EARLIEST TERTIARY PALEOGEOGRAPHY OF THE ARCTIC OCEAN

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ABSTRACT

The uppermost exposed part of the Prince Creek Formation of northern Alaska contains the most diverse Danian marine molluscan fauna known from the Arctic Ocean. Most of the fauna consists of early Tertiary mollusks; the remainder of the fauna consists of relict Jurassic and Cretaceous taxa. This unusual faunal association resulted from the almost total geographic isolation of the Arctic Ocean from the world ocean that lasted from Late Cretaceous to earliest Tertiary time.

Species- and genus-level correlations between the molluscan faunas of northern Alaska, North and South Dakota, the Canadian Arctic Islands, and Spitsbergen define a coherent, taxonomically distinct Arctic Ocean faunal realm during the Danian.

Molluscan biogeographic affinities clearly indicate a Paleocene seaway between the Arctic Ocean and the world ocean by way of the northeastern Atlantic Ocean. This supports plate-tectonic models for North Atlantic rifting reaching the Arctic Ocean Basin by the Paleocene.

INTRODUCTION

The Arctic Ocean is the last of the world's ocean basins whose paleogeographic history is not well understood, due to the paucity of faunal evidence from within the Arctic Ocean Basin itself. One of the time intervals of special interest is the Paleocene, because it was at that time that the long-isolated Arctic Ocean was connected with the world ocean by way of the northeastern Atlantic Ocean (Marincovich et al., 1990). Earliest Tertiary faunal interchanges between the Arctic and Atlantic Oceans permit dating and correlation of the previously isolated Arctic faunas and also provide insights into the paleobiogeography of the Arctic Ocean.

The Arctic Ocean was almost entirely isolated geographically from the world ocean during the Late Cretaceous. The accretion of tectonic plates between Asia and North America largely closed any connection between the Pacific and Arctic Oceans by the late early Albian (ca 105-110 Ma) (Williams and Stelck, 1975). The time at which shallow-water Pacific-Arctic connections ceased is not known with certainty due to lack of fossil evidence, but it appears to have been late in the Cretaceous (Lillegraven and McKenna, 1986). During the Late Cretaceous, the Arctic Ocean communicated with the world ocean through two epicontinental seaways: the Western Interior Seaway in North America and Turgai Strait in western Siberia (Marincovich et al., 1990).

The Western Interior Seaway extended some 7,000 km from the Arctic Ocean to the Gulf of Mexico, connecting the two oceans sporadically during the late Albian and continuously from the Cenomanian through the early Maastrichtian (Williams and Stelck, 1975; Balkwill et al., 1983). This connection is shown by the affinities of Late Cretaceous marine microfaunas of arctic North America with those of the Gulf of Mexico (Tappan, 1962; Bergquist, 1966). However, steep gradients in the salinity, temperature, and oxygen content in shelf waters, as shown by the poor representation of normal-marine groups, evidently were barriers to long-distance molluscan migrations, especially during the later stages of the seaway's existence (Waage, 1968; Speden, 1970). Despite these restrictive factors, the early Maastrichtian Fox Hills Formation in South Dakota contains some bivalves and cephalopods clearly related to faunas of the Gulf and Atlantic Coastal Plain some 2,000 km to the south (Speden, 1970).

Turgai Strait in western Siberia was the only seaway connecting the Arctic Ocean and the world ocean in the latest Cretaceous (Vinogradov et al., 1968; Beznosov et al., 1978). Although Turgai Strait was fully open during the Late Cretaceous, it was thereafter only intermittently open. The "strait" was a coastal plain that was periodically inundated by the sea in the Paleocene and became more continuously marine during the Eocene until its closure by regression in the late Eocene or Oligocene (Vinogradov et al., 1967). Turgai Strait deposits are entirely subsurface and have yielded no mollusks for comparison with faunas elsewhere. Faunal affinities between northern Alaskan and Turgai Strait deposits are based on genus-level similarities of marine ostracodes (Marincovich et al., 1990; Brouwers and De Deckker, 1993).

Morphologically similar ammonite faunas in the Western Interior Seaway and West Greenland (Birkelund, 1965) suggest that the Arctic Ocean extended as an embayment into the northern part of present-day Baffin Bay (Fig.1) during the Late Cretaceous (Balkwill et al., 1983). Whether this embayment extended from Baffin Bay southward to the North Atlantic *per se* is not known. In any case, the marine connection between the Arctic Ocean and Baffin Bay evidently did not survive into the early Tertiary, as evidenced by profound dissimilarities between Danian molluscan faunas of the Arctic Ocean realm (i.e., Ellesmere Island, Spitsbergen, northern Alaska, and the Dakotas) (Marincovich et al., 1990; Marincovich, 1993), and Danian faunas of Nûgssuaq, West Greenland (Fig.1) (Kollmann and Peel, 1983). These major differences in faunal composition suggest that there probably was a land barrier between the Arctic Ocean and Baffin Bay throughout the Danian.

