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PALEONTOLOGIC RESPONSE TO POST-JURASSIC CRUSTAL PLATE MOVEMENTS--ETC(U)
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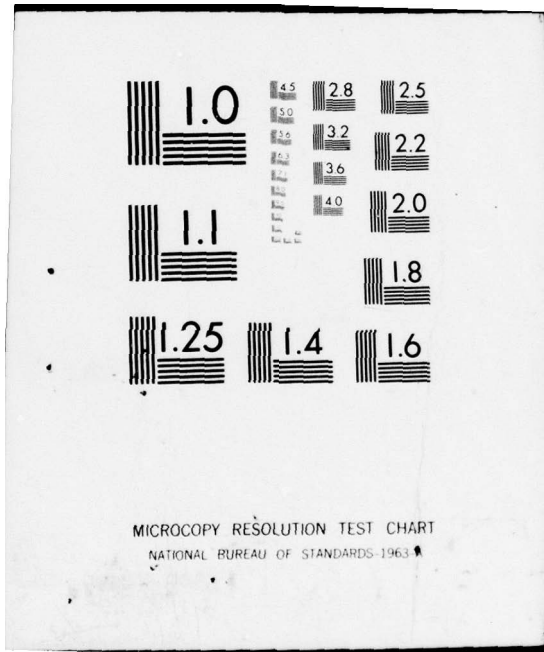
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PALEONTOLOGY AND PLATE TECTONICS

edited by Robert M. West

Proceedings of a symposium presented at the
North American Paleontological Convention II
August 9, 1977 - Lawrence, Kansas

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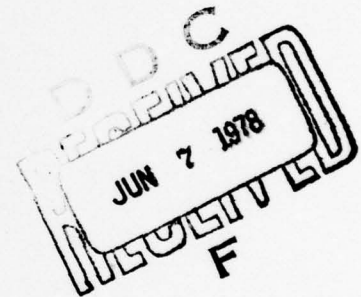
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PALEONTOLOGY AND PLATE TECTONICS
WITH SPECIAL REFERENCE TO THE HISTORY
OF THE ATLANTIC OCEAN

Proceedings of a symposium presented at
the North American Paleontological
Convention II, Lawrence, Kansas
August 9, 1977

edited by
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PALEONTOLOGIC RESPONSE TO POST-JURASSIC CRUSTAL PLATE MOVEMENTS

IN THE ARCTIC OCEAN

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ABSTRACT-- The central Arctic Ocean may be a good model of tectonic and evolutionary interplay in the development of endemism. Crustal plate movement of the Late Mesozoic to Late Paleocene (~81-53 m. y.) permitted continual circulation of the central Arctic Ocean water with that of the North Pacific as well as with a continental sea (Obik?) that extended south onto the Russian Platform. During this interval, the central Arctic Ocean was one-half its present size and consisted only of the Amerasian Basin. Some 20 silicoflagellate species have been identified in Cretaceous and Paleocene sediment from this Basin. Strong Pacific affinities are suggested by the Cretaceous taxa while Late Paleocene forms have stronger Russian affinities. A few species appear unique to the Arctic.

The opening of the North Atlantic and Eurasian part of the Arctic Ocean began 63-40 m. y. and this motion restricted the Pacific-Arctic interchange. This Cenozoic spreading almost doubled the size of the Arctic Ocean by development of the Eurasian Basin.

Some 115 paleontologically significant species have been identified in the modern Amerasian Basin, including 73 benthic and 2 planktic Foraminifera, 18 benthic and 1 epipelagic ostracodes, 9 species of bivalves, 4 sponges, 3 holothurian species, 1 pteropod, 1 gastropod, 1 crinoid, 1 ophiuroid, and 1 echinoid species. In addition, 26 other planktic species (17 radiolarian, 4 dinoflagellates, 4 tintinnids, and 1 silicoflagellate) have been described from the southern margin of the Canadian Basin and may be added to the central Arctic Ocean number giving 141 paleontologically significant species.

Most of the benthic Foraminifera and ostracodes appear endemic. As the modern ecosystem developed, benthic Foraminifera and ostracodes became established early. Four endemic species constitute 50% of the volume of the paleontologically significant benthic fauna. Species volume dominance appears to be a good guide to endemism in the Arctic.

INTRODUCTION

The evolution of the Arctic Basin has involved a number of important physical and biologic developments that can be documented to have occurred since the Jurassic. This includes 1) doubling of the size of

the Arctic Ocean, 2) the change from a Pacific-Russian platform water circulation with the central Arctic Ocean to a predominantly North Atlantic link, and 3) significant changes in biological relationships corresponding to water circulation patterns. The relationship of these factors to each other as well as to the evolution of the present Arctic endemic fauna of paleontologic significance is the subject of this paper.

