THE AGE OF THE AMERASIA BASIN

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ABSTRACT

Available geological and geophysical data from the oceanic Amerasia Basin and the adjacent continental areas indicate that the basin opened by the counterclockwise rotation of northern Alaska and adjacent northeastern Russia away from the Canadian Arctic Islands. The continental rifting that initiated this rotational movement appears to have begun in early Middle Jurassic (Aalenian), as evidenced by the initial age of margin-parallel faults in the southwestern Arctic Islands and Mackenzie Delta region. Sea-floor spreading is interpreted to have begun in the Hauterivian on the basis of the assignment of the widespread Hauterivian unconformity as the breakup unconformity. Rotation ceased in the Cenomanian as indicated by the termination of faulting in the rotation pivot area at a widespread Cenomanian unconformity, paleomagnetic data from Alaska, and terrane-overlap relationships in northeastern Russia.

INTRODUCTION

The Amerasia Basin comprises a triangular-shaped portion of the Arctic Ocean and is completely ringed by continental crust. The tectonic development of this small ocean basin has been debated for many years because it has not been possible to identify within the basin a set of magnetic lineations that would allow an unambiguous interpretation of sea-floor spreading directions. Numerous diverse hypotheses have been proposed for the opening of the basin and are succinctly summarized by Lawver and Scotese (1990).

The favoured hypothesis is that opening occurred by the counterclockwise rotation of northern Alaska and adjacent northeastern Russia away from the Canadian Arctic Islands (Carey, 1955; Tailleur, 1969, 1973). Recently compiled geological and geophysical data from northern Alaska and the Canadian Arctic strongly support this hypothesis (Embry, 1990). The most convincing evidence includes the precise restoration of the following linear trends that intersect the Amerasian margins at high angles in both northern Alaska and the Canadian Arctic Islands (Fig.1):

(1) The Ellesmerian (latest Devonian-earliest Carboniferous) tectonic front.

(2) The basin axes of Upper Paleozoic to Jurassic strata. It should be pointed out that the 270-km offset of these axes as shown by Grantz et al. (1990, Fig.12b) is untenable. The authors used an old and out-of-date reference (Drummond, 1973) for the positioning of the axis of the Sverdrup Basin in the Arctic Islands. Available data show an excellent alignment of the axes with no apparent offset (Embry, 1990).

(3) Upper Paleozoic-Jurassic facies boundaries.

With rotational restoration, an isolated area of Devonian clastic strata in the Chukchi Sea becomes part of a regional foreland basin (Fig.1), and structural and paleocurrent trends determined in the Devonian strata of the Chukchi Sea become aligned with structural and paleocurrent trends of the Devonian clastics of Prince Patrick Island (Embry, 1990). Finally, paleomagnetic data from northern Alaska are compatible with a 65-70° counterclockwise rotation of the area (Halgedahl and Jarrard, 1987).

The question of when the rotation occurred also has been debated in the literature (Lawver and Scotese, 1990), and various interpretations on the ages of the initiation of rifting, the initiation of sea-floor spreading, and the cessation of sea-floor spreading have been offered. In this paper, we evalaute the available evidence for determining the age of each of the above three main events in the evolution of the Amerasia Basin (given that it formed by counterclockwise rotation) and offer our preferred interpretations.

INITIATION OF RIFTING

The first cogent arguments for determining the initiation of continental rifting that eventually led to the formation of the Amerasia Basin were put forth by Grantz and May (1983). On seismic data from offshore northern Alaska, they identified normal faults that parallel the Amerasian margin. They interpreted the graben fill to be Jurassic to earliest Cretaceous in age and concluded that "the earliest manifestation of rifting off northern Alaska is the unconformity at the base of inferred Jurassic fill in Dinkum graben" (Grantz and May, 1983, pp. 95-96). This basal unconformity was correlated with the unconformity that underlies the Jurassic succession along the Canadian Beaufort margin, and hence Grantz and May (1983) interpreted the initiation of rifting as earliest Jurassic.

