Reconstructions of the Arctic: Mesozoic to Present *

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Abstract


Plate reconstructions using both geological and geophysical data are reviewed and examined. The Arctic Ocean opened in three stages: anomaly 24/25 time to the present when documented seafloor spreading occurred in the Eurasia Basin. The middle event occurred from anomalies 34 to 25 when interaction of the North American and Eurasian plates caused crustal shortening or strike-slip motion in the Arctic. The first event occurred from prior to anomaly 34 time when the Amerasia Basin opened by a rotation with some translation about a pole near the Beaufort–Mackenzie Basin. Crustal shortening caused by this rotation may have been accommodated in the Brooks Range and in the South Anyui Suture Zone. The Alpha Ridge was formed during the opening of the ocean but was not the spreading centre. It is a feature similar to the Iceland–Faeroe Ridge. Prior to the onset of seafloor spreading in the Amerasia Basin the circum-Arctic sedimentary basins formed during a long period of rifting.

Introduction

The Arctic Ocean can be divided into the Eurasia and the Amerasia basins, where the Amerasia Basin includes the Canada and the Makarov subbasins (Fig. 1). The Cenozoic plate motions in the Arctic were focused in the Eurasia Basin. Since marine magnetic anomalies 24/25 seafloor spreading has been taking place in the Eurasia Basin contemporaneous with the seafloor spreading in the North Atlantic and in the Norwegian–Greenland Sea. The plate reconstructions developed for this area and time are well constrained and changes to existing models will concern details only. In contrast, interaction of plates in the Arctic just prior to anomaly 24/25 occurred in the Amerasia Basin, probably involved compression and/or strike-slip motion that is not as well constrained as the most recent stage. The lack of clearly defined seafloor spreading anomalies in the Amerasia Basin has prevented detailed reconstructions and has led to many and varied hypotheses for its opening.

There is a consensus that the Eurasia Basin opened by seafloor spreading about the Arctic Mid-Ocean Ridge (Pitman and Talwani, 1972; Herron et al., 1974; LePichon et al., 1977; Kristoffersen and Talwani, 1977; Srivastava, 1978, 1985; Burke, 1984; Vink, 1984; Reksnes and Vågnes, 1985; Srivastava and Tapscott, 1986; Smith, in press). However, many suggestions have been made for the development of the Amerasia Basin. Three groups of workers support the idea that the Amerasia Basin was created by in-situ seafloor spreading but disagree on the location and direction of the spreading. Group one advocates that the Amerasia Basin (Fig. 1) opened by

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The rotation of Alaska away from the Canadian polar margin (Carey, 1958; Tailleur, 1969; Rickwood, 1970; Grantz et al., 1979, 1981; Harland et al; 1984). A second possibility is that the basin opened when Alaska sheared along the Canadian polar margin (Christie, 1979; Kerr, 1980; Jones, 1980, 1982). A third idea is that the ocean crust in the basin may have been formed by complex spreading patterns by the motion of two or more small plates (Vogt et al., 1982). A fourth theory, that is not based on in-situ seafloor spreading, is that the oceanic crust in the Amerasia Basin was formed in the Pacific Ocean and trapped in its present location (Churkin and Trexler, 1980). A fifth theory, the oldest, is that the crust was formed by oceanization (Belousov, 1970; Pogrebbitskiy, 1976).

The objectives of this paper are to review and evaluate the plate tectonic models suggested for the evolution of the Arctic Ocean based on data available up to 1988. This was done in three stages (Fig. 2). In stage III (from the present to anomaly...
Stage III Cenozoic evolution: anomaly 0–24/25

Since the time of magnetic anomaly 24/25, the Eurasia Basin has been opening along the Arctic Mid-Ocean Ridge, the northernmost extension of the spreading axis between the North American plate and the Eurasian plate (Kristoffersen and Talwani, 1977; Srivastava, 1978, 1985; Vink, 1982; Srivastava and Tapscott, 1986). The fit of the magnetic anomalies from 50°N to and including the Eurasia Basin is shown in Fig. 3.