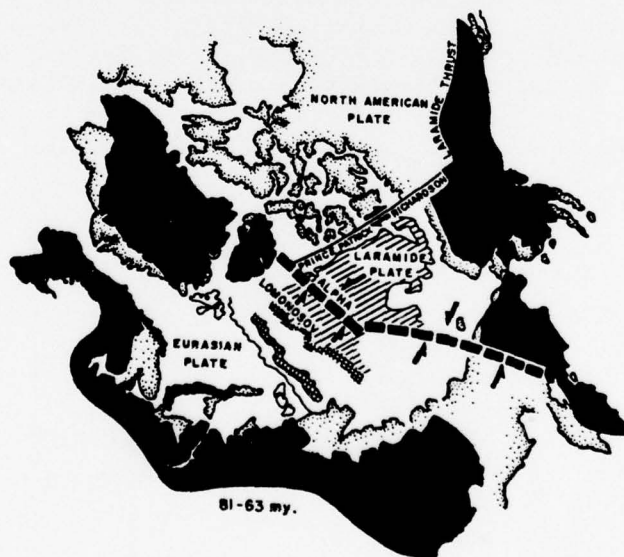
ORIGIN OF THE ARCTIC OCEAN AND ITS LATE MESOZOIC-EARLY CENOZOIC HISTORY

The modern deeper or central Arctic Ocean is divided by the Lomonosov Ridge into unequal portions, the Amerasian and Eurasian Basins (Text-fig. 1). The Lomonosov ridge was part of the Barents-Eurasian Shelf until ~ 63 m. y. Spreading from the modern Nansen Ridge was initiated at that time and the Eurasian Basin was formed. In the process, the Lomonosov Ridge was "moved" to its present position. Thus, the Eurasian Basin was formed during the Cenozoic, and the Late Mesozoic central Arctic Ocean was considerably smaller than at present, consisting only of the Amerasian Basin (Clark, 1975).



TEXT-FIG. 1. Important physiographic features of the Central Arctic Ocean and adjacent areas. Modified from Ostenso and Wold (1973) and used with their permission and the American Association of Petroleum Geologists.

Additional details concerning the Late Mesozoic Arctic Ocean are meager and are based more on inferred relationships with known Mesozoic history of the present surrounding continental area, than on data from the Ocean. Pitman and Talwani (1972) suggested that from 81 to 63 m. y. ago, the relative motion between the North American and Eurasian plates in the Arctic was compressional and that this compression probably was expressed by such things as folding in the Sverdrup Basin of north-central Canada, deformation in the Brooks Range and Verkhoyansk Mountains and subduction at Bowers Ridge in the Bering Sea. Herron et al. (1974) refined the ideas of Pitman and Talwani (1972) to include the Kolymski block as a separate plate that may have filled the Paleozoic Arctic Ocean (=Amerasian Basin) and by colliding with the Canadian Arctic Islands, formed the Parry Island fold belt. According to this theory, the Kolymski block was in contact with the North American plate until the Jurassic, at which time it reversed its motion, collided with Siberia along the Verkhoyansk fold belt (Early Cretaceous) and opened the Amerasian Basin in the process (Text-fig. 2). This theory visualizes



TEXT-FIG. 2. Possible Alpha Cordillera subduction according to Herron et al. (1974). Black = plate positions 81 m. y. ago, stippled = plate positions at 63 m. y. ago. Used with permission of authors and the Geological Society of America.

subduction along the Alpha Cordillera, as the expression of northern extension of the Laramide orogeny and crustal shortening to the south.

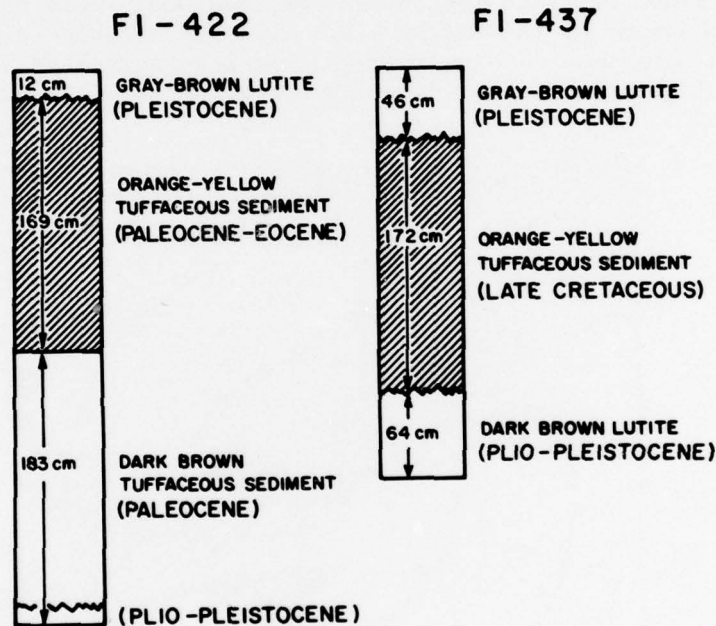
In contrast, earlier, Vogt and Ostenso (1970) proposed that the sketchy magnetic data available suggested to them that the Alpha Cordillera may have been a spreading axis, at least during the Early Cenozoic. More detailed study of magnetic anomalies of the Alpha now available (but unpublished) suggest that the patterns are not related to spreading. As now interpreted, Alpha Cordillera magnetics seem unrelated to typical spreading patterns, nor are they the patterns that are readily interpreted to be associated with subduction (P. Vogt personal communication, 1977). The role of the Alpha Cordillera in Mesozoic and Cenozoic plate tectonics still is to be resolved.

Hopkins (1967) and others (in Hopkins, 1967) have suggested that during the Late Mesozoic-Early Cenozoic interval, the Bering Straits closed free circulation of Pacific and Arctic waters because of a land bridge. According to these ideas it was not until late Miocene that the Bering Straits became intermittently open to provide for Atlantic-Pacific-Arctic interchange. Pitman and Talwani (1972) have indicated that Pacific-Arctic Ocean links are a necessary ingredient of their Arctic Ocean evolution model during this same interval (83-60 m. y.) and do not believe that a bridge could have formed prior to 60 m. y. Evidence summarized in a later chapter supports the idea of some Late Mesozoic-Early Cenozoic Pacific-Arctic Ocean circulation, even if it were indirect (e. g. through the Russian platform Obik Sea) (Text-fig. 3).



