

A PALEOBIOGEOGRAPHIC STUDY OF PALEOZOIC-EARLY CRETACEOUS FOSSIL FAUNA AND FLORA OF THE ARCTIC ALASKA TERRANE

by

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Abstract: This report provides a synoptic overview and digital database of the Arctic Alaska terrane faunas and floras of Cambrian to Early Cretaceous age in order to better constrain speculation as to the paleogeographic origin of the terrane, host to the largest petroleum province in North America. At present the two most popular models for its origin include: 1.) a counter-clockwise rotation out of the Canada Basin (commonly referred to as the “Windshield-Wiper” model) originating from a putative late Mesozoic rifting event; and 2.) an Eurasian origin whereby it represents a rift fragment of the Siberian paleocontinent (or associated pericratonic terrane) or less likely of Baltica.

Cambrian-early Late Devonian (Frasnian) marine faunas show a strongly consistent Siberian affinity, although a few occurrences of Cambrian trilobites with North American affinities have also been previously noted (A.R. Palmer recently indicates these earlier alleged North American trilobite faunas should be re-examined, as more modern work shows closely similar forms to exist as well in Siberia). Early Mississippian marine faunas have very strong linkages with faunas from the western and mid-continent portions of North America, but this may reflect the broad, cosmopolitan condition of marine faunas of this time as many of these species names are also recognized in the Russian Platform. The Late Mississippian was apparently a time of greater provincialism, and it is during this time that strong Eurasian linkages are again noted among the brachiopods (especially in the presence of gigantoproductids, unknown anywhere in Laurentia) and in Angaran Floral Realm plants found in the region near Kurupa Lake. Little is known of Pennsylvanian faunas, but they, too, also seem to be Eurasian in character. Permian marine fauna are distinctly of Arctic Permian (or Boreal) cast, but need more intense study at the species level. The low diversity (or near absence) of Early Permian fusulinids (in contrast to their relative abundance in the Canadian Arctic Islands) is consistent with a Siberian origin (or alliance) as they are also almost totally lacking there during this time.

Late Triassic bivalves, brachiopods, and to a lesser degree the ostracodes indicate a very strong alliance with northeastern Siberia. Likewise, Early Jurassic bivalves (notably the species *Otapiria tailleuri* Imlay which is extremely abundant in Sinemurian strata across the breadth of this terrane) suggest closer ties with northeastern Siberia (where it is present), rather than with the Canadian Arctic Islands (where it is absent). By Middle Jurassic time, bivalves and ammonite faunas of the Arctic Alaska terrane are very closely

similar to those in Arctic Canada (and southern Alaska as well), suggesting that this terrane had more or less attained its present geographic position relative to North America. Late Jurassic and Early Cretaceous marine faunas, likewise, indicate a nearly identical taxic content with that found in adjoining Arctic Canada and the northern part of the Cretaceous Interior Seaway.

In summary, this overview of paleobiogeographic affinities of the Arctic Alaska terrane fossil biota suggest that it represents a continental margin sequence that was rifted away from, or in close proximity to, the present-day northern or northeastern margin of the Siberian continent. Much further work remains to be done with determining the paleobiogeographic affinities and ecology of Arctic Alaska terrane faunas, and numerous suggestions are made herein as to areas which I feel could be addressed that would further help resolve the paleogeographic origin of this terrane.

INTRODUCTION

Paleobiogeographic evidence provides one of the strongest lines of evidence in determining the former paleogeographic positions of accreted terranes, and hence, is most critical in the assessment of the origins and former paleogeographic setting of Arctic Alaska. Only two previous synoptic overview publications have previously been published on Arctic Alaska terrane paleobiogeographic affinities (Blodgett and others, 2002a; Dumoulin and others, 2002), one (the former) restricted to an overview of Paleozoic (primarily Ordovician-Devonian) megafauna and the other (the latter) to the affinities of Late Cambrian-Ordovician conodonts. While both papers favor a Siberian origin or affinity for the Arctic Alaska terrane, Blodgett and others (2002a) favored a Devonian or younger age for this rifting event, while Dumoulin and others (2002) favor a rifting event that occurred in the Neoproterozoic. I feel that the consistent stable sequence stratigraphic setting (in the original sense of the term as established by Sloss, 1963 and 1972) of the Arctic Alaska terrane, consistent with that of other large continental blocks of northeastern Siberia and the consistent paleogeographic reconstructions of a northern land source for this terrane, indicate that this terrane was probably attached to Siberia or to another peri-Siberian terrane probably through much of the Phanerozoic, with rifting occurring as late as Late Triassic or even Early Jurassic time. Several additional abstracts have also been published which relate to the paleobiogeographic affinities of Arctic Alaska terrane faunas (Blodgett and others, 2002b; Clough and Blodgett, 2002 and 2006; Dumoulin and Harris, 2006; Silberling, 1970) as well as one earlier paper (Dumoulin and others, 1998).

Support for the counterclockwise origin of the Arctic Alaska terrane by counterclockwise rotation of Arctic Alaska terrane away from the Canadian Arctic Island can be found in Grantz and others (1982), Mull (1984), and TAILLEUR and BROSGÉ (1970).

Sources for this data compilation include a complete inventory of published papers and abstracts on Arctic Alaska terrane paleontology and stratigraphy (see Appendix A, which is a bibliography of all paleontological and ancillary stratigraphic papers on the Paleozoic

and Mesozoic of the Arctic Alaska terrane) as well as access to the vast collection of unpublished, internal reports (the so-called E&R reports) made by paleontologists of the USGS dating back to 1898. Many of the latter reports are now available to the general public via my government-funded paleontological database on Alaska (URL: www.alaskafossil.org). I have also benefited from seeking the advice of a number of other paleontologists (most of whom are now retired) who have had significant experience working fossils from or closely allied with those of the Arctic Alaska terrane. These workers include: A.K. (Gus) Armstrong, Norman J. Silberling, J.T. Dutro, Jr., Benita L. (Bonnie) Murchey, Robert L. Ravn, E.W. (Wayne) Bamber, Michael Orchard, Bernard Mamet, David M. Rohr, A.J. Boucot, Michael R. Sandy, and Terry Poulton.

This report also includes two appendices: 1.) Appendix A, which presents an updated bibliography of all paleontological literature pertaining to the Arctic Alaska terrane (as well as ancillary stratigraphic papers containing detailed faunal and/or floral lists); and 2.) Appendix B, which is an Excel spread sheet providing information (geographic location, fossil taxa, biogeographic affinities, etc.) for paleobiogeographically significant (or potentially biogeographically significant) localities in the Arctic Alaska terrane. The age summaries used in the latter are summarized using the current geological time scale utilized in Gradstein and others (2004).

ARCTIC ALASKA TERRANE

The Arctic Alaska terrane, equivalent here to the Arctic Alaska superterrane of Moore (1992), extends the entire length of the Brooks Range in northern Alaska, and includes to the west the Seward Peninsula and St. Lawrence Island, as well as the Chukotka block of northeastern Siberia. To the east the terrane also includes rocks of the British and Barn Mountains in northernmost Yukon Territory. The Arctic Alaska terrane incorporates a number of previously defined terranes (or subterranes)(i.e., North Slope, Endicott Mountains, De Long Mountains, Hammond, and Coldfoot terranes – see Fig. 1 for their distribution). Following the suggestion of Karl and Mull (1993) against the proliferation of terrane names in the Brooks Range and Arctic Coastal Plain, I will not employ or use these “subterranes” here, as their usage commonly results in confusion, especially in transitional areas where subterrane boundaries are still in debate.