An alternative hypothesis was put forward by Embry (1985, 1991), who interpreted that rifting did not begin until the Middle Jurassic. This interpretation was based on stratigraphic and structural studies in the southwestern portion of Sverdrup Basin in the Canadian Arctic Islands. In the Prince Patrick Island area, numerous normal faults that parallel the Amerasian margin are present. Pre-Middle Jurassic facies trends are perpendicular to the faults, and thickness trends show no relationship to the faults (Fig.2A). On the other hand, Middle Jurassic and younger strata in the area were affected by the faulting during deposition as determined by facies and thickness trends (Fig.2B) (Harrison et al., 1988). It is clear that, in this area, normal faulting, parallel to the Amerasian margin, was initiated in early Middle Jurassic.

A Middle Jurassic age for the initiation of Amerasia rifting is supported by the occurrence of early Middle Jurassic faults in the Mackenzie Delta region (Poulton, 1982), by the reinterpretation of the offshore Alaskan faults as Middle Jurassic in origin (Hubbard et al., 1987), and by the occurrence of a major pre-Middle Jurassic unconformity on Svalbard (Steel and Worsley, 1984) and Franz Josef Land (Embry, this volume).

In summary, present data indicate that continental

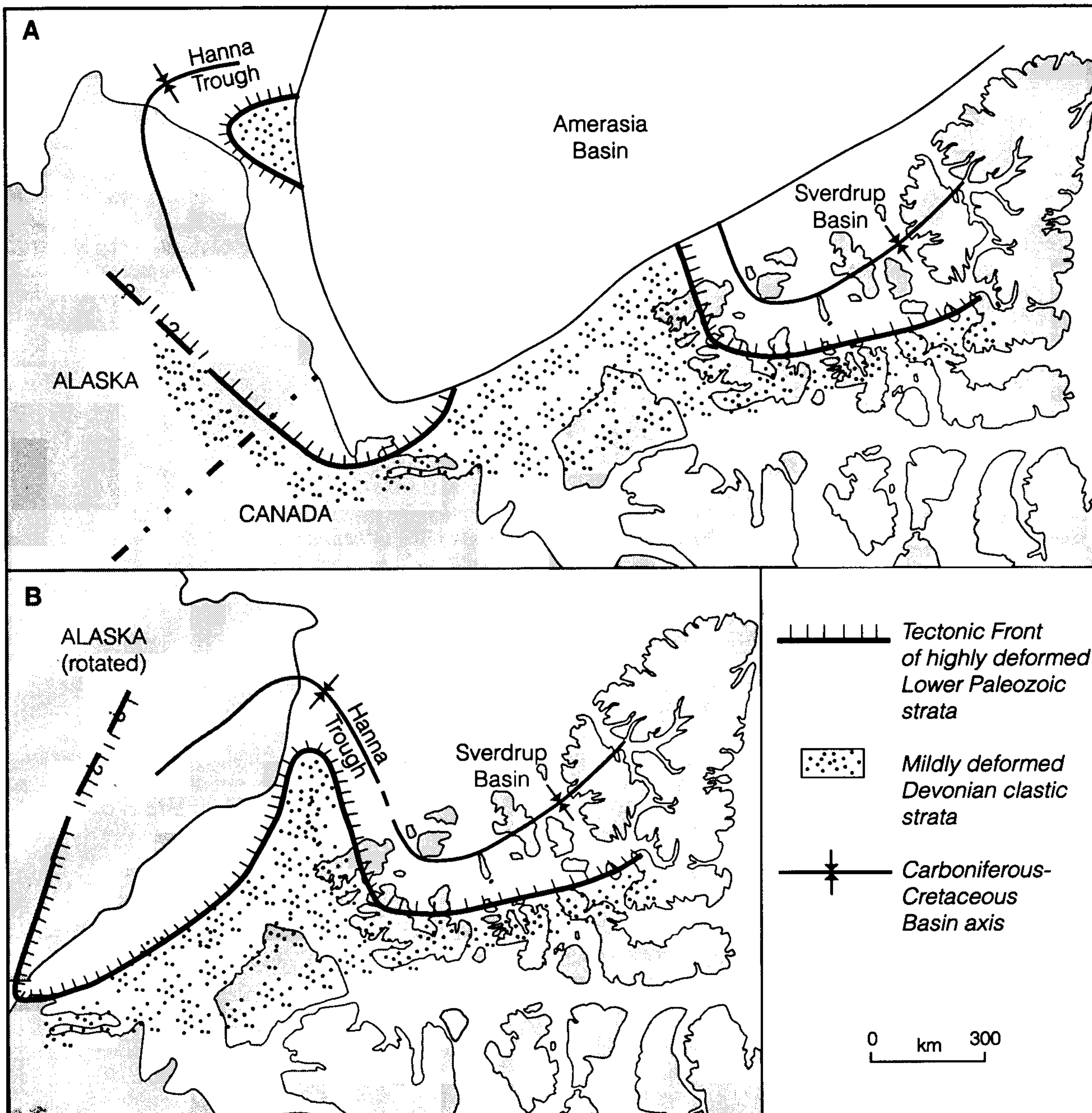

Fig.1.
A. The tectonic front of Ellesmerian deformation (Devonian) and Carboniferous to Cretaceous basin axes are plotted for both the Canadian Arctic Islands and northern Alaska. These linear trends are truncated on the margins of the Amerasia Basin in both areas.
B. The Ellesmerian tectonic front and the Carboniferous to Cretaceous basin axes form coherent, through-going patterns following rotational restoration of northern Alaska against the Canadian Arctic Islands. Also note that an isolated area of Devonian clastic strata in the Chukchi Sea (A) becomes part of the regional Devonian foreland basin (B).