TEXT-FIG. 3. Paleogene seaway onto the Russian platform linking Tethys and Arctic Ocean. Adapted from McKenna (1975).

The only Mesozoic sediment known from the Amerasian Basin to-date is from a core recovered from the Alpha Cordillera (Clark, 1974). The sediment is an altered volcanic tuff (Text-fig. 4) and it encloses a rich silicoflagellate-diatom assemblage. The Cretaceous age of the sediment recovered from the crest of the Alpha Cordillera is supportive of the idea that the Alpha was a subduction center at that time. Similarly, the only Early Cenozoic sediment known from the Amerasian Basin was cored from a site on the Alpha Cordillera approximately 100 km from the site of the Cretaceous core (Clark, 1974). The sediment is an altered tuffaceous material (Text-fig. 4) and similar to the Cretaceous



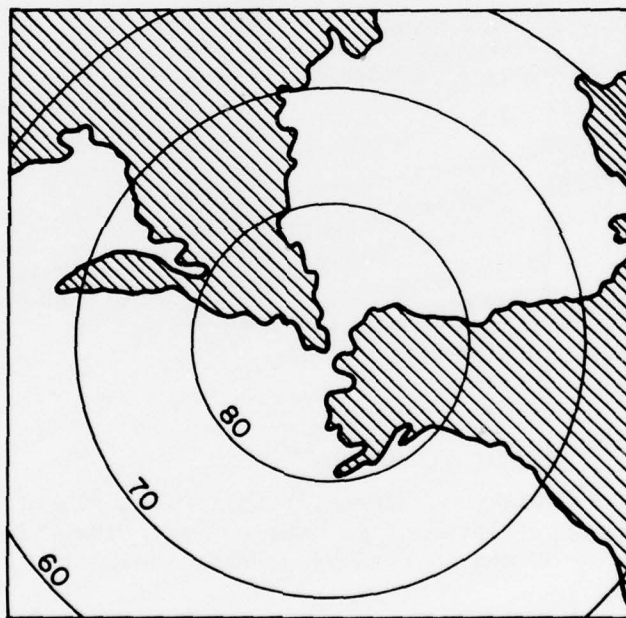
TEXT-FIG. 4. Late Cretaceous and Early Cenozoic sediment in two cores from the Alpha Cordillera. Both sections are slump blocks of older sediment resting on and covered by younger sediment. Modified from Clark (1974).

core, contains a rich silicoflagellate and diatom assemblage. Thus, the only direct record of the Late Mesozoic-Early Cenozoic Amerasian Basin is from two cores of similar lithology and flora, taken 100 km apart on the Alpha Cordillera, one Late Cretaceous and the other late Paleocene.

Specific identification of the silicoflagellates of the two cores indicates that the Cretaceous assemblage has Pacific and Russian affinities (Ling et al., 1973). The Paleocene assemblage has the same taxa as those described from considerably south on the Russian platform, perhaps through a connection similar to that proposed for the Obik Sea (e. g. McKenna, 1975). Only a few endemic Arctic taxa are

suggested. Evidently the late Mesozoic-Early Cenozoic Arctic Ocean circulation was with the Pacific and with the Russian Platform. This could be interpreted as support of the idea of Pitman and Talwani (1972) that no Bering Land Bridge was in place before 60 m. y. ago.

The silicoflagellate assemblage consists of taxa that probably would not survive in water temperatures similar to that which exists in the Arctic at the present. In addition, the paleomagnetic evidence for the Late Mesozoic north pole suggests a Bering Straits position. This position would place parts of the Late Mesozoic-Early Cenozoic Amerasian Basin between 60-70° latitude. (Clark, 1977) (Text-fig. 5). During this same time, if plate motion was compressional, this may have involved movement of the Kolyma block into the Siberian block. Subduction along the Alpha Cordillera has been suggested for this time but there is little firm evidence to support this idea (Text-fig. 2).



TEXT-FIG. 5. Late Mesozoic-Early Cenozoic pole positions for the Amerasian Basin (primitive Arctic Ocean). Modified from Clark (1977).

ARCTIC OCEAN---MID CENOZOIC

Introduction

Between 63 and 40 m. y., extension at the North Atlantic Ridge and its Arctic extension, the Nansen Ridge, opened the North Atlantic and Eurasian Basins. The North Atlantic has grown at least 2-3 cm/yr

