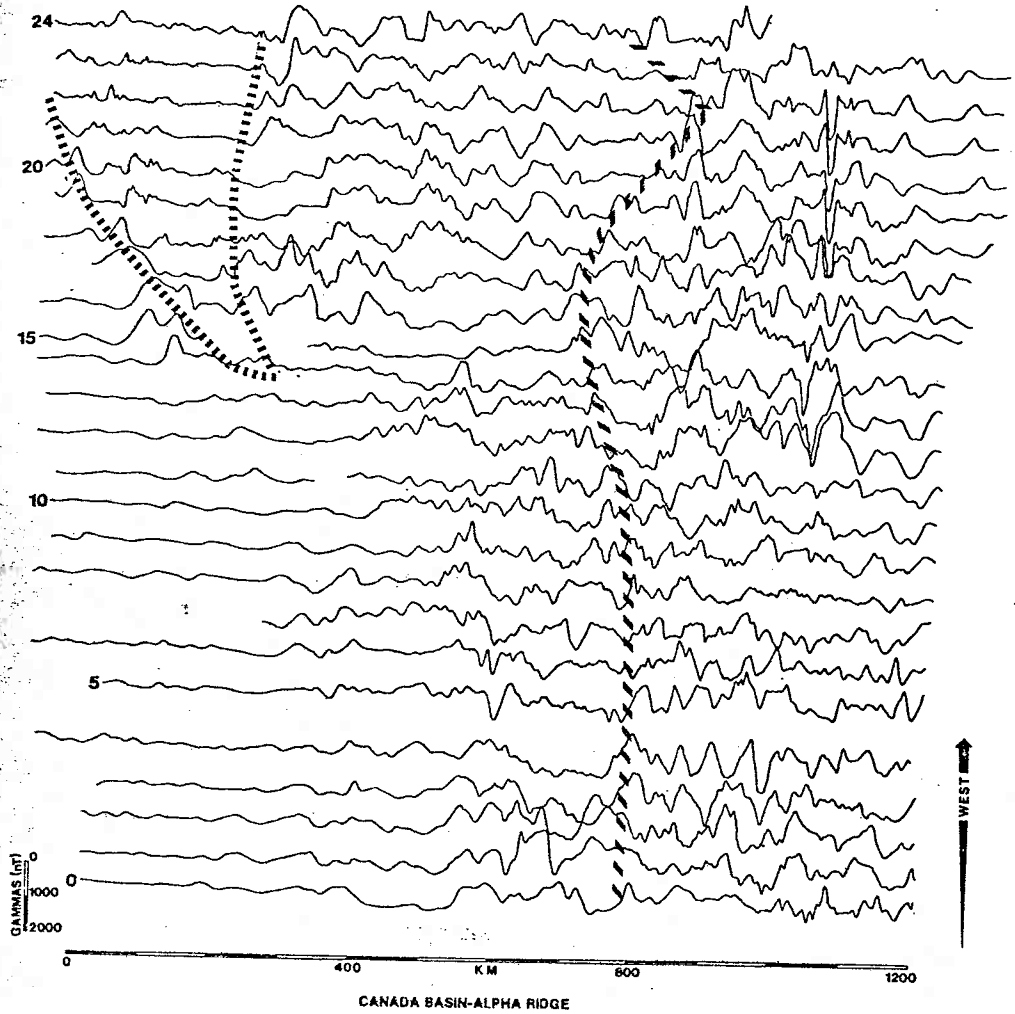

Fig. 4. Aeromagnetic profiles across Alpha Ridge. Regional field removed is the 1975 IGRF [*IAGA Division 1 Study Group*, 1975]. Oblique dashed line is the 3000-m isobath of the southern flank of Alpha Ridge. Dashed line outline is the Chukchi Plateau. North is to the right and south to the left. Profile numbers refer to those given in Figure 1*b*.

Since the deepest sector of this basin is approximately 4000 m, this would correspond to an age of about 18 m.y. B.P., alternately an 80-m.y.-old crust, which we propose would be at a depth of 5700 m [*Sclater et al.*, 1971]. It is not possible for us to resolve this contradiction. We do not, however, that the *Sclater et al.* [1971] model was empirically derived from the large ocean basins, where processes are long lived and can reach a quasi-equilibrium condition or steady state. The same relations may not be valid for smaller ocean basins of the order of 330 km wide. No sediment thickness correction was made.

DISCUSSION

When the results of our recent surveys are combined with the other available data sources, we are able to propose dates for the major crustal movements in the Arctic and suggest a plate tectonic history of this region (Figure 5).