However, when the magnetic anomalies from the opposite sides of the spreading axis are superimposed there are some complications and discrepancies that occur on the landmasses and in the oceans. For example, overlap occurs between
Fig. 3. Plate-tectonic reconstructions for the North Atlantic, Norwegian–Greenland seas and the Eurasia Basin, Arctic Ocean, for the period between anomaly 13 and 25 from Srivastava (1983). The superimposed circles and squares represent the magnetic anomalies from adjacent plates. The dashed and solid lines are the continent–ocean boundaries of the plates.
the continental shelves of Greenland and Svalbard (Vink, 1982; Smith, in press). It is unclear whether the plates in this area behaved in a non-rigid manner or whether better definition of the continent-ocean boundary will resolve the problem. Srivastava and Tapscott (1986) explain the overlap with a combination of strike-slip motion and crustal stretching and thinning.

A second problem occurs in the reconstructions north of Greenland for anomalies 13 and 24 time with the overlap in the Morris Jesup and Yermak plateaus (Fig. 1). A triple junction existed in the area during this interval (Feden et al., 1979). The oceanic or continental origin of these features has been debated by a number of authors (Feden et al. 1979; Crane, 1982; Jackson et al., 1984). Limited refraction data on the flanks of the Morris Jesup Rise and the magnetic anomalies indicate this feature is oceanic. On the Yermak Plateau refraction and magnetic data are consistent with the northern section being of oceanic origin (Fig. 4) and only the southern being of continental origin. Thus, these plateaus are not impediments to the plate reconstructions.

A third problem is that no single pole satisfies the anomalies in the Norwegian-Greenland Sea and the Labrador Sea (Kristoffersen and Talwani, 1977; Talwani and Eldholm, 1977; Srivastava, 1978); however, these three discrepancies are not large and do not indicate first order non-rigidity in the plates.

Of particular interest is the non-symmetrical nature of a broad band of negative magnetic anomalies that occur on the margins of the Eurasia Basin.
in the Arctic Ocean. Therefore, plate reconstructions are based on other criteria. One approach is extrapolation. The opening of the Eurasia Basin resulted from the relative motion between the EU and NA plates; so, perhaps the same was true prior to anomaly 25. The reconstructions of Srivastava and Tapscott (1986) based on this assumption show the Arctic Basin to be 600 km wider in the vicinity of the East Siberian Sea from anomaly 25 to M0 time (Fig. 1). In contrast, more recent poles indicate strike-slip motion between these plates in the Arctic during this interval (Srivastava, pers. commun., 1988). We consider two possible locations on either side of the Lomonosov Ridge where compression could have occurred during anomaly 25 to 34 time.

**Lomonosov Ridge part of the North American plate**

In this model, the Lomonosov Ridge is considered to be a part of the NA plate joining northeast of Ellesmere Island (Fig. 1). Figure 5A shows the basin at anomaly 34 time, together with the positions of NA, EU, and Gr plates based on the fit of magnetic anomalies in the North Atlantic (Srivastava and Tapscott, 1986). Morphologically the Lomonosov Ridge is narrow, linear and steep sided (Ostenso and Wold, 1977). Crustal refraction measurements over the ridge (Mair and Forsyth, 1982) suggest that it is a continental structure. Gravity and magnetic data are also consistent with a continental origin (Sweeney et al., 1982; Weber and Sweeney, 1985). The Siberian termination of the ridge is not bathymetrically continuous with the shelf (Demenitskaya and Hunkins 1970); therefore, it is unlikely to be a tectonic continuation.

In Fig. 5A the Lomonosov Ridge is attached to the NA plate and the Eurasia Basin at anomaly 34 is about 150 km wider than at anomaly 24. This implies that crustal shortening occurred in this basin during the Late Cretaceous and the early Tertiary or there was an error in the plate reconstruction. Assuming the reconstruction is valid for the present, one area that could be considered a possible location of shortening was along the Amundsen Basin side of the Lomonosov Ridge where the region of undefined crust occurs (Fig.
Fig. 5. The Arctic Ocean reconstructed to anomaly 34 with the Lomonosov Ridge (LR) considered part of the NA plate (A) and as an independent plate (B). In (A) the space between the dashed line and crossed line is the amount of compression required in the Eurasia Basin between anomalies 34 and 24. In (B) between the simple outlined Lomonosov Ridge and the stippled Lomonosov Ridge compression is required in the Amerasia Basin perhaps adjacent to the Alpha Ridge (a). GR Greenland plate, EU Eurasian plate, NA—North American plate. Data from either area that supports crustal shortening is ambiguous and insufficient.
4). If the crustal shortening occurred adjacent to the Lomonosov Ridge, the ridge itself may have been produced or deformed by crustal shortening. One interpretation of the deep penetration seismic line (Jackson et al., in press) collected over the ridge and into the Amundsen Basin is consistent with this scenario. The reflection profile shows that the crust of the ridge terminates about 80 km into this basin. The mantle associated with the thinner oceanic crust dips under the seaward extension of the ridge (Fig. 6). In areas where crustal shortening has taken place negative free-air anomalies are characteristic (e.g. Kaula, 1972). The relative low-amplitude anomalies over the Lomonosov Ridge are not compatible with major crustal shortening here.