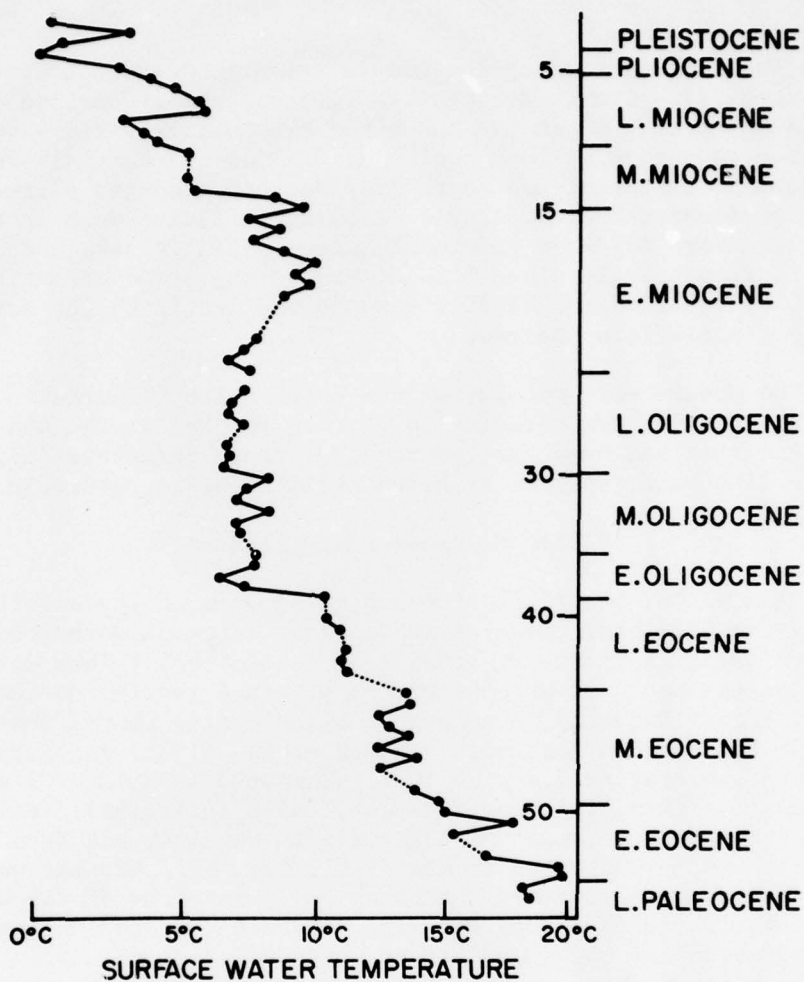
since the Eocene, forming the modern Atlantic Ocean and Eurasian Basin (Text-fig. 1). Growth during this time has almost doubled the size of the deeper Arctic Ocean and has moved the Lomonosov Ridge to its present position as a more or less central ridge for the central Arctic. Subsequent fusion of the North American and Siberian plates effectively restricted north Pacific-Arctic circulation during much of the time. Some land link may have existed between present Alaska and Siberia at least intermittently since ~ 60 m. y. No migration of marine invertebrates from the Pacific through the Arctic to the North Atlantic is known until late Miocene.

The progressive opening of the North Atlantic-Eurasian Basins provided a major new circulation pattern for the Arctic and biologic elements that had been part of the Cretaceous-Paleocene Pacific-Obik-Arctic link were replaced by North Atlantic biota, at least in part.

Middle Cenozoic Paleoclimatology

Related to changing tectonic developments of the Arctic Ocean during the Late Cretaceous-Early Cenozoic interval were profound worldwide climatic changes. Progressive Cenozoic cooling was documented early on the basis of paleobotanical evidence (Wolfe and Leopold, 1967; Dury, 1971). Recently, a number of workers have quantified this cooling for various latitudes. Savin et al. (1975) demonstrated a Cenozoic temperature lowering that culminated in a late Oligocene minimum ($\sim 4^{\circ}$ C marine temperature for high latitudes), followed by a gradual temperature rise until the middle Miocene, and then a cooling that has continued to the present (Text-fig. 6). Surface water temperatures were lowered as much as 10° C in parts of the world. Ingle et al. (1976) agreed that the Oligocene was the "major refrigeration" of the Cenozoic but suggested that this point was reached first ~ 38 m. y. ago, near the Eocene-Oligocene transition. The Miocene temperature dip has been linked to Antarctic glaciation and the resulting southern hemisphere high latitude circulation (Shackleton and Kennett, 1975). Colder climate, corresponding with world wide sea level lowering, apparently correlates very well. Recently, Donn and Shaw (1977) suggested that the Cenozoic cooling of the Earth can be accounted for by the "migration" of continents, without resorting to external causes at all.

It was during this time that the North Atlantic-Arctic circulation was well established. The combination of circulation change, worldwide climatic deterioration and pole location in the central Arctic, lead to the first freezing of the Arctic (Clark, 1977). Whether this occurred during the Oligocene or middle Miocene has not been established. Unfortunately, middle Cenozoic sediment has not been identified from among the Arctic cores available for study. Berggren (1972) and Berggren and van Couvering (1974) have concluded that glaciation in the northern hemisphere was initiated 3 m. y. ago.

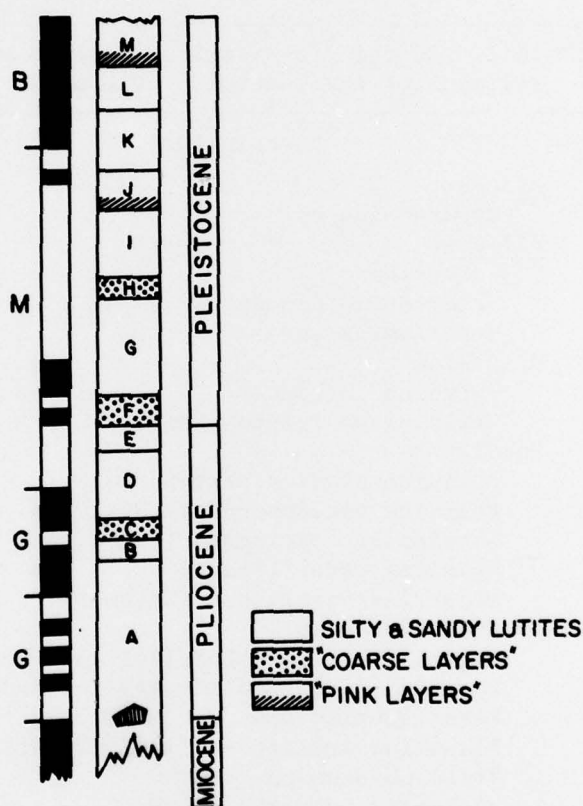


TEXT-FIG. 6. Cenozoic paleotemperature curve from oxygen isotope data for planktic Foraminifera at DSDP sites 277, 279 and 281. Modified from Shackleton and Kennett, (1975).