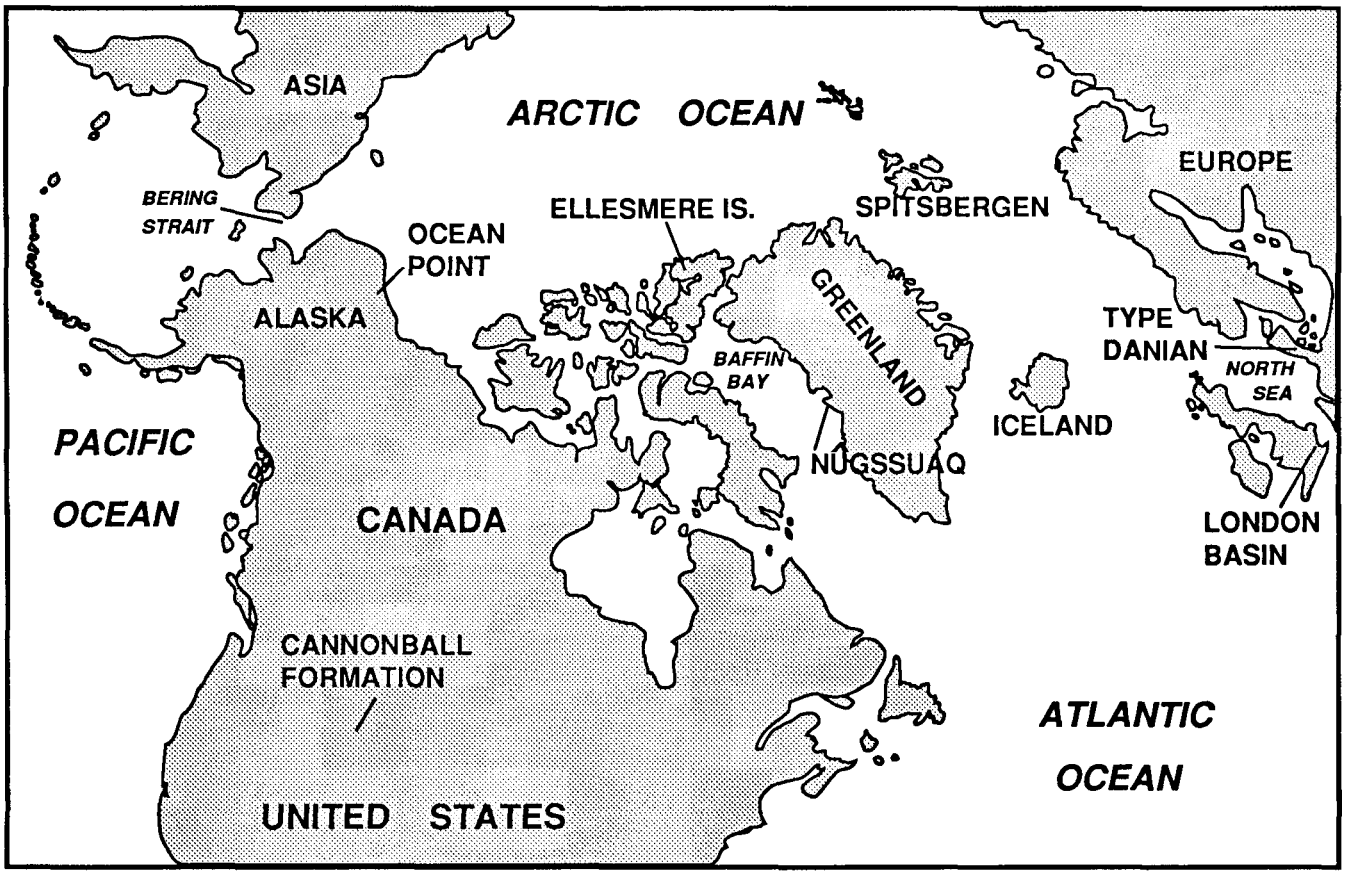

Fig.1. Location of places mentioned in text.