HISTORY OF PALEONTOLOGICAL RESEARCH IN ARCTIC ALASKA

Paleontological work in Arctic Alaska (north of the Arctic Circle) has primarily been the domain of U.S. Geological Survey (USGS) paleontologists from the earliest days of research well up into the early 1980's. Research on the part of USGS in this part of Alaska received a major input of energies and money during the exploration of the NPRA-4 area during the years 1944-1953. Many thousands of fossil collections were gathered during this period and submitted for analysis and identification, occupying many

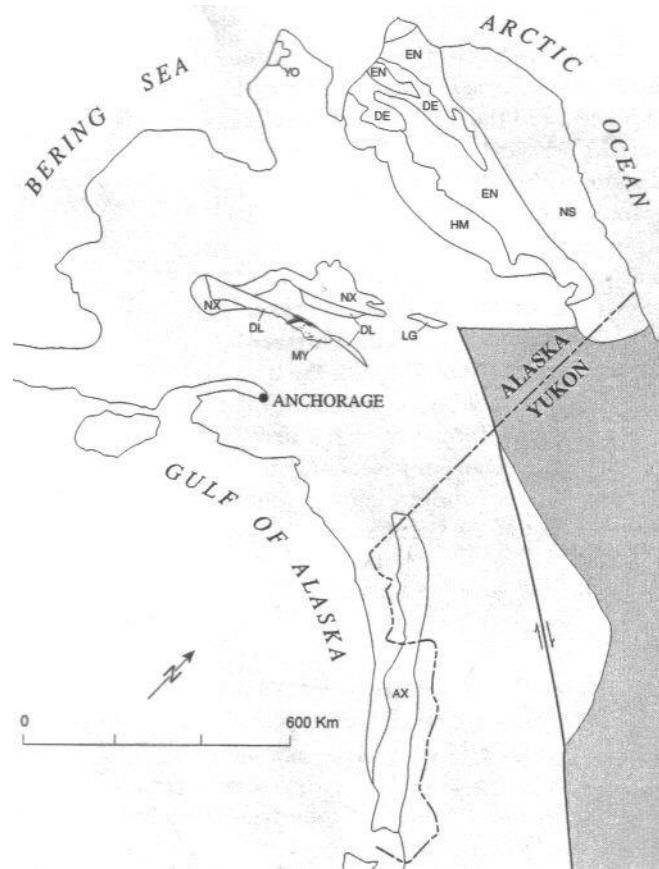


Figure 1. Map showing distribution of Arctic Alaska terrane (and its subterrane) as well as other accreted terranes of southern Alaska which show paleobiogeographic affinity with the Arctic Alaska terrane. Arctic Alaska terrane: HM—Hammond subterrane, DE—De Long subterrane, EN—Endicott Mountains subterrane, NS—North Slope subterrane, YO—York subterrane; Farewell terrane: NX—Nixon Fork subterrane, MY—Mystic subterrane, DL—Dillinger subterrane; LG – Livengood terrane; and AX—Alexander terrane (from Blodgett and others, 2002a).

full-time positions on the part of members of the Branch of Paleontology and Stratigraphy of the USGS. Many papers (especially Professional Papers) were released on various components of the fossil invertebrates and microfossils. Paleontologists who really stand out in terms of the published work from these early days include Ralph W. Imlay (Jurassic-Lower Cretaceous mollusk worker), Harlan R. Bergquist (Paleozoic-Mesozoic Foraminifera specialist) and Helen Tappan (Mesozoic Foraminifera) specialist. Subsequently other “stars” of research on northern Alaska fauna were August (Gus) K. Armstrong (Upper Paleozoic corals) and Bernard Mamet (Upper Paleozoic Foraminifera and microflora), who although not a USGS member, collaborated with the research efforts in northern Alaska as a consultant. Unfortunately several other individuals who were assigned more of less full-time to work on Arctic Alaskan faunas were not anywhere as productive, and in some cases produced next to nothing after 40 or more

years. Subsequently, much of our knowledge of the paleontology and biostratigraphy of Arctic Alaska has been rather uneven. Much work is especially needed on Upper Paleozoic brachiopods, which is the dominant megafossil group in rocks of that age. Although specialists were assigned to their study, no monographs, or even smaller papers with systematic descriptions were ever produced, creating a major gap in our knowledge for this time interval. This stands out even more when compared to the same interval in the Arctic regions of the former USSR, where probably upwards of 100+ papers exist on the late Paleozoic record of this group. A number of Soviet brachiopodologists had been assigned to work on this group, and hence stratigraphic correlation, paleoecology, and paleobiogeographic insights for this group are much more advanced than in North America. In general, knowledge of the paleontological framework of the Arctic Russian Paleozoic and Mesozoic is more advanced than that of the Arctic regions of North America.

Beginning in the early 1980's, a number of oil company paleontologists began to publish on Arctic Alaska paleontology, but this trend eventually slowed down somewhat with the decline of funding for paleontological research work as the global price of oil dropped. At the same time, work was also slowing down at the USGS, and came to sudden stop with the 1995 destruction of the Branch of Paleontology and Stratigraphy, resulting in the immediate loss of most paleontologists who had specialized on Alaska fossils. Since that time, only a few paleontological workers have remained active in Arctic Alaska faunas, including Will Elder (Cretaceous mollusks), Anita G. Harris (Paleozoic conodonts), and I (Paleozoic and Mesozoic megafossils). All of us had formerly been associated with the Paleontology and Stratigraphy Branch of the USGS, but now all act as independent consultants.

CAMBRIAN

Cambrian strata were unknown from the Arctic Alaska terrane until the 1970's. Even now, they are known from only a few scattered areas within thick platform carbonate sequences extending across the length of western, central, and the northeastern Brooks: 1. south of Mt. Angayukaqraq, Baird Mountains C-1 quadrangle, western Brooks Range; 2. in the western Doonerak anticlinorium, Wiseman C-3 quadrangle and nearby on the north flank of Snowden Mountain, Chandalar D-6 quadrangle, both in the central Brooks Range; and from the base of member 8 of the Nanook Limestone, Mt. Michelson C-3 and C-4 quadrangles, northeastern Brooks Range. Cambrian strata are known further to the east in the dominantly siliciclastic succession of the Neroukpuk Formation (within the volcanic and carbonate member) in both Mt. Michelson and Demarcation Point quadrangles, northeastern Brooks Range.

Cambrian faunas globally are dominated by trilobites, followed secondarily by brachiopods that start to play a more significant role by the Middle Cambrian. Archaeocyathids are a major faunal group in carbonate buildups of the Lower Cambrian and are useful for paleobiogeographic studies. This group is still unreported in the Arctic Alaska terrane; however, this group is common in the cratonic North American rocks of east-central Alaska.

Trilobites – References to Cambrian trilobites from the Arctic Alaska terrane are found in the following references: Blodgett and others (1986), Dumoulin and Harris (1987, 1994), Dutro and others (1972, 1984a, b), and Palmer and others (1984). Cambrian trilobites from Arctic Alaska have attracted considerable attention due to the paleobiogeographic affinities, which surprisingly include both strongly Siberian and North American signals.

The volcanic and carbonate member of the Neroukpuk Formation has yielded two collections of Cambrian trilobites, both of North American affinities. The oldest locality is from the east bank of the Marsh Fork of the Canning River in the Mt. Michelson A-4 quadrangle where numerous specimens of a single species of an olenellid trilobite were recovered. This species was identified by A.R. Palmer who reported on the collection as follows (from Dutro and others, 1972):

“This is a good Lower Cambrian collection with North American affinities. It contains all growth stages of a single olenellid that is assignable to *Olenellus* s.s. The species is not like any of those from the Great Basin or from western Canada, but it is close to *O. praenuntius* described by Cowie from the Canadian Arctic. *Olenellus* s.s. is found primarily in the upper part of the Lower Cambrian and, at least in western North America, in beds above those with archeocyathids where we have any faunal control on fossils of both groups.”

This small collection is currently deposited in the USGS fossil storage facility in Denver, Colorado, and A.R. (Pete) Palmer indicated to me recently (phone conversation of Sept. 1, 2006) that this olenellid should definitely be re-examined from a paleobiogeographic point of view. He said that Siberian olenellids are now well known, but differ considerably from those found in Laurentia (North America), and he recommended that the best candidate to do this would be Dr. Mark Webster at the University of Chicago.

The second Neroukpuk trilobite collection is from near the Aichilik River in the Demarcation Point B-3 quadrangle. A.R. Palmer (in Dutro and others, 1972) reported three trilobites as being present: a ptychoparioid, an agnostid identified as *Geragnostus* sp., and a form that is most like species of *Saratogia*, the latter genus indicative of a middle Franconian (mid-Late Cambrian) age. Palmer indicated the collection is “definitely a fauna with American affinities.”

Middle Cambrian [of Amgan (or early Middle Cambrian) age] trilobites from the central Brooks Range are known from two separate localities, both containing faunas of distinctly Siberian Platform character. The first locality (discussed in great detail by Dutro and others, 1984a) is represented by a single collection discovered in 1981 in the Doonerak anticlinorium in the Wiseman C-3 quadrangle. It yielded three trilobite taxa: *Kootenia* cf. *K. anabarensis* Lermontova, cf. “*Parahmania*” lata Chernysheva and *Pagetia* sp. (see Fig. 2 for illustrations of these specimens). This fauna was considered to have strong affinities with faunas from the Siberian Platform and correlated with the Early/Middle Cambrian transition interval in Siberia by Palmer and others (1984) and with the Amgan (early Middle Cambrian) Stage of Siberia by Dutro and others (1984a, b). Somewhat similar faunas are also reported from Amgan age strata of the Nixon Fork subterranean of the Farewell terrane in southwestern Alaska [Palmer and others, 1985;

Babcock and Blodgett, 1992; St. John and Babcock, 1997]. The second locality was discovered in 1983 on the north flank of Snowden Mountain in the Chandalar D-6 quadrangle, and was noted to also be strongly Siberian in affinities by Palmer and others (1984):

“This sample contains numerous specimens of *Kounamkites* cf. *K. frequens* Chernysheva and less common specimens of *Chondranomocare* cf. *C. speciosum* M. Romanenko.