This conclusion is based primarily on the presence of glacial sediment in Labrador Sea cores taken on Leg 12 of the DSDP. I had made an earlier projection (Clark, 1971) that glaciation may have been underway in the central Arctic as early as 3.5 m. y. Studies now in progress confirm the presence of glacial sediment at 5-6 m. y. in the central Arctic. Whether the glaciation responsible preceded, accompanied or followed the freezing of the Arctic Ocean has not been determined with precision. Magnetic and lithologic interpretation of the oldest glacial sediment suggest that the ice cover had formed by 5-6 m. y., however (Text-fig. 7).

THE LATE CENOZOIC ARCTIC OCEAN

The oldest post-Paleocene sediment identified in the central Arctic Ocean is late Miocene. Miocene, Pliocene, and Pleistocene have been recognized in a number of cores and a relatively widespread stratigraphy for this interval can be recognized. Thirteen lithologic units, ranging in thickness from 2 to 163 cm have been identified in hundreds of cores from most parts of the Alpha Cordillera and Canada Basin margin (Text-fig. 7). The Canadian Basin portion of the Amerasian Basin is a completely different sedimentologic province (Campbell and Clark, 1977)



TEXT-FIG. 7. Stratigraphy of central Arctic Ocean sediment cores showing 13 units recognized over the Alpha Cordillera. Classification and magnetic stratigraphy shown.

and neither the sediment nor very meager fauna is considered here. The uniform nature of the units in the Alpha area, some only a few cm thick, is of considerable importance in correlation of cores and interpretation of paleomagnetic data. Three of the units recognized are characterized

by a high percentage (15-25%) of fine sand size material. These sandy or coarse units have proven to be "key beds" in correlation. The widespread occurrence of these Pliocene-Pleistocene units and their consistency over such an enormous area are factors to be explained. Turbidity deposition, contourities, and glacial rafting have been considered but the processes understood in the formulation of these things are not completely consistent with what is known concerning the sediments. This is a matter of current investigation in our lab.

The Pliocene Foraminifera and ostracode faunas identified from 11 cores is listed on Table 1. The taxa are North Atlantic-Arctic and

Table 1. Benthic fossils from Miocene and Pliocene sediment of the Central Arctic Ocean*

Foraminifera

Miocene

Hyperammina sp.

Pliocene

Textulariina

Cribrostomoides sp.

Hyperammina sp.

Miliolina

Pyrgo sp. B Lagoe

Triloculina frigida Lagoe

Rotaliina

Bolivina arctica Herman

Bolivina pseudopunctata Høglund

Cassidella complanata (Egger)

Eponides tener (Brady)

Fissurina ventricosa (Wiesner)

Fissurina ? sp.

Lagena flatulenta Loeblich and Tappan

Parafissurina fusuliformis Loeblich and Tappan

Parafissurina spp.

Planulina weullerstorfi (Schwager)

Protelphidium sp.

Stetsonia horvathi Green

Valvulineria arctica Green

Ostracode

Pliocene

Cytheropteron bronwynae Joy and Clark

holothurian

Pliocene

Elpidium glacialis Theel

* data from 11 Alpha Cordillera cores

most, probably, are endemic Arctic forms. Two of the four endemic species that dominate the modern benthic fauna are present in the lower Pliocene, as well. This suggests that the most common members of the modern endemic fauna were established before the Pliocene. The lack of Oligocene-Miocene material inhibits further speculation on time of development.

The abundance of glacially rafted sediment throughout the Pliocene portion of the cores and the sparse nature of the fauna supports the idea that the Arctic ice-cover had formed by this time. Evidently, the ice-cover did not inhibit the migration of North Pacific invertebrates across the Arctic into the North Atlantic. Durham and MacNeil (1967) have documented the movement of 69 species of gastropods, 41 species of bivalves, 3 species of echinoids and 1 brachiopod that successfully used the Arctic Ocean as a migration route from the Pacific to the Atlantic during the Late Miocene-Early Pliocene. At the same time fewer species of Atlantic invertebrates (2 gastropods, 12 bivalves, 1 echinoid and 1 brachiopod) moved across the Arctic from the Atlantic to the Pacific.

Probably as the Eurasian-North Atlantic crustal spreading progressed, the changing current patterns encouraged this migration in spite of the ice-cover of the Arctic. Most of the migration probably was across the Arctic shelves rather than through the deeper Arctic. None of the migrants listed by Durham and MacNeil have been found in the central Arctic Pliocene sediment. Alternately, the migration may have included lower latitude crossing, for example, before the central America fusion in the Pliocene.