Lomonosov Ridge as an independent plate

Another possibility is that when the EU and NA plates were interacting in the Arctic during anomaly 25 to 34 time, the Lomonosov Ridge was detached from both of them as an independent plate. The reconstruction is shown in Fig. 5B. The
total size of the Makarov Basin was approximately 150 km larger than at anomaly 24 and in this case compression is required between the Lomonosov and the Alpha ridges (Kovacs et al., 1982). In this reconstruction the poles for the EU and NA plates are taken from Srivastava and Tapscott (1986) and LR was independently rotated adjacent to the Barents Sea and Kara Sea shelves. Few seismic lines exist between the Lomonosov and the Alpha Ridge (Jackson et al., in press) and they do not show basement clearly. No obvious zone of shortening is seen in the sedimentary section. This could be due to shortening taking place before the sediments were deposited, or the lack of data to identify structures or the features being masked by later extension. Magnetic data on the Alpha Ridge display an interesting and perhaps significant feature. Calculations of depths to magnetic basement (Kovacs and Vogt, 1982) show a basement depression along the north side of the ridge. Depths to basement of between 7.5–10 km are too large to be due to the normal subsidence of oceanic crust. Kovacs and Vogt (1982) suggest several possible reasons for this feature including a relict oceanic subduction zone.

**Variable plate boundary**

A third possibility for the configuration of plates in the Arctic is that the compression in the Arctic Basin was not collinear with the zone of extension but took place in the region between Alaska and Siberia. In the Late Cretaceous to Early Tertiary in the Bering Sea region, between the Chukotskiy Peninsula and northern Alaska (Fig. 1), crustal shortening is observed in the deflection of structural trends (Patton and Tailleur, 1977). This shortening could be regarded as compatible with the compression predicted by Srivastava and Tapscott (1986) from anomaly 25.
to 34 (Eocene to Late Cretaceous). Furthermore, Harbert et al. (1987) correlate periods of strong convergence in the Bering Sea region with the interaction of NA and EU plates during this interval and indicate that the timing and style of the deformational events can be explained by these plate interactions.

No compression in the Arctic

A fourth possibility to be considered is that the plate motions in the North Atlantic did not affect the Arctic at this time, or that the poles examined here are inaccurate. In this case there is no reason to assume that the Arctic Basin changed size between anomaly 25 and 34, and there is no need to consider the possible locations for crustal shortening. Wilson (1985) points out, based on world-wide plate considerations, that many plates are converging on the present-day Arctic and it should be undergoing compression and there should be insufficient space to permit spreading that is presently taking place. He suggests the crustal shortening is being taken up along the globe-encircling zone of subduction and the continental collisions that separate the Gondwana continents from the others. Although by detaching the Lomonosov Ridge from the NA plate, it is possible to decouple the motions of the NA plate from the Arctic; it is not possible to decouple the motions of the EU plate from the Arctic.

Summarizing, at anomaly 34 (Fig. 5) the distribution of the landmasses around the Arctic was similar to anomaly 24 time but the Labrador Sea was closed and there was greater separation between Greenland and Ellesmere Island. There is the possibility that 150 km of compression occurred between the Lomonosov Ridge and the Barents Shelf or between the Alpha Ridge and the Lomonosov Ridge, but the only good evidence for compression is in the Bering Sea area. The most recent plate reconstruction of Srivastava (pers. commun., 1988) that does not require compression in the Arctic Ocean is consistent with the limited seismic and gravity data available. The shape of Alaska was about what it is now with the suturing of small terranes occurring later (Harbart et al., 1987). The rest of the Amerasia Basin existed in its present day configuration.