Kounamkites, widespread in the earliest Middle Cambrian beds of the northern Siberian Platform, is the nominal genus of the *Kounamkites* Zone of the Amga Stage. It has a distinctive cranidial morphology that is not known in any North American Middle Cambrian trilobites. *Chondranomocare*, a widespread Asiatic corynexochid trilobite, is also found in the *Kounamkites* Zone.

The *Kounamkites* Zone fauna and the trilobites closest to those from the Doonerak collection come from the open shelf facies of the Siberian Platform, a depositional context consistent with that of the Alaskan samples. However, no similar trilobites are found in the North American Cordilleran open shelf facies of comparable age. The strong to unequivocal Siberian affinities of the central Brooks Range trilobites raise interesting questions about both Cambrian biogeography and post-Cambrian tectonics.”

Upper Cambrian trilobites were discovered in 1985 from two localities in the lower part of member 8 of the Nanook Limestone (Blodgett and others, 1986a, b) in the Mt. Michelson quadrangle. This formation that had previously been thought to be of Devonian age (Dutro, 1970), but has subsequently undergone significant age revision (Blodgett and others, 1986a, b). The first locality (USGS loc. D3455-CO) yielded a single species identified by A.R. Palmer as *Plethometopus armatus* (Billings). The second locality (USGS loc. D3458-CO) yielded only two poorly preserved trilobites identified by Palmer as *Plethometopus?* sp. According to Palmer (in Blodgett and others, 1986a, p. 7):

“The paleobiogeographic affinity of the Lower Cambrian fauna is with shallow, warm water carbonate platform sites around the North American craton.”

In a recent phone conversation with A.R. Palmer (Sept. 1, 2006), he indicated to me that he felt these collection should be re-examined as smooth forms similar to *Plethometopus* occur in Siberia, which could possibly be confused with true *Plethometopus*. If such a modern re-investigation was to take place, he suggested the best person to currently undertake this would be Dr. Steve Westrop at the University of Oklahoma.

A single Late Cambrian agnostid trilobite was reported and illustrated by Dumoulin and Harris (1987) from their measured section at Mt. Angayukaqsaq (formerly known as Hub Mountain) in the Baird Mountains C-1 Quadrangle. The trilobite was identified by A.R. Palmer as *Homagnostus* sp., indicative of a late Dresbachian to early Franconian age. No comments have appeared in publication in regards to the paleobiogeographic implications, if any, of this taxon (Note: A.R. Palmer in a recent phone conversation in August, 2006, also affirmed the agnostic trilobite reported here has no paleobiogeographic significance). The same sample yielded the monoplacophoran mollusk *Pelagiella*, identified by John Pojeta, Jr., who also thought it indicative of a shallow-water depositional environment.

Brachiopods – References to Cambrian brachiopods from the Arctic Alaska terrane are found in Dutro and others (1972 and 1984a) and Dumoulin and Harris (1987). The acrotretid brachiopods *Acrothele* sp., *Linnarssonina* sp., and *Prototreta* sp. were reported by Dumoulin and Harris (1987) from Middle Cambrian (probably late Middle Cambrian) strata south of Mt. Angayukaqsaq, Baird Mountains Quadrangle, western Brooks Range. Dutro and others (1984a, b) report the articulate brachiopod *Nisusia* and the acrotretid brachiopod *Linnarssonina* sp. from Middle Cambrian rocks in the Doonerak anticlinorium, central Brooks. Dutro and others (1972) report slightly metamorphosed articulate brachiopods that are most probably *Billingsella* from Upper Cambrian strata exposed near the Aichilik River in the Demarcation Point Quadrangle. The limited taxonomic data currently available for Cambrian representatives of this group (most of which are broadly distributed on several continents) in the Arctic Alaska terrane is of no major utility in helping to resolve the paleobiogeographic affinities of the terrane at this time.

Summary of Cambrian paleobiogeographic affinities of Arctic Alaska terrane:

Trilobites provide the only firm evidence at hand for the paleobiogeographic affinities of the Arctic Alaska terrane during Cambrian time. Results to date are rather mixed, with both Siberian and North American affinities shown at differing localities. The absence of any Cambrian age Siberian-like trilobite faunas in the Canadian Arctic Islands suggests that the rotational model of Arctic Alaska away from the latter region is not viable. Both Siberian and North American-like trilobite faunas have been reported from the Cambrian carbonate platform succession of the central and northeastern (Shublik Mtns) portion of the Brooks Range. The non-carbonate platform Cambrian succession of rocks placed in the Neroukpuk Group in the northeastmost Brooks Range has been interpreted by several Brooks Range geologists to indicate that possibly the Neroukpuk Group rocks had a separate, more North American origin than those found to the west in the Brooks Range. One problem that I find with the suggestion is the fact that Devonian strata directly overlying the Neroukpuk Group (i.e. Ulungarat Formation of Anderson (1981) bears distinctly non-North American-like megafossils. Certainly more work is in order, but the presence of distinctly Siberian-like Cambrian trilobite faunas indicates that the Arctic Alaska terrane was closely associated with Siberia (especially eastern Siberia), but possibly was close enough to the North American craton to periodically demonstrate some faunal alliance with northwestern margin (in terms of present-day coordinates) of North America. It should also be emphasized here that A.R. (Pete) Palmer, the Cambrian trilobite specialist who was responsible for nearly all the Cambrian trilobite identifications from northern Alaska now recommends that the few collections previously thought to indicate North American affinities (i.e., the Lower Cambrian olenellid and species of *Plethometopus* from the Upper Cambrian of the Shublik Mountains) should be re-examined as similar taxa are now known from Siberia, and that these forms may prove to be more closely related to these Siberian taxa.