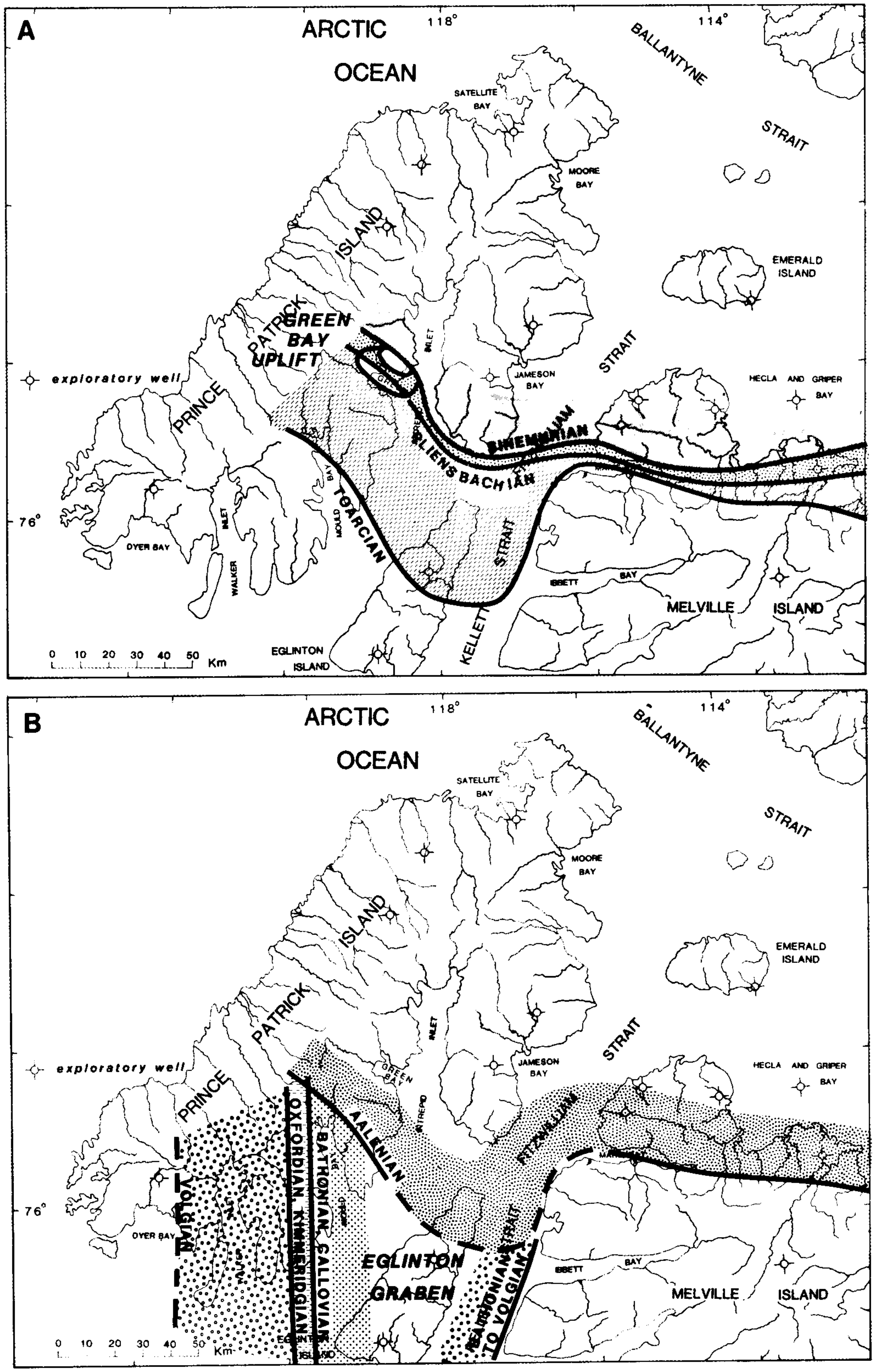

Fig.2.
A. Distribution of Lower Jurassic strata, Prince Patrick Island area, southwestern Sverdrup Basin. The erosional limits and facies trends for these strata are perpendicular to the Amerasia Basin margin.
B. Distribution of Middle and Upper Jurassic strata, Prince Patrick Island area, southwestern Sverdrup. The erosional limits and facies trends of post-Aalenian strata are aligned with margin-parallel faults (from Harrison et al., 1988).