Pleistocene stratigraphy of the central Arctic consists of 8 units that average 25 cm in thickness and show some consistency throughout the Alpha Cordillera region. Key beds for the Pleistocene include sandy layers (15-25% sand size material) and several "pink" layers that are carbonate-rich. These units are more or less uniformly present over the Alpha Cordillera and appear to be principally ice-rafted sediment (Text-fig. 7).

MODERN FAUNAL AFFINITIES AND ENDEMISM IN THE CENTRAL ARCTIC

Table 2 records the modern paleontologically significant fauna identified in the modern deeper Arctic Ocean. Globorotalia pachyderma clearly dominates all faunal elements and on this basis the modern central Arctic could be designated the G. pachyderma faunal province. Up to 80% of the volume of many bottom samples consist of the shells of this pelagic Foraminifera. Foraminifera are the dominant members of the benthic fauna, as well. Many of the taxa developed by the end of the Pliocene (Table 1); a great number probably are endemic. Modern Arctic sediment is a mixture of glacial and pelagic particles that support a relatively small fauna. Calculation of biomass for 90 Alpha Cordillera faunal stations (including non-paleontologically significant

fauna) by Paul and Menzies (1973) determined $\sim .04 \text{ g/m}^2$ for the 1000-2000 m depth range. This compares with the 5500 m depth range (red clay area) of the mid-Pacific. Low primary productivity in surface waters of both areas is considered the cause of this low figure. Paul and Menzies (1973) also report Shannon-Weaver diversity index figures for the Arctic that show how low the diversity is compared to other of the world's oceans (and at comparable depths). Approximately 25 metazoan groups are present, compared to 35 groups at mid-latitudes. These figures indicate that the Arctic is impoverished, compared to other of the world's oceans. According to Paul and Menzies (1973), 100% of the biomass of the modern Arctic is accounted for as follows:

Benthic Foraminifera	53%
bivalves	27%
sponges	7%
polychaets	5%
all others	8%

It is significant that a high percentage of the organisms constituting the Arctic biomass are potentially paleontologically significant. Data from our work, that of Paul and Menzies (1973) and Tibbs (1967) on taxa that are central Arctic or marginal (Tibbs data), yield 112 benthic and 29 planktic species (total 141) with paleontologic significance (table 2). This compares with 241 total species that are known in the central Arctic region. Thus, almost 60% of the species known have potential paleontologic significance and this 60% constitutes $\sim 75\%$ of the biomass.

Table 2. Pleistocene and modern paleontologically significant fauna from the Central Arctic Ocean

Foraminifera

Planktic

- Globorotalia pachyderma (Ehrenberg)
- Globigerina quinqueloba Natland

Benthic

Textulariina

- Hyperammina sp.
- Trochammina nitida Brady
- Glomospira gordialis (Parker and Jones)

Miliolina

- Cyclogyra involvens ? (Reuss)
- Cyclogyra sp.
- Quinqueloculina akneriana d'Orbigny
- Quinqueloculina arctica Cushman
- *Quinqueloculina seminulum (Linnaeus)
- Quinqueloculina sp. A Lagoe
- Quinqueloculina sp. B Lagoe
- *Quinqueloculina sp. Paul and Menzies

- Pateoris hauerinoides* (Rhumbler)
Pyrgo rotalaria Loeblich and Tappan
 ***Pyrgo williamsoni* (Silvestri)
Pyrgo sp. A Lagoe
Pyrgo sp. B Lagoe
Triloculina frigida Lagoe
Triloculina oblonga (Montagu)
Triloculina rotunda d'Orbigny
 ***Triloculina trihedra* Loeblich and Tappan
Miliolinella chukchiensis Loeblich and Tappan
 **Gordiospira arctica* Cushman
 Rotaliina
Nodosaria cf. *N. doliolaris* Parr
 **Dentalina communis* d'Orbigny
 ***Dentalina frobisherensis* Loeblich and Tappan
Dentalina cf. *D. frobisherensis* Loeblich and Tappan
 ***Dentalina pauperata* d'Orbigny
Lagena cf. *L. flatulenta* Loeblich and Tappan
Lagena gracillima (Sequenza)
 **Lagena mollis* Cushman
Lagena striata (d'Orbigny)
Lagena cf. *L. sulcata* var. *spicata* Cushman and McCulloch
Lagena sp. A Lagoe
Lagena sp. B Lagoe
Lagena sp. C Lagoe
 **Elphidium bartletti* Cushman
Lenticulina sp.
Polymorphina ? sp.
Esosyrinx ? sp.
Oolina apiopleura (Loeblich and Tappan)
Oolina hexagona (Williamson)
 ***Oolina melo* d'Orbigny
Oolina melo d'Orbigny var. A
Fissurina bassensis Parr
 ***Fissurina* cf. *F. marginata* (Montagu)
Fissurina ventricosa (Wiesner)
Fissurina sp. A Lagoe
 **Fissurina* sp. Paul and Menzies
Parafissurina arctica Green
Parafissurina aff. *P. arctica* Green
 ***Parafissurina fusuliformis* Loeblich and Tappan
Parafissurina groenlandica (Stschedrina)
Parafissurina cf. *P. tectulostoma* Loeblich and Tappan
Parafissurina sp. A Lagoe
Parafissurina sp. B Lagoe
Parafissurina sp. C Lagoe
Parafissurina sp. D Lagoe
Parafissurina sp. E Lagoe
 **Bulimina exilis* Brady
Buliminella elegantissima var. *hansonii* Lagoe