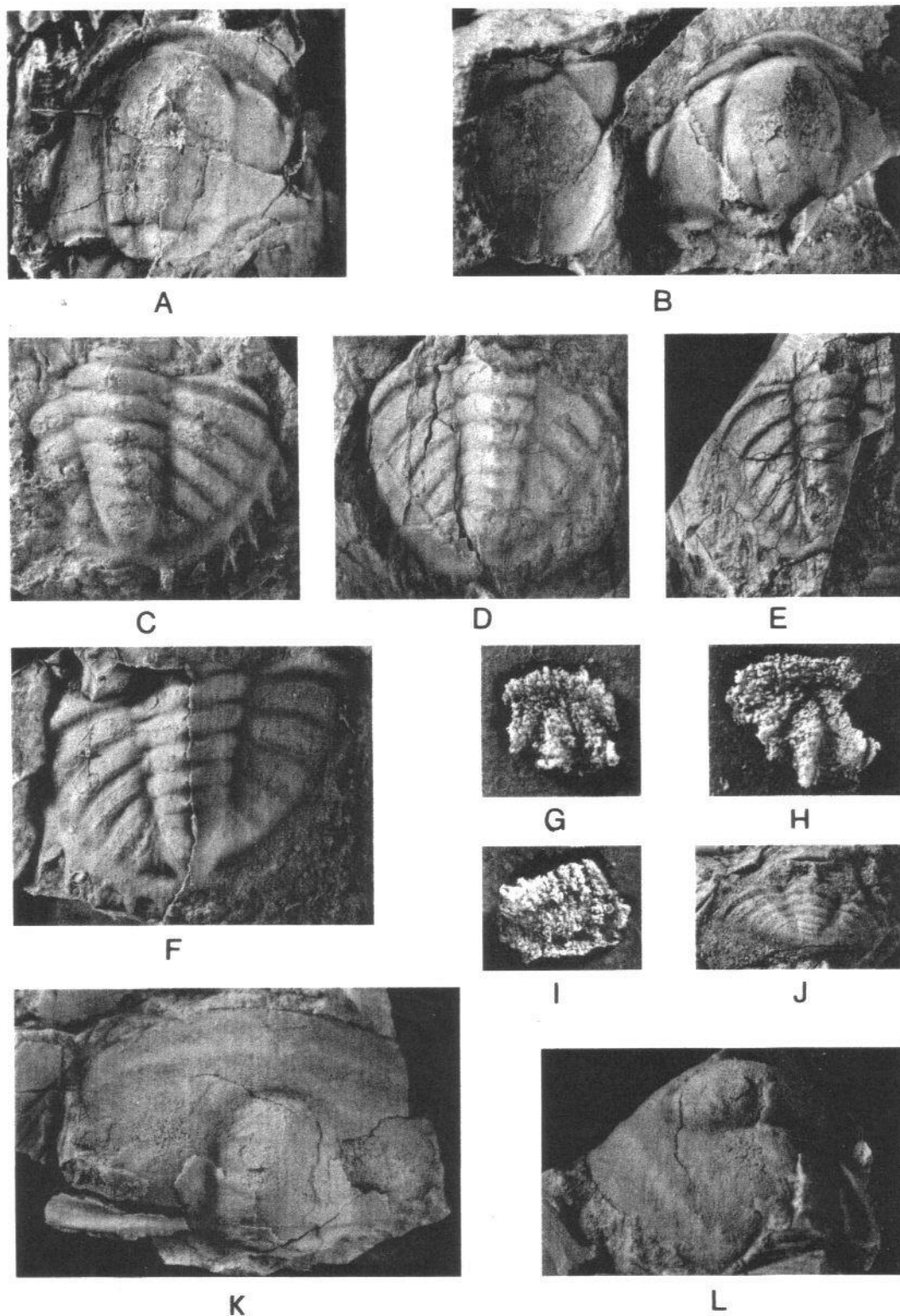


Figure 2. Views of the various trilobites present in the Early Middle Cambrian (Amgan age) beds exposed in the Wiseman C-3 quadrangle (from Dutro and others, 1984)

Recommendations for future study:

- 1.) Relocating and gathering large megafossil collections from the two Cambrian fossil localities cited in Dutro and others (1972) in the volcanic and carbonate member of the Neroukpuk Formation in the Demarcation Point and Mt. Michelson quadrangles. One locality was cited as being of Early Cambrian age, and additional trilobite material from here (plus an extensive search for archaeocyathids – very useful for paleobiogeography) is highly desired. A.R. Palmer (who originally identified the material) now suggests the original collection, consisting of a single olenellid specimen should be re-examined. He recommends Dr. Mark Webster as the leading authority on current olenellid taxonomy. The other locality is Late Cambrian age, but again additional trilobite material is highly desired. Both localities were collected by field geologists during routine geologic mapping, and larger, more taxonomically diverse collections would be valuable.
- 2.) Gathering additional megafossil (trilobite) collections from the Upper Cambrian strata of the basal part of member 8 of the Nanook Limestone in the Mt. Michelson C-3 quadrangle. I made the initial discovery collections of Cambrian fossils from the Shublik Mountains at the type section (Nanook Creek) of the Nanook Limestone in 1985. However, my field efforts at those localities consisted of only a few hours, and I strongly believe that additional scouting and collecting from different horizons will give us a much broader picture of the overall paleobiogeographic affinities of the Late Cambrian fauna from here. Collections made from here were identified by Michael Taylor and A.R. (“Pete”) Palmer as belonging to *Plethometopus*, a Laurentian genus. However, Palmer in a recent phone conversation, indicated that very similar smooth taxa are known in correlative age beds of Siberia, which may have been easily confused earlier on. He suggested a careful re-examination of the material by Dr. Steve Westrop, who he considers the leading expert on trilobites of this age in North America.
- 3.) Further collecting of megafossils (trilobites) from Middle Cambrian strata on the north flank of Snowden Mountain in the Chandalar D-6 quadrangle. Several trilobites of distinctly Siberian Platform affinities were reported from here by Palmer and others (1984). However, this was limited to only two species, and further searching here and in nearby strata will undoubtedly augment our knowledge of this important fauna.

ORDOVICIAN

Like the Cambrian, Ordovician strata were unknown from the non-Seward Peninsula portion of Arctic Alaska terrane until well into the 1970's when conodont analyses started to indicate the presence of rocks of this age in the Brooks Range. For the most part, Ordovician strata in the Brooks Range have been moderately metamorphosed, making recognition of megafossils difficult. However, a few scattered areas exist within thick platform carbonate sequences extending across the length of western, central, and

the northeastern Brooks where relatively well-preserved Ordovician megafossils have been recovered [notably in the Shublik Mountains (Mt. Michelson C-3 and C-4 quadrangles) and near Mount Angayukaqsaq in the Baird Mountains C-1 quadrangle]. Ordovician rocks (representing all three Series) have long been known from the York Mountains area of the western terminus of the Seward Peninsula (Collier, 1902; Knopf, 1908; Kindle, 1911; Steidtmann and Cathcart, 1922; Sainsbury, 1969; Sainsbury and others, 1971). This area is especially remarkable in that the megafossils are well preserved, and much work still remains to be done on various faunal groups represented here.

Brachiopods – Lower Ordovician brachiopods have been reported from the York Mountains of the western part of the Seward Peninsula (Sainsbury, 1969 – identifications by R.J. Ross, Jr.), however, only in the form of a faunal list containing the following forms: *Apheoorthis* n. sp., *Finkelburgia* n. sp., closest to *F. bellatula*, probable rhynchonellid, and a probable orthid. Little can be said paleobiogeographically regarding this small fauna.

Brachiopods are also known from Upper Ordovician strata of the York Mountains in the western part of the Seward Peninsula, but their faunal content is so far known only from faunal lists (Potter, 1984; Potter and others, 1988a, b; also Ormiston and Ross, 1979), the most frequently cited genera being *Austinella* (represented here by a new undescribed species), *Plectocamara*, *Lepidocyclus*, and *Monomerella*.

The pentameroid brachiopod *Tcherskidium unicum* (Nikolaev, 1968) is present in Late Ordovician (Ashgillian) carbonates exposed near Mt. Angayukaqsaq (formerly known as Hub Mountain) in the northwestern Brooks Range (Blodgett and others, 2002a). These specimens are from Irv Tailleux's field locality 66ATr82.3, collected in 1966 from about 200 ft (~60.8 m) above the base of a carbonate unit in the Baird Mountains C-1 quadrangle (lat. 67°44.15' N, long 159°27.5' W). The occurrence of the genus *Tcherskidium* was also noted from this locality in Blodgett and others (1992b). Earlier, in an E&R report by J.T. Dutro, Jr., dated 5/29/1968, these specimens were assigned to *Conchidium* cf. *C. alaskense* Kirk and Amsden (a species known from the Late Silurian of southeastern Alaska), and hence, thought to indicate a Ludlow (Late Silurian) age. This resulted in the miscorrelation of these beds [considered to be part of the Baird Group of Tailleux and others (1967)] with the Silurian. *Tcherskidium unicum* (Nikolaev, 1968), the type species of *Tcherskidium*, was originally described based on specimens collected in the Kolyma River basin of northeastern Siberia (see Fig. 3.6 for illustration of a Siberian specimen of this taxon), and has been subsequently reported from the basin of the Lower Taimyr River in central Taimyr (Nikiforova, 1989; Cocks and Modzalevskaya, 1997; Modzalevskaya, 2003). The Taimyr specimens, based on their illustrations, appear to me to represent a separate new species, probably conspecific with *Tcherskidium* n. sp. from the Shublik Mountains.

Upper Ordovician (Ashgillian) brachiopods are known from the uppermost part of member 8 of the Nanook Limestone in the Shublik Mountains in the Mt. Michelson C-3 quadrangle (Blodgett and others, 1988b, 2002a). Most notable among the brachiopods

are two large pentameroids. The first, identified *Tcherskidium* n. sp. (Figs. 3.1-5) appears to be conspecific with specimens of *Tcherskidium* illustrated from the Taimyr Peninsula