Our anomaly mapping reveals that the structure of the Alpha Ridge extends further to the south than is indicated by the topographic expression of this feature. Figures 4 and 5 show ridgelike magnetic anomalies reaching to 78°N or some 3° (or 330 km) to the south and into the region mapped as the Canadian basin (Figure 1*a*). If this ridge has a continentallike nature, then it has existed as a positive topographic feature for much longer than the flanking crust, and therefore it may be considered as a reference prior to the latest episode of seafloor spreading. The Alpha Ridge could therefore be similar to Lord Howe Rise in that it is continental with abundant volcanism [*Taylor*, 1978]. Since there is no history of motion of the Alpha Ridge, the first tectonic event, in this most recent epoch of crustal dynamics in the Arctic region, was the formation of the Canada Basin and the Beaufort Sea by the rotation of Alaska away from Arctic Canada (for a complete discussion of this event see *Grantz et al.* [1979]).

Prior to 153 m.y. B.P. (mid-Jurassic) the region displayed no recent crustal movement. Shortly after this time, or at anomaly M-25 time [*Vogt and Einwich*, 1979], the Alaskan peninsula began to rotate away from the Queen Elizabeth Islands of the Canadian Arctic; this movement continued until 127 m.y. B.P., or anomaly M-12 time. The Northwind Ridge (or Escarpment) acted as the northern boundary for this movement, analogous to a railroad track. The rate of total opening averaged out to 2.6 cm/yr.

We can only speculate as to the tectonic activity which was associated with this rotation. It is interesting to note that the proximal Sverdrup Basin started to receive sediment deposits

Fig. 5. Polar projection of Arctic with major magnetic lineations from this study and *Srivastava* [1979], *Phillips et al.* [1981], and *Vogt et al.* [1979*a*]. Bathymetric base from *Johnson et al.* [1979]. Dashed lines represent inferred axes of seafloor spreading.

in the mid-Mississippian (330 m.y. B.P.) [*Yorath and Norris,* 1975; *Balkwill,* 1978]. This region continued to receive sediments into the Lower Jurassic. Banks Basin (shelfward of Banks Island) began to form when the Sverdrup Basin ceased to act as a locus for the deposition of sediment. Banks Basin formed as a rifted basin connected to the Sverdrup Basin [*Yorath and Norris,* 1975] and was active from the Lower Jurassic to the Lower Cretaceous. The opening of the Canada Basin started close to the time when the activity in the Banks Basin ceased. We might speculate that the rifting activity began in the Sverdrup Basin and migrated southwest to the Banks Basin. This rifting may have been an earlier stage in the same process that was to open the Canada Basin and the Beaufort Sea [*Monahan and Johnson,* 1981].

The Arctic region was quiescent for approximately 47 m.y. until seafloor spreading began in what is now the Makarov Basin (Fletcher Abyssal Plain), between the Alpha Ridge and the present day Lomonosov Ridge. At this time, the Lomonosov Ridge was a part of the Eurasian mainland. The oldest recognizable anomaly in this region is number 34 (80 m.y. B.P.). Spreading proceeded from a central axis which is presently inactive and located in the approximate center of this abyssal plain (Figure 5) [*Taylor et al.,* 1980].