Stage I closure reconstructions: pre-anomaly 34

The time of opening of the Amerasia Basin is derived from rocks associated with the breakup phase of continental margin development observed in northeastern Alaska and on Banks Island. Opening occurred about 131–113 m.y. ago (Sweeney, 1985). Seafloor spreading occurred in the interval from 118 to 79 m.y., based on a variety of data that include the age of tholeiitic basalts, age versus depth and age versus heat flow curves. Sweeney (1985) summarizes this information. The age–depth relationships, based on comparisons with other oceans, predict a crustal age of between 125 and 74 m.y. The heat flow–age curves from the Canada Basin also give a crustal age of between 110 and 84 m.y. The Late Cretaceous sediment, recovered in a core (Mudie et al., 1986) from the Alpha Ridge, was deposited in the time interval that corresponds to anomaly 33 (78 m.y.) and suggests that the development of the ridge occurred prior to this time.

Amerasia Basin

In most of the models presented here the Alpha Ridge (Fig. 1) is considered to be an oceanic crust formed in place at the time of opening of the basin. This assumption is based on the information acquired during the CESAR experiment (Jackson et al., 1986; Mudie et al., 1986; Sweeney and Weber, 1986). The Mendeleev Ridge is considered to be part of the Alpha Ridge in this paper. A wide range of geological and geophysical data supported the conclusion that the Alpha Ridge is oceanic near Canada (Jackson et al., 1986; Sweeney and Weber, 1986). For example, seismic refraction data (Forsyth et al., 1986) measure a thick oceanic crust with a high-velocity lower crustal layer typical of that found in the large oceanic plateaus. The twenty similar rocks dredged from the Alpha Ridge are highly altered basalts (Van Wagoner and Robinson, 1985; Van Wagoner et al., 1986). Heat flow is consistent with an oceanic origin but greater than that expected for continental crust (Taylor et al., 1986). The Alpha Ridge is considered to be a large oceanic feature formed at the time of seafloor spreading.
but not along the spreading axis (Jackson et al., 1986). A present-day analogue is the Iceland–
Faeroe Ridge system.

The Makarov Basin in the following reconstruction is considered to have formed at the same
time and by the same processes that produced the Alpha Ridge (Jackson and Johnson, 1986).
Bathymetry data indicate that the Alpha Ridge continues morphologically almost to the Lomonosov Ridge near Ellesmere Island. Refraction data in this region indicate that the crust is thinner but
similar to the Alpha Ridge (Forsyth et al., 1986); in particular, the distinctive high-velocity lower
 crustal layer of 7.3 km/s is observed in both areas. This suggests that there is a gradual thinning of the oceanic crust of the Alpha Ridge towards the Makarov Basin. Sweeney and Weber (1986) consider the basin as enigmatic and propose it formed from 118 to 54 m.y. ago.

The Chukchi Borderland is flat-topped and as shallow as 273 m (Johnson et al., 1979). Grantz et al. (1979) believe that the feature is of continental origin, but rifted away from the mainland, and is not a hinderance to tectonic reconstructions. A comparable problem in the North Atlantic would be the overlap between Galicia Bank and Flemish Cap, which is considered to be reconcilable with the plate reconstructions if the features are stretched continental crust that were displaced seaward during the initial opening stages of the
ocean (Srivastava and Tapscott, 1986). Karasik (pers. commun., 1984) indicates that a magnetic
edge anomaly is present on the borderland. The magnetic edge anomaly is described as similar to
that observed on the oceanic Viking Plateau which has been drilled and shown to be composed of mafic volcanic material (Eldholm et al., 1987). The paucity of data from the Chukchi Borderland makes it difficult to assess its origin; however, the limited information suggests it is not a major impediment to closing the Amerasia Basin.

Aeromagnetic data in the Canada Basin and over the Alpha Ridge are reviewed by Vogt et al.
(1982). The anomalies in the Amerasia Basin are chaotic and contrast strongly with the well-lin
eated anomalies observed in the Eurasia Basin. However, there are anomalies that can be traced
for 100 km or more and an extinct spreading centre was identified on the basis of a magnetic
low and a gravity high in the southern Canada Basin. Unfortunately, this gravity high was found to be nonexistent on recent gravity compilations of the region. Limited data already discussed suggest the basin was formed during the Cretaceous period of constant polarity (Sweeney, 1985). Thus, the magnetic anomalies may be due to the topography on basement as on the Alpha Ridge (Jackson et al., 1986). The lack of evidence for clear magnetic anomalies in the Canada Basin thwarts detailed reconstructions of the basin.