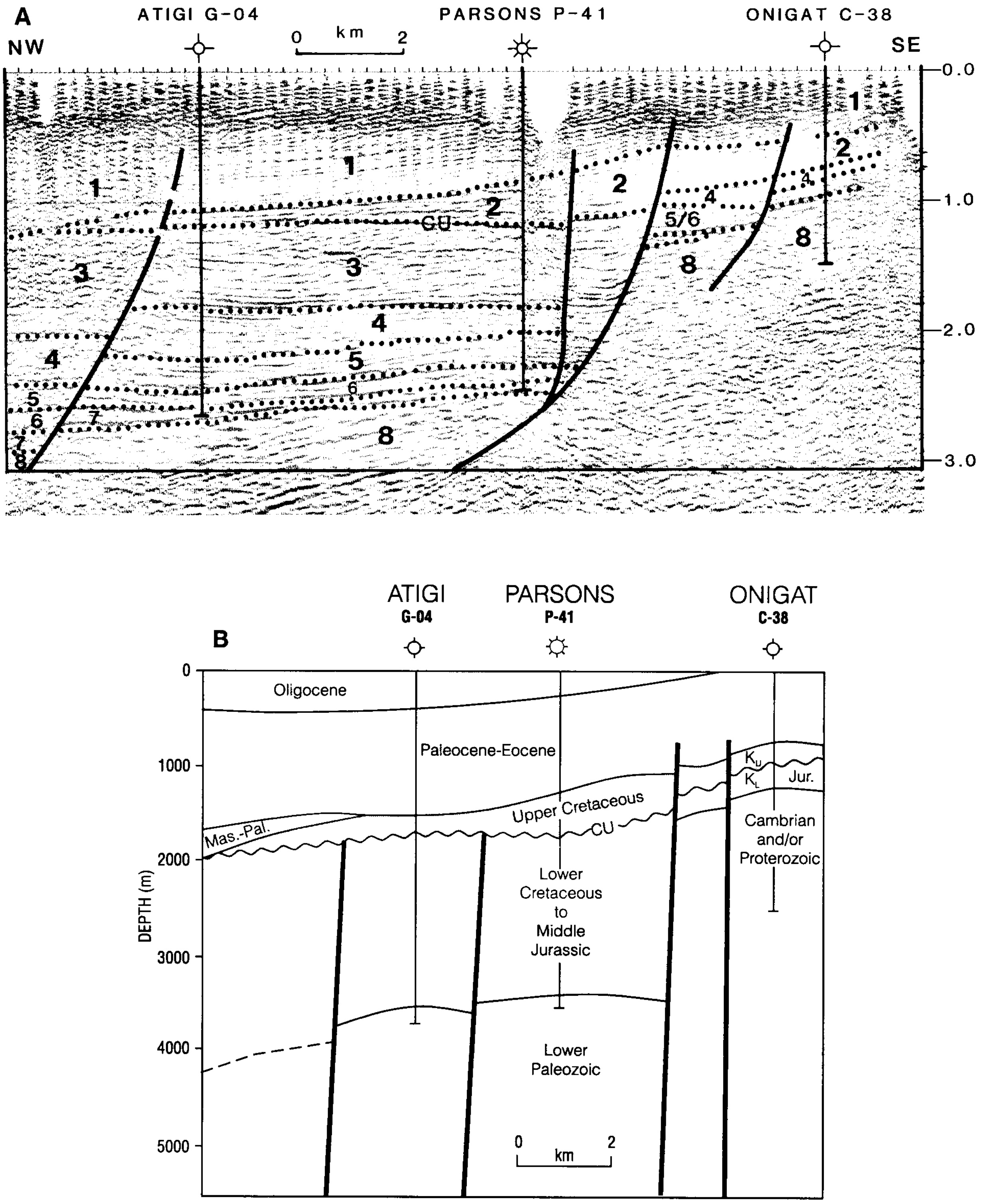

Fig.3.
A. Reflection seismic section across the Eskimo Lake fault zone, southern Mackenzie Delta. The Cenomanian unconformity (CU) is placed at the base of unit 2.
B. Simplified geological cross section along the seismic line illustrated in A. Faults are truncated or show greatly reduced offset at the CU. The location of this section very near the pivot point suggests that sea-floor spreading and associated rifting near the pivot ceased in early Cenomanian.

rifting, which initiated the opening of the Amerasia Basin, most likely began in early Middle Jurassic (Aalenian).

INITIATION OF SEA-FLOOR SPREADING

The timing of the rift-drift transition and the initiation of sea-floor spreading in the Amerasia Basin is currently contentious. Heat flow studies and depth to oceanic-basement analysis (Lawver and Baggeroer, 1983; Langseth et al., 1990) indicate that the Amerasia ocean is Cretaceous in age. The paleomagnetic data of Halgedahl and Jarrard (1987) are from lowermost Cretaceous strata and thus indicate that most, if not all, the rotation was post-Valanginian. Furthermore, other paleomagnetic data from Alaska (Harbert et al., 1990) and terrane-overlap relationships in northeastern Russia (Rowley and Lottes, 1988) demonstrate that most of the rotation occurred before the Late Cretaceous. All of these data strongly point to initiation of sea-floor spreading sometime in the Early Cretaceous.

A reasonably precise age of this event probably is best determined with available data by identifying the breakup unconformity within the Cretaceous succession. Data from continental margins throughout the world demonstrate that the age of the breakup unconformity very closely approximates the beginning of sea-floor spreading in the adjacent ocean. The key characteristic of a breakup unconformity is that normal faults that characterize the strata of the rifting stage are truncated or show greatly reduced offset at the unconformity (Falvey, 1974).

Various authors have interpreted three different unconformities within the Cretaceous succession as the breakup unconformity. The ages of the three candidates for the breakup unconformity are Hauterivian (Grantz and May, 1983; Embry, 1985; Dixon and Dietrich, 1990), Aptian (Craig et al., 1985; Hubbard et al., 1987), and Cenomanian (Embry and Dixon, 1990; Dixon, in press). The Hauterivian unconformity clearly truncates numerous normal faults on seismic lines offshore Alaska (Grantz and May, 1983, Fig.11,12; Hubbard et al., 1987, Fig.15). However, as noted by these authors and by Craig et al. (1985), some normal faults cut the Hauterivian unconformity; and these are truncated at the Aptian unconformity. The fact that most of the fault movement occurred before or during the development of the Hauterivian unconformity suggests that it is the best choice for the breakup unconformity.