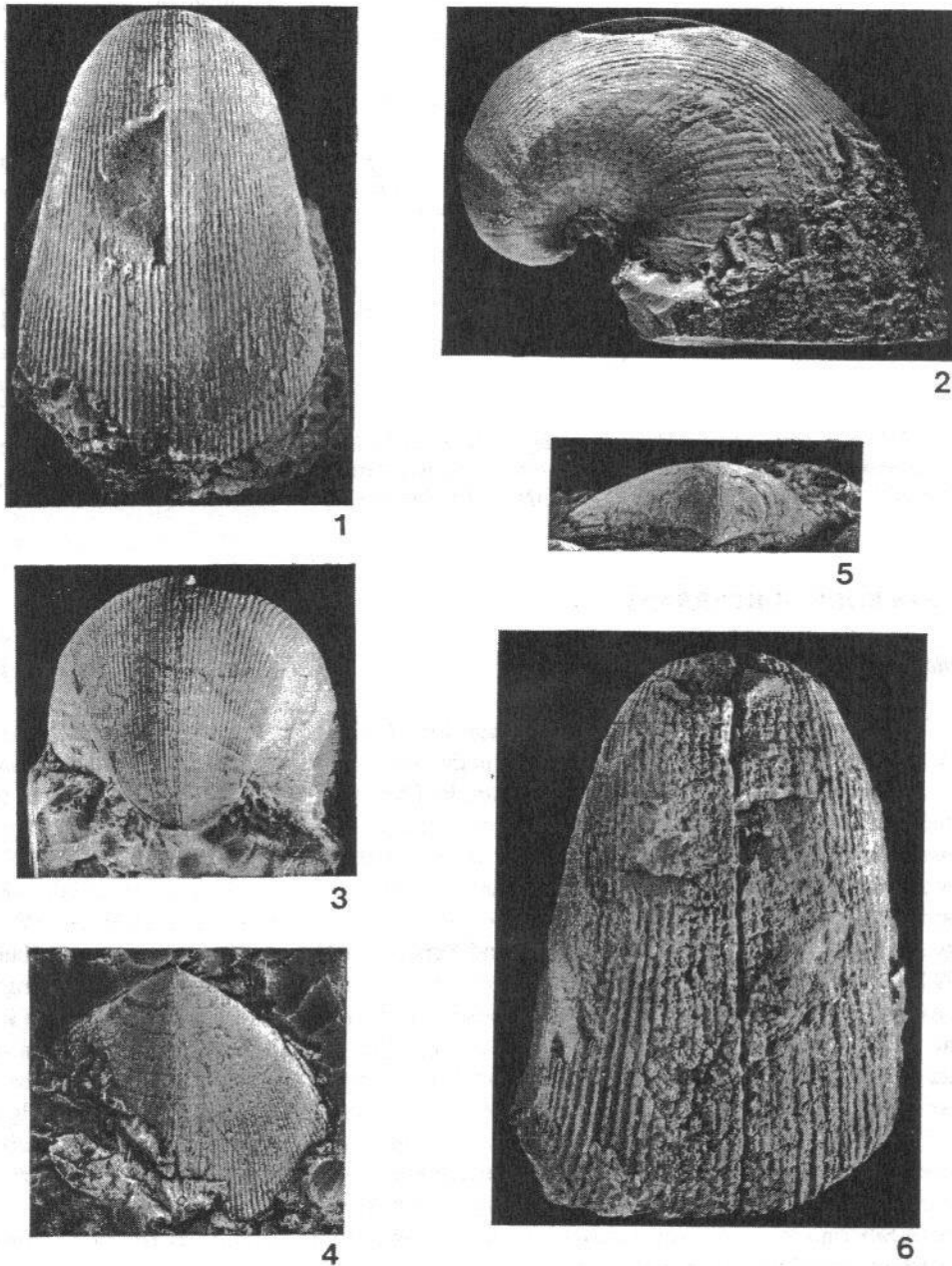


Figure 3. 1-5, *Tcherskidium* n. sp. from the uppermost beds (Ashgillian) of the Nanook Limestone, Shublik Mountains, Mt. Michelson C-3 quadrangle. 6, *Tcherskidium unicum* (Nikolaev, 1968) from Upper Ordovician (Ashgillian) strata on the Ina River, Kolyma region, northeastern Siberia (all views from Blodgett and others, 2002a).

of Siberia under the name *Tcherskidium unicum* (I don't think these Taimyr specimens are conspecific with the original Kolyma form). The genus *Tcherskidium* according to Sapelnikov (1985) is restricted to the Ashgillian of northeastern USSR (Kolyma and

Chukotka) and, possibly, southern Kazakhstan. Recently, the genus has been reported by Rong and Han (1986) from middle Ashgillian strata of the Jiangxi Province, east-central China. The second pentameroid, *Eoconchidium* sp. (Fig. 4.1-3), represents a genus which has previously been reported only from the Ashgillian of northeastern Siberia (type species, *E. indigiricum*, from the Kolyma region) and Kazakhstan.

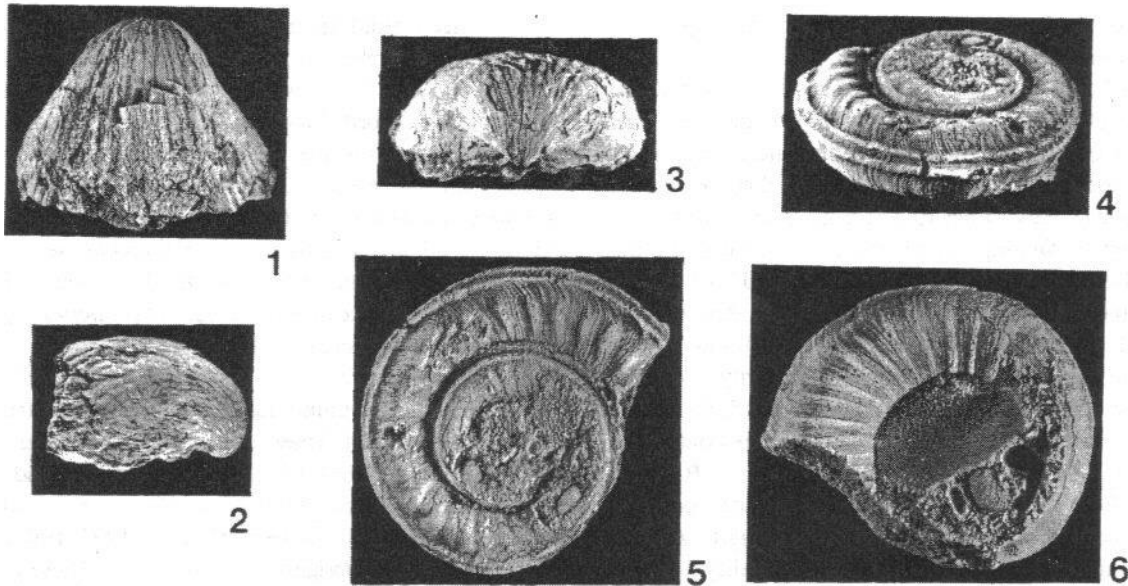


Figure 4. 1-3, *Eoconchidium* sp. from the uppermost beds (Ashgillian) of the Nanook Limestone, Shublik Mountains, Mt. Michelson C-3 quadrangle. 4-6, *Siskiyouspira* sp., also from the uppermost beds (Ashgillian) of the Nanook Limestone, Shublik Mountains, Mt. Michelson C-3 quadrangle (all views from Blodgett and others, 2002a).

Gastropods – Upper Ordovician (Ashgillian) gastropods are extremely common in the York Mountains (Don River area, Teller B-4 quadrangle) of the Seward Peninsula. Sainsbury and others (1971) provided lengthy faunal lists based material identified by Ellis Yochelson. More recently, this fauna became well documented (Rohr and Potter, 1987; Rohr, 1988; and Rohr and others, 2003). Rohr and Potter (1987) recognized a new gastropod operculum, which they named *Rousseauspira teichert* n. gen., n. sp. Rohr (1988) described the greater bulk of this well-preserved silicified fauna, which contained a number of new species including: *Helicotoma blodgetti*, *H. robinsoni*, *Ecculiomphalus? potteri*, *Pachystrophia spiralis*, *Raphistoma tellerensis*, and *Trochonemella reusingi*. This fauna displayed a remarkable similarity noted by Blodgett and others (1992b) to the Ashgillian gastropod fauna described by Rohr and Blodgett (1985) from the Lone Mountain area of McGrath quadrangle in west-central Alaska (part of the Nixon Fork subterrane of the Farewell terrane), which is now thought to be of Siberian origin (Blodgett and others, 2002a). Rohr and others (2003) established a new genus and species, *Alaskadiscus donensis* (see Figs. 5.1-7), based on a form which had earlier been identified as *Tropidodiscus* aff. *T. subacutus* (Ulrich, 1987) in Rohr (1988). This species

is also present in the Lone Mountain fauna of the Farewell terrane (Blodgett and others, 1992b, Rohr and others, 2003).

Upper Ordovician (Ashgillian) gastropods are also known from the uppermost part of member 8 of the Nanook Limestone (Blodgett and others, 1988b), most notable being *Siskiyouspira* sp. (Figs. 4.4-6). The genus is known only from the Farewell terrane of southern Alaska and the Eastern Klamaths terrane of northern California. Also present are *Ectomaria* cf. *E. prisca* (Billings) and *Maclurites* cf. *M. manitobensis* (Whiteaves).