*Nonion sp. Paul and Menzies
 Bolivina arctica Herman
 Bolivina cf. B. pseudopunctata Høglund
 Bolivina sp. A Lagoe
 *Bolivina sp. Paul and Menzies
 Buccella frigida (Cushman)
 Episotominella arctica Green
 Epistominella ? sp.
 Stetsonia horvathi Green
 Valvulineria arctica Green
 *Valvulineria horvathi Green
 **Patellina corrugata Williamson
 Protelphidium orbiculare (Brady)
 **Eponides tener (Brady)
 Eponides tumidulus var. horvathi Green
 **Planulina weullerstorfi (Schwager)
 Carsidella complanata (Egger)
 Carsidella fusiformis (Williamson)
 Cassidulina islandica Norwang
 Cassidulina norcrossi Cushman
 **Cassidulina teretis Tappan
 Chilostomella elongata Lagoe
 Ceratobulimina arctica Green
 **Robertinoides chartollensis (Cushman)
 *Buccella inusitata Anderson
 *Polymorphina sp. Paul and Menzies

* = reported by Paul and Menzies (1973).
 ** = reported by Lagoe (1977) and Paul and Menzies (1973).
 All unmarked benthic species from Lagoe (1977).

Ostracoda

Popocopida

Pseudocythere caudata Sars
 Pedicythere neofluitans Joy and Clark
 Krithe "bartonensis" (Jones)
 Parakrithella ? minuta Joy and Clark
 Cytheropteron alatum Sars
 Cytheropteron bronwynae Joy and Clark
 ?Cytheropteron medistriatum Joy and Clark
 ?Cytheropteron nealei Joy and Clark
 Acetabulastoma arcticum Schornikov
 Paracytherois chukchiensis Joy and Clark
 Echinocythereis dasyderma (Brady)

Myodocopida

Polycope inornata Joy and Clark
 Polycope punctata Sars
 Polycope bispinosa Joy and Clark
 Polycope ? arcuous Joy and Clark

Polycope bireticulata Joy and Clark
 Polycope ? moinis Joy and Clark
 Polycope semipunctata Joy and Clark
 Polycope horrida Joy and Clark

data from Joy and Clark (1977)

Bivalvia

*Nucula zophos	*Malletia abyssopolaris
Nucula sp.	*Hyalopectin frigidus
Portlandia intermedia Sars	*Cyclopecten groenlanedecium
Bathyarca frielei Friele	
Pectinidae	
Limatula hyperborea Jensen	
Cuspidaria sp.	

Porifera

*Thenea abyssorum	
Thenea sp.	*Geodia phlegraei
tetxarons	*Polymastia sol
triradiates	*Tentorium semisuberites
Klostose monaxons	

Holothuroidea

**Kolga hyalina Danielssen and Koren
 **Elpidia glacialis Theel
 Myriotrochus sp.

Gastropoda

Limacina helicina Phipps
 *Margarites sp. A

Echinoidea

Pourtalesia jeffreysi Thomson

Crinoidea

*Bathycrinus carpenteri

Ophiuroidea

*fragments

* = reported by Paul and Menzies (1973).
 ** = reported by Gamber (1976) and Paul and Menzies (1973).
 Unmarked species from Gamber (1976).

Plankton collected from ARLIS 1, on
margin of Central Arctic Ocean (Tibbs, 1967)

Silicoflagellate

Distephanus speculum Müller

Radiolarians

**Spongotrochus glacialis* Popofsky
Echinommatleop odermum Jørgensen
Chromyechinus borealis (Cleve)
Plectacantha oikiskos Jørgensen
Phormacantha hystrix (Jørgensen)
Dictyophimus gracilipes (Bailey)
Tetraphormis rotula Haeckel
Tetraphormis triloba Haeckel
Conarachnium profundum (Ehrenberg)
Botryopyle setosa Cleve
Aulacantha scolymantha Haeckel
Aulastrum spinosum Borgert
Aulopathis variabilis Haeckel
Cannosphaera antarctica (Haeckel)
Cadium melo (Cleve)
Coelodecas pygmaea (Haecker)
Protocystis harstoni Murray

Tintinnids

Parafavella gigantea (Brandt)
Ptychocyllis drygalski Brandt
Salpingella acuminata (Claparède and Lackman)

Dinoflagellates

Noctiluca miliaris Suriray
Peridinium pellucidum (Berg)
Peridinium depressum Bailey
Ceratium arcticum (Ehrenberg)

* = also in our collections from the Central Arctic Ocean

NORTH ATLANTIC AFFINITIES

The most important paleontologic species are the Foraminifera and the ostracodes. Fewer mollusks, echinoderms, sponges and protistians complete the list. Determination of endemic species is difficult but at least 50% of the 73 benthic Foraminifera and 70% of the ostracodes species apparently are endemic. Among the non-endemic Foraminifera, 30% have North Atlantic affinities and 10% have Pacific affinities, with 10% undeterminable (Lagoe, 1977). Among the non-endemic ostracodes, 15% have Atlantic affinities, and a single species has been previously recorded from the Atlantic and Pacific (Joy and Clark, 1977). The Atlantic affinity of the modern non-endemic Foraminifera and ostracodes is apparent.

All of the 11 mollusks, echinoderms and sponges that have been identified in our lab also are found in the Atlantic, 4 have been found in the Atlantic and Pacific; none are exclusively Pacific forms.