The Makarow Basin remained as the only active region of

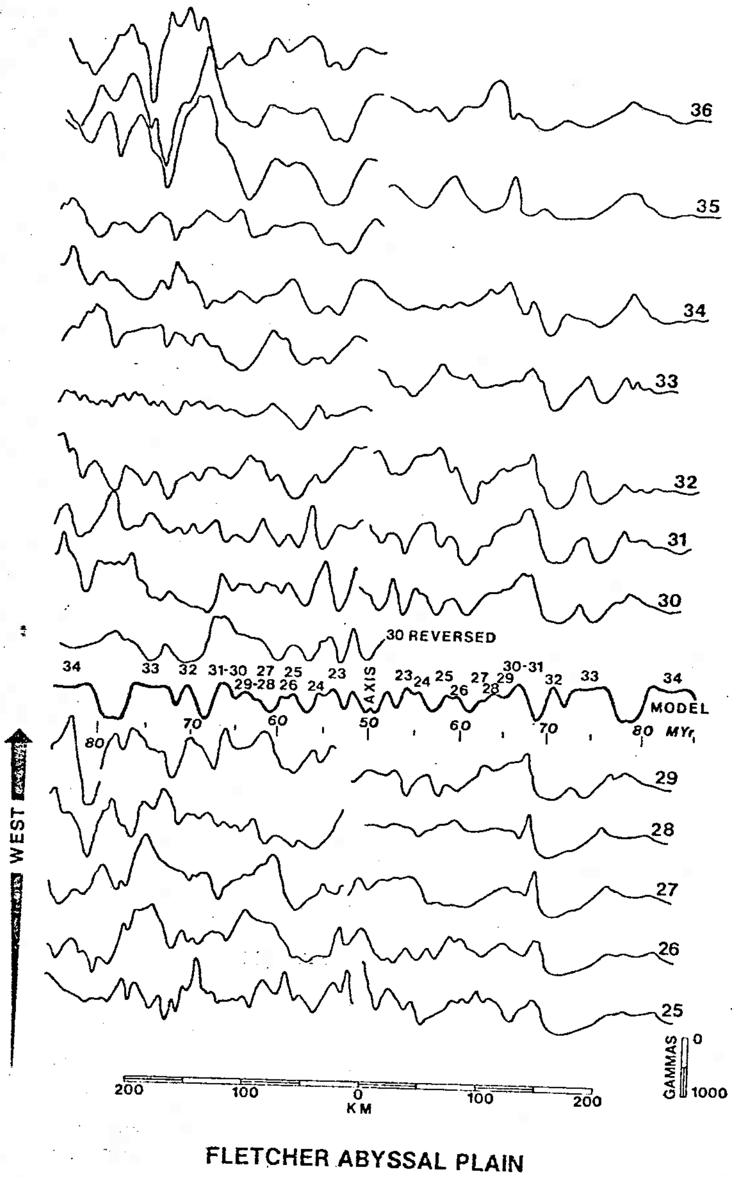

Fig. 6. Aeromagnetic profiles across Fletcher Abyssal Plain (Makarov Basin). Heavy line is model profile [*La Breque et al.*, 1977]. Regional field removed is the 1975 IGRF [*IAGA Division 1 Study Group*, 1975]. North is to the right and south to the left. Numbered profiles refer to Figure 1*b*.

crustal accretion in the Arctic Basin for some 20 m.y., until anomaly 21 time. At this time there was the commencement of a great deal of rifting and seafloor spreading in The Arctic and the surrounding region. Baffin Bay began to open [*Srivastava*, 1978; *Jackson et al.*, 1979]. Spreading started on the Nansen Ridge [*Vogt et al.*, 1979*a*] and continues to the present. The Mohns Ridge and Norwegian-Greenland Sea [*Vogt et al.*, 1979*b*] also became active at about this time (i.e., anomaly 24 time). These three areas of coincident tectonic activity could have been linked by way of the Nares Strait, which formed in a complex plate boundary junction in the Lincoln Sea [*Kovacs*, 1981].

At the time of anomaly 24 there was a second-order reorientation of the opening of the North Atlantic ocean, south of the Charlie-Gibbs fracture zone [*Pitman and Talwani*, 1972; *Srivastava*, 1978; *Kristoffersen*, 1978]. This reorientation involved not only a change in the direction of opening but a significant change in the rate as well. Prior to anomaly 24 the rate of total opening in the North Atlantic was 5 cm/yr, but at anomaly 21 time the rate slowed to 2 cm/yr and remained at this relatively slow movement until anomaly 5 time, when it increased to 2.8 cm/yr [*Pitman and Talwani*, 1972]. It is interesting to speculate that energy was transferred from the relatively rapid (5 cm/yr) opening of the North Atlantic to the quiescent Arctic Basin which produced the commencement of spreading in the latter.

At present, the only region in the Arctic Basin which is currently tectonically active is the Nansen-Gakkel (Arctic mid-Ocean) Ridge [*Vogt et al.*, 1979*a*]. This ridge has a total opening rate of about 1.6 cm/yr and is one of the slowest spreading segments of the worldwide mid-oceanic ridge system. *Vogt et al.* [1981] and L. C. Kovacs, R. H. Pilger, Jr., P. R. Vogt, P. T. Taylor, and G. L. Johnson (manuscript in preparation, 1980) have summarized the plate tectonic history in the Arctic.

Approximately 240 km from the northern end of the westernmost profiles over the Alpha Ridge (Figure 5, profiles 11–

23) there is a distinct large-amplitude (<−1000 nT), short-wavelength (25 km) negative magnetic anomaly. Since supporting ground data are not available, we can only speculate as to the origin of this linear negative anomaly. From the most recent bathymetric data [*Johnson et al.,* 1979] we note that there is a small lineated ridge beneath our track data; it is tempting to correlate these two features.