The assumption that the crust of the Amerasia Basin is oceanic and formed in situ by the processes that produced the Alpha Ridge eliminates two types of evolutionary scenarios (Lawver et al., 1983). Namely, the basin was formed by oceanization of the continental crust (Beloussov, 1970; Pogrebitskii, 1976) and that the oceanic crust was formed in the Pacific and trapped in its present location (Churkin and Trexler, 1980).

Arctic–Alaska plate

The size of the Arctic–Alaska plate (AA) is an important factor in the reconstructions for the
Amerasia Basin (Fig. 8). The AA plate was extended across the Bering Strait for the following
reasons. Common Paleozoic terrains in Alaska and Chukotka (Cherkin and Trexler, 1980) suggest
that the plate boundary extends across the Bering Strait. Paleozoic to early Mesozoic stratigraphic sequences in the Lawrence Islands are nearly identical to those found in the western Brooks Range; as well, distinctive belts of Late Paleozoic to Mesozoic mafic volcanics and alkaline intrusives are traceable from the Lawrence Islands onto the Chukotka Peninsula (Patton and Tailleur, 1977). The AA plate is extended to the South Anyui fold belt because it is the clearest example of crustal suturing in the region (Shilo and 'Il'man, 1981; Fujita and Newberry, 1982). The polarity of crustal shortening is difficult to determine and it is possible that subduction occurred under both margins before the final collision (Fujita and Newberry, 1982), now dated as the Haueterivian (131–125 m.y.). Although this date left too short an interval for crustal compression due to the opening of the
Canada Basin, more studies in the region should clarify the problem.

The first reconstruction of the Amerasia Basin (Carey, 1958; Tailleur, 1969; Rickwood, 1970; Grantz et al., 1979, 1981; Harland et al., 1984) involves the rotation of the AA plate about a pivot at the mouth of the Mackenzie River (Table 1, Fig. 9). The basin opened with a simple rotation which requires 500 km of crustal shortening at the Chukotka end of the place. As described in the introduction, all rotations for this interval are based on matching the 2000 m contour on the adjacent plates excluding the portions of the contours that describe the Alpha and Mendeleev ridges and the Chukchi borderlands. The Lomonosov Ridge lies adjacent to the Barents–Kara shelf and is considered an independent plate. This position of the ridge was necessary to prevent serious overlap with the AA plate.

Summarizing, independent observations that support or refute this reconstruction; the pre-rift position of the AA plate along the edge of the Sverdrup Basin is compatible with the Late Paleozoic and Mesozoic sedimentary transport directions for both the NA and AA plates. In addition, seismic reflection profiles along the Alaskan margin indicate that it is a rifted as opposed to a transform margin (Grantz and May, 1983). Also supporting the rotation hypothesis for the AA plate are paleomagnetic studies on a lower
### TABLE 1

<table>
<thead>
<tr>
<th>Plates</th>
<th>Pole position</th>
<th>Rotation angle</th>
<th>Reference</th>
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<td>lat.(°)</td>
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**Anomaly 34: LR part of NA (Fig. 5A)**
- GR/NA 73.97 -107.20 -13.62 1
- EU/NA 76.23 148.80 -21.83 1

**Anomaly 34: LR separate plate (Fig. 5B)**
- GR/NA 73.97 -107.20 -13.62 1
- EU/NA 76.23 148.80 -21.83 1

**Anomaly 34 to M0 (Fig. 9)**
- GR/NA 73.97 -107.20 -13.62 1
- EU/NA 79.5 151.92 -25.59 1
- AA/NA 69.1 -135.0 -65, -45, -35, -25 2

**Anomaly 34 to M0 (Fig. 10)**
- GR/NA 73.97 -107.20 -13.62 1
- EU/NA 79.5 151.92 -25.59 1
- AA/NA 66.5 -135.0 -50 3
- AA/NA 61.0 -135.0 -45 3
- AA/NA 68.0 -135.0 -35 3
- AA/NA 69.0 -135.0 -25 3