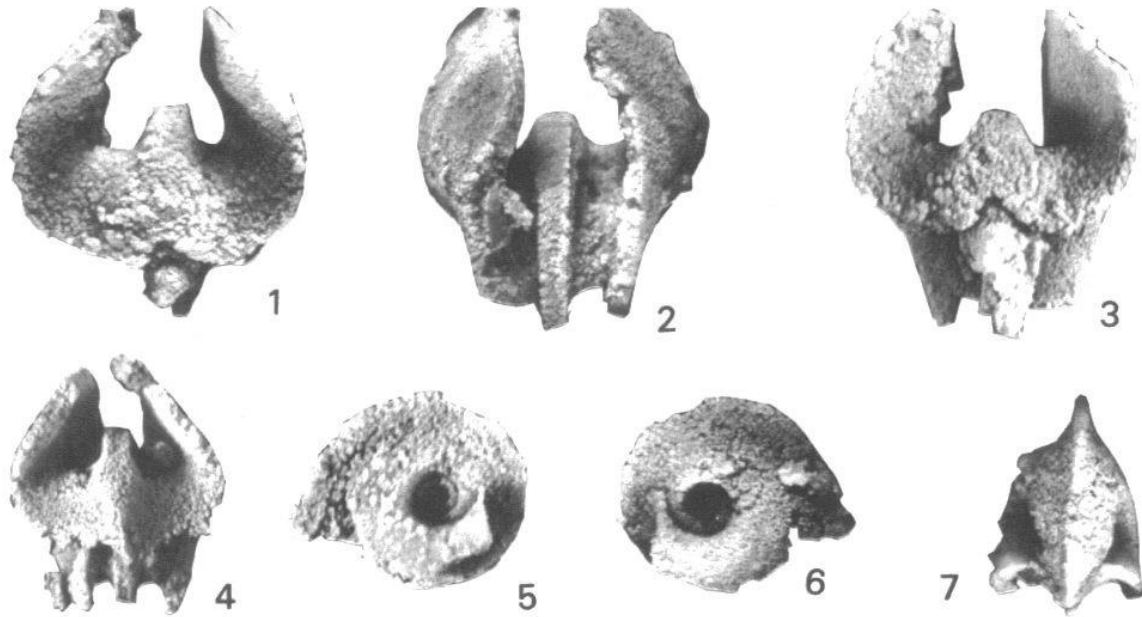


Figure 5. The gastropod *Alaskadiscus donensis* Rohr, Frýda, and Blodgett, 2003 from the Late Ordovician (Ashgillian) of the Seward Peninsula (from Rohr and others, 2003).

Corals – Siberian and/or Russian affinities are also indicated for Upper Ordovician corals from the York Mountains (Robert J. Elias, 1998, written commun.). Elias wrote the following (our brackets, quote taken from Blodgett and others, 2002a, p. 283):

“With regard to Seward [Peninsula] biogeography, the only possible useful information I can provide at this time is based on collections 68-ADu-16 (USGS 6746-CO) and 66-ASn-442 (USGS 6026-CO), both from the same horizon situated near the base of the Ordovician-Silurian section at Hill 760, about 1 mile west of Don River, Seward Peninsula, Alaska (Sainsbury et al., 1971, p. C55-C56, fig. 3). Oliver (in Oliver et al., 1975, p. 23, table 2) identified *Bighornia* sp.; in my opinion this is an undescribed new species of *Bighornia*. It differs all known species of the genus in having a circular cross-sectional shape throughout ontogeny, rather than subcalceoloid or modified subcalceoloid form. It resembles three species, which also have a cardinal septum that becomes thin and decreases in length during intermediate ontogenetic stages: *Bighornia patella* (Wilson, 1926), which occurs widely in Richmondian strata within the Red River-Stony Mountain Province of North America,

Bighornia orvikui Kaljo, 1960, from the Ashgill of Estonia, and *Bighornia* sp. of Sytova, 1979, from the Boorsky Subhorizon of the Ketsky Horizon (Ashgill) in the Morkoka River basin of the Siberian Platform. It may be closest to *Bighornia* sp. of Sytova, in having a very large columella.”

Cephalopods – Ordovician cephalopods are very common in the York Mountains of the western part of the Seward Peninsula, and a number of publications have been focused at least in part to their study (Flower, 1941, 1946, 1968a, b, 1970; and Miller and Kummel, 1945); however, despite the attention the cephalopods have received, little information is available as to their paleobiogeographic implications.

Trilobites – Early Ordovician trilobites from the York Mountains on the Seward Peninsula were documented by Ross (1965), who noted the following taxa as being present: *Triarthrus?* sp., *Hystricurus? sainsburyi* n. sp., *Nileus* cf. *N. armadillo* (Dalman), genus and species indeterminate, and a pygidium suggestive of *Bathyurellus*. Subsequently, Ormiston and Ross (1979, p. 57) noted: “...trilobite fauna of Nova Zemlya includes all the Lost River genera except *Triarthrus* and suggests a close faunal tie between Novaya Zemlya, Alaska and eastern Balto-Scandia in the Early Ordovician.” Even later, Adrain and others (2003, p. 562) in a study of two trilobite families represented in the Lower Ordovician of Nevada and Utah assigned the *Hystricurus? sainsburyi* Ross, the species established by the Ross from the Seward Peninsula, to a previously established Siberian trilobite genus *Tersella* Petrunina, 1973, known only from the Siberian Platform. Adrain and others (2003, p. 562) also indicated that much of the remainder of Ross’s (1965) described trilobite fauna from the Lower Ordovician of the York Mountains also suggested strong Siberian affinities.

Ormiston and Ross (1979) pointed out the occurrence of the trilobite genus *Monorakos* in Upper Ordovician strata of the York Mountains, western Seward Peninsula, suggesting close linkage of the latter region with what they termed the “Siberia-Kolyma continent” because this genus had been reported previously only from the Siberian Platform, Taimyr, New Siberian Islands, Kolyma, and Chukotka. The Seward Peninsula *Monorakos* was recognized to represent a new species, named *Monorakos kledos* by Ormiston (1978), based on material he collected along the Don River.

Holloway (2004) in a syoptic treatment on the subfamily Monorakinae (which includes the genus *Monorakos*) gave their stratigraphic range as Caradoc-Ashgill and their known geographic distribution was limited to the Siberian Platform, Taimyr, the Russian Far East and the Seward Peninsula of Alaska (see Fig. 6), areas which he believed to be the Ordovician part of the palaeocontinents of Siberia and Arctida.

Lower Ordovician trilobites are also known from the uppermost part of unit 8 of the Nanook Limestone in the Shublik Mountains (Blodgett and others, 1986a, b), and represented by a number of hystricurid species which have been identified by Michael Taylor as *Hystricurus? sainsburyi* Ross, *Hystricurus* cf. *H.?* sp. E of Ross (1951), and *Hystricurus* sp. Taylor’s certain identification of the species *Hystricurus? sainsburyi* Ross suggests close affinity of the Nanook hystricurids with the Lower Ordovician trilobite fauna of the York Mountains.

Upper Ordovician (Ashgillian) trilobites were present in collections I made in the uppermost part of unit 8 of the Nanook Limestone in the Shublik Mountains. I had passed these specimens on to Allen R. Ormiston (trilobite expert, formerly of Amoco Petroleum Company) for study, but his subsequent poor health has prevented further study on his part. Some of these specimens were very well preserved and deserving of taxonomic study.



Figure 6. Map showing all known location of Upper Ordovician monorakine trilobites. Note the restriction of this group to Siberia and the Seward Peninsula (map from Holloway, 2004).

Ostracodes – Jean Berdan in Blodgett and others (1988) identified the leperditicope ostracode genus *Sibiritia* Abushik from Ashgillian strata of member 8 of the Nanook Limestone in the Shublik Mountains. This is the only known occurrence of an otherwise Silurian ostracode genus known only from the Llandoveryan (early Silurian) of Siberia (reported by Abushik (2003) from the regions of Kolyma and the Taimyr Peninsula).

Chitinozoans – Sven Laufeld in Carter and Laufeld (1975, p.462) stated that “It is evident that the Middle and Late Ordovician chitinozoans of the Baltic area and the North Slope of Alaska display such a strong affinity that they belong to the same chitinozoan faunal province.” He made this statement based on the recovery of chitinozoans from a number of samples of argillaceous rocks from Ordovician-Silurian intervals in wells along the Barrow Arch. In light of the relatively small amount of published literature on Ordovician chitinozoans in general, it seems probably premature to comment whether or not these affinities could also be made with other Ordovician chitinozoans from other parts of the Circum-Arctic region (i.e., Siberia, Canadian Arctic Islands).