SUMMARY

Our aeromagnetic surveys have revealed the presence of two regions (Canada and Makarov basins) which we interpret to be areas where seafloor spreading was once active. The Canada Basin was formed when Alaska rotated away from the Queen Elizabeth Islands of the Canadian Arctic during the Late Jurassic by a process which may be analogous to the formation of the Bay of Biscay [cf. *Ries,* 1978]. During the Late Cretaceous and Paleocene the separation of the Alpha and Lomonosov ridges formed the Makarov Basin (Fletcher Abyssal Plain); we propose that a nonstandard type seafloor spreading process was the geologic mechanism of formation. The Alpha Ridge, which dominates the bathymetry of the west Arctic Basin (Figure 1*a*), lies between the Canada and Makarov basins; our magnetic profiles fail to define its origin. We suggest, however, that the lack of a well-defined pattern of lineated anomalies does not support the hypothesis that this ridge was the former site of a seafloor spreading process.

It can be suggested that magnetic data have made their contribution to the study of the tectonics of the Arctic on a regional scale. It is now necessary to acquire detailed bathymetric data and bottom samples by either coring or dredging or drilling in order to establish the age and composition of the major features in the Arctic.

Acknowledgments. We wish to thank the officers and enlisted men of squadron VXN-8 (Patuxent River Naval Air Station) for their cooperation and efforts. W. Martin (U.S. Naval Oceanographic Office) was the electronic technician, J. A. Green (NORDA) and D. Handschumacher (NORDA) aided during certain parts of the field program. The U.S. Geological Survey personnel from the magnetic observatory at College, Alaska, were most helpful in supplying temporal field data.

REFERENCES

American Geographical Society, *Map of the Arctic Region,* New York, 1975.

Balkwill, H. R., Evolution of Sverdrup Basin, Arctic Canada, *Am. Ass. Pet. Geol. Bull., 62,* 1004–1028, 1978.

Carey, S. W., A tectonic approach to continental drift, in *Continental Drift, A Symposium,* edited by S. W. Carey, pp. 17–355, University of Tasmania, Hobart, 1958.

Churkin, M., Jr., and J. H. Trexler, Jr., Circum-Arctic plate accretion—Isolating part of a Pacific Plate to form the nucleus of the Arctic basin, *Earth Planet. Sci. Lett., 48,* 356–362, 1980.

Eardley, A. J., History of geologic thought on the origin of the Arctic Basin, in *Geology of the Arctic,* edited by G. O. Raasch, pp. 223–249, University of Toronto Press, Toronto, Ont., 1961.

Fujita, K., Pre-Cenozoic tectonic evolution of northeast Siberia, *J. Geol., 86,* 159–172, 1978.

Grantz, A., S. Eittreim, and D. A. Dinter, Geology and tectonic development of the continental margin north of Alsaka, *Tectonophysics, 59,* 263–291, 1979.

Herron, E. M., J. F. Dewey, and W. C. Pitman III, Plate tectonics model for the evolution of the Arctic, *Geology, 2,* 377–380, 1974.

IAGA Division 1 Study Group, International geomagnetic reference field 1975, *Eos Trans. AGU, 57,* 120–121, 1975.

Jackson, H. R., C. E. Keen, R. K. H. Falconer, and K. P. Appleton, New geophysical evidence for sea-floor spreading in central Baffin Bay, *Can. J. Earth Sci., 16,* 2122–2135, 1979.

Johnson, G. L., D. Monahan, G. Gronlie, and L. Sobczak, GEBCO sheet 5.17, Arctic Ocean, map series, Can. Hydrogr. Serv., Ottawa, Ont. Can., 1979.

Jones, P. B., Evidence from Canada and Alaska on plate tectonic evolution of the Arctic Ocean Basin, *Nature, 285,* 215–217, 1980.

King, E. R., I. Zietz, and L. R. Alldredge, Magnetic data on the structure of the central Arctic region, *Geol. Soc. Am. Bull., 77,* 619–646, 1966.

Kovacs, L. C., Motion along Nares Strait recorded in the Lincoln Sea: Aeromagnetic evidence, Nares Strait Symposium, *Medd. Groenl., Ser. Geosci.,* in press, 1981.

Kristoffersen, Y., Sea floor spreading and the early opening of the North Atlantic, *Earth Planet. Sci. Lett., 38,* 273–290, 1978.

LaBrecque, J. L., D. V. Kent, and S. C. Cande, Revised magnetic polarity time scale for late Cretaceous and Cenozoic time, *Geology, 5,* 330–335, 1977.

Larson, R. L., and T. W. C. Hilde, A revised time scale of magnetic reversals for the Early Cretaceous and Late Jurassic, *J. Geophys. Res., 80,* 2586–2594, 1975.