**Anomaly 34 to M0 (Fig. 11)**
- GR/NA 73.97 -107.20 -13.62 1
- EU/NA 79.5 151.92 -25.59 1
- AA/NA 40.0 124.0 -15, -10, -5 4

**Anomaly 34 to M0 (Fig. 12)**
- GR/NA 73.97 -107.20 -13.62 1
- EU/NA 79.5 151.92 -25.59 1
- AA/NA 69.1 135.0 40, -35 2
- CH/NA 69.1 -135.0 -65, -60 2

* References: 1—Srivastava and Tapscott (1986); 2—Grantz et al. (1979); 3—Jackson et al. (1986); 4—Jones (1982)

Cretaceous (Neocomian) formation on the north slope of Alaska (Halgedahl and Jarrard, 1986). When the paleomagnetic poles for the AA plate are compared to those of the cratonic NA plate, significant relative motion since the Neocomian is suggested, which is compatible with the counterclockwise rotation of the AA plate from the NA plate. There were two structural lineations in the vicinity of the pole of opening that agreed with this model. They are the NF-trending Kaltag fault system, along the continental margin of the western Arctic Islands, and the northwestern trending folds and faults of the Brookian orogen in the Yukon and Alaska (Hea et al., 1980). Crustal shortening in front of the AA plate was accommodated in the South Anyui Suture zone and in the Brooks Range. Unfortunately geological data from the Brooks Range (Oldow et al., 1987) do not support differential shortening along its length, which is required by this model.

The second reconstruction (Table 1, Fig. 10) is a modification of the first. It attempts to retain the virtues of the first and lessen the need for differential shortening along the Brooks Range. A combination of strike-slip and rotational translation for the Amerasia Basin is suggested by Green and Kaplan, (1986) and Jackson et al. (1986). The AA plate is defined as before, but the pole of rotation was chosen further to the south and migrated north with time. In this case the Lomonosov Ridge is assumed to be part of the NA plate. This pole produced 200 km left-lateral motion in the Beaufort-Mackenzie Basin which is compatible with the sinistral motion indicated by the structural studies of Oldow et al. (1987). This reconstruction also required less differential compression along the Brooks Range which is more compatible with the mapped structural trends in the area (Oldow et al., 1987).

The third set of reconstructions is based on the concept that the Arctic Ocean Basin was formed by shear (Kerr, 1980; Jones, 1980, 1982). This theory is based on the linear shape of the Canadian margin and its position as part of a lineament extending from Alaska to Norway. The Lomonosov Ridge is considered part of the NA plate. Dextral faulting in the Beaufort-Mackenzie Basin is indicated by Yorath and Norris, 1975; Young et al., 1976; Jones, 1980 and Churkin and Trexler, 1980. Sinistral as well as dextral shear are postulated for the Canadian Arctic margin (Christie, 1979; Kerr, 1980). The pole of opening suggested by Jones, (1982) that forms a small circle of the margins has been used (Table 1, Fig. 11); consequently, to open the Amerasia Basin to put the AA plate in its present position, left-lateral shear was required. In this set of reconstructions the amount of rotation is difficult to choose because of the gaps or overlaps that occurred in different
Fig. 9. The rotation of the Arctic-Alaska plate with the pole of opening near the Beaufort-Mackenzie Basin (Fig. 1). AA indicates the Arctic Alaska plate, NA the North American plate, GR the Greenland plate, EU the Eurasian plate and LR is the Lomonosov Ridge plate in this and the following figures. The narrow black line is the 2000 m bathymetric contour along the AA plate which is assumed to be the edge of the plate but also includes the Chukchi Borderland and the Mendeleev Ridges. The dotted line is the 2000 m contour associated with the NA plate which encompasses the Alpha Ridge. The principle objection to this rotation is the differential shortening required along the AA plate boundary which is not observed.

parts of the region. When the Amerasia Basin is closed so that the 2000 m contour associated with the Mendeleev Ridge is adjacent to the LR plate, then encroachment of the AA plate occurred on Banks Island (Fig. 1). In addition, between the AA plate and the Lomonosov Ridge there is a gap filled by the overlapping Alpha and Mendeleev Ridge 2000 m contours. This is possible if the Mendeleev Ridge is of continental origin and the Alpha Ridge is oceanic.