On seismic lines in the Mackenzie Delta region, normal faults cut the entire Lower Cretaceous succession and are truncated at the Cenomanian unconformity (Fig.3). On the basis of these relationships, Embry and Dixon (1990) proposed the Cenomanian unconformity as the breakup unconformity. However, this interpretation is no longer tenable given the paleomagnetic and terrane-overlap data mentioned earlier. The occurrence of faulting throughout the Lower Cretaceous in the Mackenzie Delta region is best explained by the close proximity of the area to the pole of rotation. In such an area, normal faulting and rifting would continue throughout both the rift and drift phase of basin development. Of note is the significant increase in normal fault activity in the area following the Hauterivian unconformity. This is interpreted as accelerated rifting in the pivot region due to the onset of sea-floor spreading.

The assignment of the Hauterivian unconformity as the breakup unconformity is supported by the occurrence of a major Hauterivian unconformity with associated volcanism in the Sverdrup Basin (Embry, 1991), Svalbard (Steel and Worsley, 1984), and Franz Josef Land (Embry, this volume).

In summary, current data point to the Hauterivian unconformity as the best candidate for the breakup unconformity, and thus sea-floor spreading in the Amerasia Basin likely began in the Hauterivian.

CESSATION OF SEA-FLOOR SPREADING

The time when sea-floor spreading stopped in the Amerasia Basin has been interpreted only in general terms. Rowley and Lottes (1988) called attention to the overlap of the Okhotsk-Chukotsk volcanic belt on the South Anyui suture. This suture represents the transform fault and collision zone along which the northern Alaska-northeast Russia plate rotated. Radiometric and biostratigraphic data indicate an Albian age for the volcanics; thus most, if not all, of the sea-floor spreading in the basin had to have taken place by late Albian. In corroboration of this interpretation, Harbert et al. (1990) state (p. 578) that "on the basis of remagnetized rocks from the Brooks Range, significant relative motion for the North Slope ceased shortly before about 100 Ma" (late Albian).

Given the above general constraints, a reasonable way of dating the cessation of spreading more precisely is to identify a widespread unconformity that reflects the major tectonic change associated with the end of drift. The only widespread, significant unconformity that developed in the circum-Arctic area in the mid-Cretaceous is the mid-Cenomanian unconformity (Hubbard et al., 1987; Dixon, 1993; Embry, 1991; Embry and Dixon, 1990; Embry, this volume).

The interpretation that the Cenomanian unconformity coincides with the termination of spreading is supported by the stratigraphic-structural relationships in the Cretaceous strata of the Mackenzie Delta region. This area was located very near the pole of rotation and, as discussed earlier, normal faulting would have continued throughout the interval of sea-floor spreading and ceased when sea-floor spreading stopped. As shown on Fig.3 normal faults cut the entire Lower Cretaceous succession and are truncated by or show significantly decreased offset at the Cenomanian unconformity. On the basis of this relationship, this unconformity was initially, and erroneously, interpreted as the breakup unconformity by Embry and Dixon (1990). However, because of its occurrence in the pivot region, it is much better interpreted as the drift-cessation unconformity.

In the Sverdrup Basin, a thick unit of volcanic rocks that represents the last phase of an episode of basic volcanism that began in Hauterivian (Embry and Osadetz, 1988) is overlain by the Cenomanian unconformity. The unconformity also is present on Franz Josef Land, where it also overlies a thick basalt-dominant succession of Hauterivian-Albian age (Embry, this volume).

In summary, an array of diverse data indicates that sea-floor spreading in the Amerasia Basin ceased in the early Cenomanian.

CONCLUSIONS

Geological and geophysical data from the Amerasia Basin and the surrounding continental areas strongly indicate that the basin opened by counterclockwise rotation of northern Alaska and adjacent northeast Russia away from the Canadian Arctic Islands. Accepting this method of opening, the time of initiation of rifting, of initiation of sea-floor spreading, and of cessation of spreading can be interpreted from stratigraphic and structural relationships and paleomagnetic data. Continental rifting began in the early Middle Jurassic (Aalenian, 175 MA), with sea-floor spreading being initiated some 40 m.y. later in the Hauterivian (135 MA). Sea-floor spreading lasted for about 45 m.y. and ceased in the early Cenomanian (95 MA). These three major shifts in the tectonic regime of the Amerasia Basin are reflected in widespread unconformities on the adjacent continental margins.

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