Graptolites – Ordovician graptolites have been reported from a number of localities in the Arctic Alaska terrane including the York Mountains of the western Seward Peninsula (Ross, 1967; Sainsbury, 1969), from the the Deceit Formation on the northern Seward Peninsula (Ryherd and Paris, 1987; Ryherd and others, 1995); from the Lisburne Hills (Grantz and others, 1983), and from the Baird Mountains (Tailleur and others, 1973; Carter and Tailleur, 1984). However, due to their general cosmopolitan character, they provide no paleobiogeographic information needed to help resolve the paleogeographic origin of the Arctic Alaska terrane.

Conodonts – Ordovician conodonts from the Arctic Alaska terrane have been listed (and illustrated in many instances) in the following papers: Blodgett and others (1988b); Dillon and others (1987); Dumoulin and Harris (1987, 1994); Dumoulin and others (2002); Harris and Repetski (1987); Repetski and others (1987); and Sainsbury and others (1971). The only definitive overview of Ordovician conodont paleobiogeography of the Arctic Alaska terrane is that of Dumoulin and others (2002) who recognize both Siberian and Laurentian affinities in Ordovician conodont faunas from this terrane. They recognized four time intervals characterized by strongly Siberian elements: the early Arenig, the late Arenig-early Llanvirn, latest Llanvirn-early Caradoc, and middle (?) Ashgill; and suggested that these intervals coincided approximately with global sea-level highstands. In their Ordovician collections from the Arctic Alaska, they noted that Laurentian province species outnumbered what they termed “Siberian-Alaskan” province species.

Summary of Ordovician paleobiogeographic affinities of Arctic Alaska terrane:

Ordovician fossils from the Arctic Alaska terrane consistently show strong affinities with coeval faunas from Siberia as well as with the Nixon Fork subterrane of the Farewell terrane of southwestern Alaska [Blodgett and others (1992b, 2002a,b); Dumoulin and others (1998, 2002); Ormiston and Ross (1979); Rohr and others (2003); and Holloway (2004)]. This trend seems to be consistent for both Lower and Upper Ordovician fauna, and no distinctive North American (Laurentian) endemics have been identified beyond doubt from among the fossil megafauna.

Recommendations for future study: Two primary areas for future studies on Arctic Alaska terrane Ordovician paleobiogeography come to mind. Both of these areas stand out because the nature of preservation of shelly fossils is remarkably good to excellent:

- 1.) The York Mountains at the western terminus of the Seward Peninsula contain an extremely complete succession of Ordovician strata with well-preserved fossils. Highly provincial faunas have already been noted in parts of the Lower Ordovician, as well as in the Upper Ordovician (here enhanced by local silicification of the megafossils). Portions of the fauna have been characterized (i.e., gastropods and trilobites), but much work remains to be done with both of these groups, as well as the brachiopods which have received only slight attention in the form of abstracts (Potter, 1984, Potter and others, 1988a, b).

- 2.) The uppermost Ordovician (Ashgillian) beds of the redefined member 8 (see Blodgett and others, 1988b and 1992a) of the Nanook Limestone in the Shublik Mountains (Mt. Michelson C-3 and C-4 quadrangles) contain a rich megafossil assemblage consisting of brachiopods (especially rich in large pentameroids), trilobites, ostracodes, and tabulate corals. As time was limited in the collection of these megafossils, undoubtedly further time and effort will greatly enhance the taxonomic diversity of the fauna. I have already published preliminary notes on the pentameroid brachiopods (Blodgett and others, 1988b, 2002a) and other selected elements of the associated fauna. Further systematic work is planned with Dr. Rong Jia-yu (Nanjing Institute of Palaeontology & Geology, Nanjing, China) to formally describe the pentameroid brachiopods. Trilobites were also present in the fauna (some of which were very well preserved) and deserving of taxonomic study. I had passed these specimens on to Allen R. Ormiston (trilobite expert, formerly of Amoco Petroleum Company) for study, but his health now precludes him from undertaking further study with this material. I am told that this collection is probably now deposited in the University of Oklahoma Geology Department Museum collections (where most of Amoco's invertebrate collections were ultimately donated). The material is now probably available for further study upon request from the curator of the collections.
- 3.) Hystricurid trilobites were reported by Blodgett and others (1986a) from Lower Ordovician beds of the Nanook Limestone in the Shublik Mountains. In view of the Siberian affinities now suggested for *Hystricurus? sainsburyi* Ross from the Seward Peninsula (placed by Adrain and others, 2003 in the genus *Tersella*), efforts should be extended to have the Shublik hystricurids examined in further detail. My collections were submitted to Michael Taylor (USGS trilobite expert) who made several minor comments on these collections, but nothing further was ever done by him on the material. These collections are housed in the USGS warehouse at their Denver Federal Center facility, and could be easily retrieved on loan through K.C. McKinney, who is now curator of the collections.

SILURIAN

Bona-fide Silurian age strata are known from only a few places within the Arctic Alaska terrane. The central York Mountains on the western tip of the Seward Peninsula has yielded a number of Silurian shallow-marine fossil collections (mostly brachiopods, rugose and tabulate corals) and faunal lists for these strata can be found in Steidtmann and Cathcart (1922), Sainsbury (1969), Sainsbury and others (1971), and Ormiston and Ross (1979). Fossil fauna in the section suggest that only strata of probable Wenlockian-Ludlovian age are represented here, which directly overlie Upper Ordovician strata, with only short hiatus of missing basal Silurian (Llandoveryan and possibly much of the Wenlockian) age strata. At Cape Deceit on northern coast of the Seward Peninsula, Ryherd and Paris (1987) established the Deceit Formation for a sequence of Ordovician-Silurian carbonate base-of-slope apron sequence strata that has been recrystallized under

lower greenschist facies conditions. Middle to Late Silurian age conodonts were reported (but no faunal lists given) from the middle limestone member of this unit. The Deceit Formation succession was considered by its authors to represent a deep-water correlative to the coeval platform carbonate succession exposed to the west in the York Mountains.

The Skajit Limestone of the southern Brooks Range was long held to be Silurian in age, based on the occurrence of the pentameroid brachiopod *Conchidium?* sp. [identified by Edwin Kirk in Mertie (1925, p. 232) and Smith and Mertie (1930, p. 131] from the north fork of the Chandalar River in the central Brooks Range. The locality bearing this locality was Mertie's 23AMt53, which he described as being on a "tributary of W. Fork of N. Fork of Chandalar River, entering from south, about 6 mi. from confluence of W. Fork of N. Fork of N. Fork Chandalar River. About ¾ mi. upstream from mouth of tributary." (USGS E&R report by Edwin Kirk, dated January 2, 1924). Its location was shown on the then currently available topographic map base in Mertie (1925, Plate VI). The site was revisited by W. Brosgé in 1960 and shown as locality 9 in Brosge and Reiser (1964). Kirk's assignment of *Conchidium?* sp. was suggested by J.T. Dutro, Jr. to be in error (based in part on a recollection of Mertie's locality by W.P. Brosgé – his locality 60ABe346), and that the specimens mentioned belonged questionably to the Middle Devonian genus *Stringocephalus*. I recently asked my former Ph.D. advisor, Arthur J. Boucot, the world's leading expert on pentameroid brachiopods, to examine the plate showing these specimens in Smith and Mertie (1930, Pl. 16A, shown herein as Fig. 7). He concurs with the earlier assessment of Kirk, and suggests that these specimens belong to either the Silurian pentameroid genus *Kirkidium* or the related genus *Conchidium*. I find no fault with his assessment, but also suggest that possibly the specimens may also represent the Ashgillian (latest Ordovician) pentameroid brachiopod genus *Tcherskidium*, which is found at a number of sites in the Ashgillian of the Arctic Alaska terrane. Silurian megafauna may be present at a number of places in carbonate rocks that have been assigned to either the Skajit Limestone or Baird Group across the length of the southern Brooks Range, but their presence may be difficult to ascertain due to the metamorphism or highly recrystallized nature of much of these rocks. Churkin (1973, p. 17) and C.W. Merriam and J.T. Dutro, Jr. in Tailleux and others (1967, p. 1352) mentions the presence of pentameroid brachiopods of Silurian age in limestone questionably mapped as Skajit Limestone in the northeastern part of the Baird Mountains. I was able to examine the specimens in question and found them rather to represent an Ashgillian (late Late Ordovician) pentameroid brachiopod, *Tcherskidium unicum* (Nikolaev, 1968) (see Fig. 3.6 for an illustration of a Siberian specimen of this species). Dumoulin and Harris (1987) briefly mention the presence of Silurian age dolostones in the Squirrel River and Sheep Creek-Mt. Angayukaqsaq area in the Baird Mountains quadrangle. Silurian conodonts were noted, as well as halysitid corals, stromatoporoids and the Silurian brachiopod *Conchidium* cf. *C. alaskense* Kirk and Amsden (identified by J.T. Dutro, Jr.). As noted above the *Conchidium* has been re-examined and identified as the Ashgillian (late Late Ordovician) brachiopod *Tcherskidium unicum* (Nikolaev, 1968). Other Silurian localities bearing megafossils in the Brooks Range include middle to late Early Silurian graptolites (identified by Claire Carter) from the Doonerak anticlinorium in the central Brooks Range (Repetski and others, 1987).