This strong Atlantic affinity for the modern Arctic invertebrates is not surprising in light of the post-Jurassic crustal plates movements. The Durham and MacNeil (1967) report of strong Pliocene Pacific to Atlantic migrations through the Arctic seems somewhat anomalous.

DEVELOPMENT OF ENDEMISM AND DIVERSITY

Stetsonia horvathi and Epistominella arctica, both endemic benthic Foraminifera, comprise 51% of the central Arctic benthic Foraminifera fauna. Polycope inornata and Cytheropteron brownynae, both endemic species, comprise 50% of the central Arctic ostracode fauna. G. pachyderma, a planktic species, comprises 95% of the total Fauna. The Foraminifera are much more abundant (and diverse) than the ostracodes. These species clearly are the most important in their respective realms (Pl. 1).

All of these species except P. inornata have been found in Pliocene sediment. Thus, the dominant endemic species of the modern fauna were those that were established early.

The diversity of the benthic Foraminifera was measured by Lagoe (1976). He used several indexes all of which indicated that the diversity of the fauna was less than that of faunas from comparable depths at lower latitudes. Such measurements have not been calculated for the ostracodes but the data indicate that similar results would develop.

This low diversity probably is best explained by the youthfulness of the Arctic ecosystem. Probably the initiation of the modern ecosystem coincided with the initial freezing of the Arctic Ocean. The time of this event can only be fixed at post-Eocene to late Miocene from direct evidence although the world-wide climate considerations summarized in an earlier chapter indicate that the Oligocene or middle-late Miocene, may have been the time. If these assumptions are correct, then the maximum amount of time for initiation of factors leading to the Arctic ecosystem (i. e. permanent ice-cover) would be between 39 and 24 m. y.; the minimum (i. e. middle-late Miocene) would be ~ 18 m. y. If the assumption is made that the ice-cover formed after the dramatic temperature lowering rather than during the lowering, a maximum time of ~ 30 m. y. and a minimum of ~ 15 m. y. become reasonable. All other of the world's oceans had assumed their status and a great deal of their size much earlier than this. Either figure (30 or 15 m. y.) indicates that the Arctic is among the youngest of the world's major ecosystems. Ekman (1953) suggested that the higher the taxonomic rank of an endemic fauna, the longer it must have been isolated in its province. Uniqueness begins and ends with the species level in the Arctic, confirming from another line of evidence, a young ecosystem. If the 15 m. y. (Middle Miocene) figure is correct, then this may be the minimum time interval necessary in the development of a major world ecosystem, even to a youthful stage.

The Miocene-Pliocene Pacific migration across the Arctic to the Atlantic (Durham and MacNeil, 1967) apparently had little effect on the central Arctic invertebrates. This event is not recorded in the central Arctic nor are the taxa involved important in the Pliocene. The ice-cover of the Arctic had formed by that time. Either the immigrant species crossed the broad shelves without serious ice-interference or, if such a migration is not possible under such conditions, then the chronology or geography of the event should be reconsidered.

The modern central Arctic fauna with paleontological significance should be designated the Globorotalia pachyderma - Stetsonia horvathi faunal province. More than 95% of most samples studied from the floor of the central Arctic are composed of these two species, most often with G. pachyderma constituting most of the 95%.

SUMMARY

Late Mesozoic crustal plate motion between North America and Eurasia in the Arctic was compressional and this activity permitted good marine connections between the North Pacific and the Arctic. In addition, marine connections (via the Obik Sea) onto the Russian platform were in existence. Spreading from the Nansen Ridge (~ 63 m. y.) restricted Pacific circulation and consequent movement produced the modern Atlantic-Arctic circulation patterns. As a result of this crustal activity, the biologic affinity of the central Arctic has changed from one of strong Pacific-Russian affinity during the Late Mesozoic-Early Cenozoic to a strong affinity with the North Atlantic today. As the marine affinities changed, the development of the Arctic ice-cover between 30 and 15 m. y. ago, added a new and unique factor to the developing ecosystem. The dominant Arctic endemic faunal components developed at least by the Pliocene. Two species of Foraminifera and two species of ostracodes account for 50% of their respective faunas. G. pachyderma and S. horvathi account for 95% of the volume of many Arctic samples. These two endemic species constitute the principal components of the G. pachyderma - S. horvathi Arctic faunal province.

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CENTRAL ARCTIC MICROFAUNA

- Fig. 1 - 4, Globorotalia pachyderma (Ehrenberg), 1-2, core FL 224, seg. 8T, Late Miocene, x125; 3-4, core FL 235, seg. 23-1, Recent, x125.
- Fig. 5 - 7, Epistominella arctica Green, core FL 110, seg. 18-1, Recent; 5, x400, 6-7, x350.
- Fig. 8 -10, Stetsonia horvathi Green, core FL 218, seg. 14-1, Recent; 8, x250, 9-10, x300.
- Fig. 11-13, Cytheropteron bronwynae Joy and Clark, core FL 423, seg. 16-1, Recent, 11, 12, exterior right valve, 13, oblique view left valve, x110.
- Fig. 14-16, Polycope inornata Joy and Clark, core 423, seg. 16-1, Recent; 14, interior left valve, 15-16, exterior left valve, x135.
- Fig. 17-18, Limacina helicina Phipps, core 434, seg. 21-1, Recent; 17, umbilical view, x200; 18, apical view, x100.

All specimens in Depository, University of Wisconsin-Madison, SEM mount UW 1678.