Monahan, D., and G. L. Johnson, Physiography of Nares Strait and adjacent regions in light of the possible movements of Greenland, Nares Strait Symposium, *Medd. Groenl., Ser. Geosci.,* in press, 1981.

Newman, G. W., C. G. Mull, and N. D. Watkins, Northern Alaska paleomagnetism, plate rotation, and tectonics, paper presented at Alaska Geological Society Symposium, Anchorage, Alaska, 1977.

Phillips, J. D., R. Feden, H. S. Fleming, and D. Tapscott, Aeromagnetic studies of the Greenland/Norwegian Sea and Arctic Ocean, *Bull. Geol. Soc. Am.,* in press, 1981.

Pitman, W. C., III, and M. Talwani, Sea-floor spreading in the North Atlantic, *Geol. Soc. Am. Bull., 83,* 619–646, 1972.

Ries, A. C., The opening of the Bay of Biscay—A review, *Earth Sci. Rev., 14,* 35–63, 1978.

Ruppel, B. D., and A. G. McHendric, Free-air gravity anomaly map of the eastern Chukchi and southern Beaufort seas, *Map MF-785,* U.S. Geol. Surv., Washington, D. C., 1976.

Sclater, J. G., R. N. Anderson, H. Bell, and M. Lee, Elevation of ridges and evolution of the central eastern Pacific, *J. Geophys. Res., 76,* 7889–7915, 1971.

Srivastava, S. P., Evolution of the Labrador Sea and its bearing on the early evolution of the North Atlantic, *Geophys. J. R. Astron. Soc., 52,* 313–357, 1978.

Sweeney, J. G. (Ed.), Arctic geophysical review, *Publ. Earth Phys. Branch Can., 45*(4), 108, 1978.

Sweeney, J. F., E. Irving, and J. W. Geuer, Evolution of the Arctic Basin, Arctic Geophysical Review, *Publ. Earth Phys. Branch Can., 45*(4), 91–100, 1978.

Tailleur, I., Rifting speculation on the geology of Alaska's north slope, *Oil Gas J., 67,* 128–130, 1969.

Taylor, P. T., Low-level aeromagnitic data across the western Arctic Basin (abstract), *Eos Trans. AGU, 59,* 268–269, 1978.

Taylor, P. T., et al., West-Arctic Ocean Basin: Aeromagnetic results (abstract), *Eos Trans. AGU, 60,* 372–373, 1979.

Taylor, P. T., P. R. Vogt, L. C. Kovacs, and G. L. Johnson, Tectonic implications from the West-Arctic Ocean Basin aeromagnetic surveys (abstract), *Eos Trans. AGU, 61,* 277, 1980.

Vogt, P. R., and O. E. Avery, Tectonic history of the Arctic basins: Partial solutions and unsolved mysteries, in *Marine Geology and Oceanography of the Arctic Seas,* edited by Y. Herman, pp. 83–117, Springer, New York, 1974.

Vogt, P. R., and A. M. Einwich, Magnetic anomalies and sea-floor spreading in the western North Atlantic, and a revised calibration of the Keathley (M) geomagnetic reversal chronology in *Initial Reports of the Deep Sea Drilling Project,* vol. 43, edited by B. Tucholke and P. R. Vogt et al., pp. 857–876, U.S. Government Printing Office, Washington, D. C., 1979.

Vogt, P. R., and N. A. Ostenso, Magnetic and gravity profiles across the Alpha Cordillera and their relations to Arctic seafloor spreading, *J. Geophys. Res., 75,* 4925–4937, 1970.

Vogt, P. R., P. T. Taylor, L. C. Kovacs, and G. L. Johnson, Detailed aeromagnetic investigation of the Arctic Basin, *J. Geophys. Res., 84,* 1071–1089, 1979*a*.

Vogt, P. R., L. C. Kovacs, G. L. Johnson, and R. H. Feden, The Eu-

...Basin, paper presented at Norwegian Sea Symposium, Norw. Pet. Dir., Oslo, 1979*b*.

...P. R., P. T. Taylor, L. C. Kovacs, H. S. Fleming and C. Bergh, Magnetic anomalies and plate kinematics in the Arctic, ...*Acta*, in press, 1981.

...C. J., and D. K. Norris, The tectonic development of the southern Beaufort Sea and its relationship to the origin of the Arctic Ocean basin, Canada's Continental Margins, *Mem. Can. Soc. Petrol. Geol., 4,* 589–611, 1975.

(Received May 12, 1980;
revised October 13, 1980;
accepted December 31, 1980.)