The fourth reconstruction (Table 1 and Fig. 12) is based on the premise that the AA plate is not continuous across the Bering Strait (Vogt et al., 1982; Zonenshain and Napatov, in press). The hypothesis is important if the Chukchi Borderland is continental crust (Vogt et al., 1982) because the borderland overlaps the Arctic Islands when the 2000 m contour of the American portion of the AA and NA plates are superimposed (Fig. 8). This model implies that the Canadian Arctic continental margin was not formed in one stage. The available geological constraints from the Canadian polar margin are imprecise but consistent with a formation at the same time (Sweeney, 1985). The portion of the AA plate now called the AL plate is rotated to where the 2000 m contours barely overlapped. The CH plate with the Chukchi Borderland and Mendeleev Ridge attached, is rotated so that the irregular 2000 m contour slightly overlaps with the 2000 m contour of the NA plate. Now the
Alpha and Mendeleev ridges fit adjacent to each other with some overlap. This reconstruction implies that the Alpha Ridge and Mendeleev Ridge must also be foundered continental crust. The same pole of opening is chosen for both new plates so that the boundary between them is a transform fault. If this assumption is not made, it would be necessary for compression or extension to have taken place between Alaska and Chukotka. Limited geophysical data show no evidence of this. The Lomonosov Ridge in Fig. 12 is attached to the NA plate.

Summarizing, the position of the plates in pre-Arctic Ocean times, the AA plate was adjacent to the NA plate aligned along the edge of the present polar shelves (Fig. 8). The preferred way to achieve this configuration is by rotating the AA plate with a component of strike-slip motion. The size of the Alaska portion of the AA plate was smaller than at present. The eastern edge of the AA plate was adjacent the Lomonosov Ridge and overlap may have occurred in this area. The position of the GR plate relative to the NA plate was the same as at anomaly 34.

**Conclusions**

The most acceptable plate reconstruction for the Arctic Basin based on the presently available data set for stage III, anomalies 0–24/25, is the Srivastava and Tapscott (1986) plate reconstruction for the EU and NA plates that satisfies the magnetic anomalies in the Eurasia Basin and in the North Atlantic. From anomaly 25–34, the
suggestion of strike-slip motion in the Arctic Ocean is more compatible with the available data than models that require compression. The linear shape of the Lomonosov Ridge could be a product of strike-slip motion prior to the opening of the Eurasia Basin. For the time period prior to anomaly 34 (stage I), the rotation of the AA plate from the Canadian polar margin, with a pole that shifts northward, is congruous with the available geological and geophysical information. This reconstruction is consistent with the distribution and the development of the circum-Arctic sedimentary basins.

The circum-Arctic basins include the Brooks-MacKenzie, Sverdrup, Wendel Sea basins and the basins of Siberia and East Greenland. A significant amount of geological data has been gathered that indicates from the Carboniferous to pre-mid Cretaceous the circum-Arctic basins received analogous sediment types in a common tectonic setting (Balkwill et al., 1983; Haakanson and Stemmerik, 1984; Riis et al., 1986). Similarities in the marine faunas in these basins indicate long lasting connections between them (Balkwill et al., 1983) and also suggest the basins were close. In contrast, the present Arctic margins are marked by provincial faunas. Closure of the Arctic Ocean shown in Fig. 8 illustrates the proximity of the circum-Arctic basins prior to the opening of the Amerasia Basin. In fact, the rifting period associated with and that occurs before seafloor spreading that separated the AA plate from the NA plate provided the mechanism for the basin formation. It also implies that during the development of the circum-Arctic
basins—from Mississippian to mid-early Cretaceous (320 to 125 m.y.)—no major plate reorganization occurred in the region of the Arctic.

The principal difference between this Arctic closure model and others, such as those from Steel and Worsley (1984) or Worsley (1986) or that shown in Fig. 10, is that the central Arctic Ocean at closure is not left with a large continental high north of Ellesmere Island, consisting of the Lomonosov, Alpha and Mendeleev Ridges and the Chukchi Borderland, that separate the basins of the EU plate margins from those on the NA and AA plates. The preferred reconstruction in this paper is in better harmony with the history of the circum-Arctic basins than earlier reconstructions. For example, the continuous distribution of very organic-rich source rocks in the mid-Triassic from the Alaska margin, the Sverdrup Basin, Svalbard and the Barents Sea (Mork, 1987), is consistent with and explained by this reconstruction.

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