PALEOCENE PALEOBIOGEOGRAPHY

Some paleogeographic reconstructions for the terminal Cretaceous show an Atlantic-Arctic Ocean Seaway connection and others do not. Inferred north-south seaways or east-west land bridges are extrapolated from plate-tectonic models of deep-water connections between ocean basins. There is no paleontological evidence for a terminal-Cretaceous marine connection between the Arctic and North Atlantic Oceans. Furthermore, the presence of several relict Mesozoic genera in the Prince Creek beds of northern Alaska reinforces the hypothesis of a geographically nearly isolated Arctic Ocean during the Late Cretaceous. However, there was a Paleocene seaway connection between the Arctic Ocean and the world ocean by way of the northeastern Atlantic (Marincovich, 1992, 1993). The evidence for this is the biogeographic relationships of shallow-water marine mollusks from near Ocean Point, northern Alaska, and Ellesmere Island, Canada, with northeastern Atlantic faunas (Fig.1). Species- and genus-level correlations between molluscan faunas of northern Alaska, North and South Dakota, the Canadian Arctic Islands, and Spitsbergen define a coherent, taxonomically distinct Arctic Ocean faunal realm during the Danian (Marincovich et al., 1990; Marincovich and Zinsmeister, 1991; Marincovich, 1993). The Danian molluscan fauna of the Prince Creek Formation in northern Alaska contains taxa that not only allow correlations with other Arctic Ocean faunas, but also show its relationships with northeastern Atlantic faunas (Marincovich, 1993).

The molluscan fauna of the Prince Creek Formation in the vicinity of Ocean Point (Fig.1) is dated as Danian based on comparisons with independently dated molluscan faunas of the North American Western Interior, the Arctic Ocean, and the North Atlantic. Among the best age indicators are two bivalve species that have been found before only in Paleocene, mostly Danian, faunas elsewhere. The Prince Creek species *Arctica ovata* (Meek and Hayden, 1857) was formerly known only in the Cannonball Formation of North and South Dakota (Fig.1) (Cvancara, 1966) that is Danian in age based on planktonic foraminifers (Fox and Olsson, 1969). Another formerly unique Cannonball mollusk, the gastropod *Drepanochilus pervetus* (Stanton, 1920), has since been found in Danian strata of the Mount Moore Formation on Ellesmere Island (Marincovich and Zinsmeister, 1991). One of the most common Prince Creek bivalves, *Cyrtodaria rutupiensis* (Morris, 1852), has been found with *D. pervetus* in the Mount Moore Formation (Marincovich and Zinsmeister, 1991). Also, *C. rutupiensis* occurs in the Danian fauna of the Barentsburg Formation on Spitsbergen, and in late Paleocene (Thanetian) faunas of the Thanet and Oldhaven

Formations in the London Basin, England (Fig.1) (Strauch, 1972). Occurrences of *A. ovata* in the Danian Cannon-ball Formation and of *C. rutupiensis* in the Danian Mount Moore Formation imply this age for the Prince Creek beds. It is notable that these three Danian deposits are in the Arctic Ocean Basin. Arctic Ocean Danian occurrences of these species followed by Thanetian occurrences of *C. rutupiensis* in the London Basin are significant for paleogeographic reconstructions.

DANIAN PALEOGEOGRAPHY

Evidence that the bivalve *C. rutupiensis* dwelled only in the Arctic Ocean during the Danian suggests that a land barrier existed between northern Europe and northern Greenland. This is consistent with paleogeographic reconstructions based on the close relationships of Danian terrestrial vertebrates in Europe and North America (McKenna, 1983). Taken together, these marine and terrestrial data support the hypothesis of a geographically isolated Arctic Ocean during the Danian.

The presence in the Prince Creek beds of the bivalve *Arctica ovata* indicates that an embayment of the Arctic Ocean extended southward as far as South Dakota. This species was formerly known only in the Danian Cannonball Formation of North and South Dakota and had no clear ties to other faunas. The exact configuration of this southern extension of the Arctic Ocean into midcontinental North America is unknown.

While Arctic Ocean Danian marine faunas were geographically confined, there was excellent interchange of marine mollusks and microbiota between the type Danian of Denmark and Danian faunas of Nûgssuaq, West Greenland (Fig.1) (Rosenkrantz and Pulvertaft, 1969; Rosenkrantz, 1970; Marincovich et al., 1990). The fact that these more southerly and very diverse Danian faunas shared no mollusk species with the Arctic Ocean is further evidence for isolation of the Arctic Ocean at that time.

THANETIAN PALEOGEOGRAPHY

The appearance of *Cyrtodaria rutupiensis* in the Thanet Sands (type Thanetian) of the London Basin signals a late Paleocene seaway connection from the Arctic Ocean to the southern North Sea Basin. The Thanetian first appearance of the bivalve *Gari (Garum)* in western European faunas (Marincovich, 1993) is further evidence for this northern marine connection. Both *Cyrtodaria* and *Gari (Garum)* have their oldest records in the Danian fauna of the Prince Creek Formation.

Marine connections southward to the northeastern Atlantic were very likely intermittent through the early Eocene. The very close faunal relationships between abundant terrestrial and freshwater vertebrates of Ellesmere Island and Europe during the early Eocene (McKenna, 1975, 1980, 1983; Marincovich et al., 1990) strongly suggest this.

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