Silurian rocks are absent in both the Shublik and Sadlerochit Mountains, where Late Ordovician strata are disconformably overlain by late Early Devonian (Emsian) strata (Blodgett and others, 1988b, 1992).

A belt of relatively deep-water Ordovician-Silurian siliciclastic rocks were apparently situated to the north of the present-day Brooks Range along the crest of the Barrow Arch (extending from near Barrow east to the Prudhoe Bay), where they were represented by dark-gray slates of the basement complex recovered from well cores (Carter and Laufeld, 1975). Lower Silurian (late Llandoveryan) graptolites and Middle Ordovician to Silurian chitinozoans were reported by these authors at varying depths.

Brachiopods – The Silurian section in the Don River (York subterrane of the Arctic Alaska terrane) on the Seward Peninsula yielded brachiopods. Ormiston and Ross (1976, p. 54) reported the genus *Pentamerus*. Steidtmann and Cathcart (1922) listed, and Sainsbury and others (1971) mentioned the presence of brachiopods from the lowest part of the Silurian section along their Don River section which were identified by A.J. Boucot and J.T. Dutro, Jr as *Pentamerus* sp., *Pentamerus*? sp. and *Conchidium*? sp. According to Boucot, (opinion cited in Sainsbury and others, 1971, p. C56) the Silurian brachiopods were thought by him to indicate either a late Wenlockian (late Middle Silurian) or Ludlovian (Late Silurian) age (see also Sainsbury 1969). No definitive paleobiogeographic conclusion can be made other than that these brachiopods suggest a general assignment to the North Silurian Realm (Boucot and Blodgett, 2001). Brachiopods from the highest Silurian collection at Don River were later identified as *Atrypa* sp., “*Camarotoechia*” sp. cf. “*C.*” *winiskensis* Whiteaves and *Strophonella* sp. (J.T. Dutro, Jr. in Oliver and others, 1975, p. 25).

Smith and Mertie (1930, Pl. 16A on p. 137) illustrate a slab containing numerous specimens of a large pentameroid brachiopod identified by Edwin Kirk as *Conchidium*? sp. from the north fork of the Chandalar River in the Chandalar D-5 quadrangle. On the basis on this occurrence, the Skajit Limestone was assigned an “upper Silurian or highest middle Silurian” age. I asked Art Boucot, a leading expert on Silurian brachiopods to examine the photograph and he concurred that the specimen was probably a pentameroid brachiopod belonging to either the genus *Kirkidium* or the related *Conchidium*. Providing this taxonomic assignment is correct, the only paleobiogeographic conclusion that could be ascertained is that it belongs to the North Silurian Realm (Boucot and Blodgett, 2001). I would also like to comment that it is possible that these brachiopods could also belong to the genus pentameroid genus *Tcherskidium* of Ashgill (late Late Ordovician) age, common elsewhere in Ashgill strata of the Arctic Alaska terrane. This locality on the Chandalar River should be relocated and new additional material collected to confirm its proper taxonomic assignment and age.



Figure 7. Photo from Smith and Mertie (1930) showing large pentameroid brachiopod specimens identified by Edwin Kirk as *Conchidium?* sp. from the north fork of the Chandalar River in the Chandalar D-5 quadrangle. On the basis on this occurrence, the Skajit Limestone was then assigned an “upper Silurian or highest middle Silurian” age. These specimens were subsequently re-identified as belonging to *Stringocephalus?* sp. (a Middle Devonian terebratuloid brachiopod) by J.T. Dutro, Jr. Arthur J. Boucot and I believe these specimens are pentameroid brachiopods, and hence most likely suggestive of a Late Ordovician (Ashgillian)-Silurian age. This is an important locality to revisit and recollect in the future [shown as locality 9 on the map of Brosgé and Reiser (1964)].

Corals – Rugose and tabulate corals are very common in the Silurian rocks represented in the Don River section in the central York Mountains (faunal lists given in Steidtmann and Cathcart, 1922; Sainsbury, 1969; Sainsbury and others, 1971; Oliver and others, 1975; and Ormiston and Ross, 1979). By the far the most thorough treatment is that of Oliver and others (1975), which presents a detailed faunal list (Table 4 - with 28 separate taxa listed) and also provides many illustrations of some of the taxa present. According to Oliver and others (1975, p. 25), the coral collections from the Silurian part of the Don River section indicated a late Wenlockian(?) to Ludlovian age range. In addition to the Seward Peninsula Silurian occurrence, Oliver and others (1975, p. 26) reported a single collection of Silurian corals from the eastern Brooks Range from a locality in the Arctic A-1 quadrangle (68 deg. 09’N; 144 deg. 17.3’W). This latter collection contained only

two taxa (*Striatopora* sp. and *Stauria* sp.) and was suggested to be most likely of Ludlovian age. No overall paleobiogeographic affinities were suggested by Oliver and others (1975) for Silurian corals of Arctic Alaska (or elsewhere in Alaska).

Graptolites – Silurian graptolites occurrences are reported from the Arctic Alaska terrane in Carter and Laufeld (1975), Grantz and others (1983), Repetski and others (1987), and Lane and others (1995). However, in view of the highly cosmopolitan nature of Silurian graptolites, these faunas have no role to play in trying to better place the origins of this terrane.

Summary of Silurian paleobiogeographic affinities of Arctic Alaska terrane:

Our current knowledge of Silurian megafaunas of the Arctic Alaska terrane is still too poor to address the question of its proper paleobiogeographic affinities. The limited data at hand indicates that it belongs to the North Silurian Realm (see Boucot and Blodgett, 2001), but to which of its constituent regions still requires additional further collection and faunal analysis. The genera reported to date are consistent with what one would find in either Siberia or the Canadian Arctic Islands.

Recommendations for future study:

1. An attempt should be made to collect brachiopods and any accessory fauna from slabs of limestone similar to those illustrated by Smith and Mertie (1930, Pl. 16A on p. 137) that were collected on the north fork of the Chandalar River. The illustrated slab contained a monotaxic accumulation of the pentameroid brachiopod *Conchidium*? sp. (identified by Edwin Kirk). These specimens were implied to indicate a late (or late middle) Silurian age for the Skajit Formation, and additional material could provide confirmation of this taxonomic and age assignment, and together with other taxa could provide significant paleobiogeographic information.
2. Additional detailed collection and study of megafossils (especially brachiopods, gastropod, trilobites, corals) from the Silurian (Wenlockian-Ludlovian) section exposed along the Don River in the central York Mountains (Teller C-4 quadrangle) has great potential in establishing the biogeographic affinities of the Arctic Alaska terrane Silurian fauna at sub-Realm level. Our current knowledge of Silurian fauna appears to have come from small lunch-bag sized sampling, and in my experience, a focused collection of large and biotically diverse materials will provide a much better framework for biogeographic analysis. Our current knowledge of these fauna suggests only a generalized North Silurian Realm assignment, but I firmly believe detailed collecting will easily refine the provincial or subrealm-level assignment. Any collection made here should also be done in conjunction with further sampling of the underlying Ordovician strata.

DEVONIAN

Generalized stratigraphic overviews (but now slightly dated) for the Devonian of Alaska (including Arctic Alaska) can be found in Gryc and others (1967) and Churkin (1973). A much more detailed account of the Devonian stratigraphy of the western Brooks Range is to be found in Tailleux and others (1967). The latter authors recognized a bipartite division of Devonian rocks, a generally southern succession of carbonate rocks they named the Baird Group (typically exposed in the western Baird Mountains). The Baird Group was recognized to consist of the Kuguruk Formation (named by Sable and Dutro (1961)), the Eli Limestone (named by Tailleux and others, 1967), and the Skajit Limestone (which had been named by Schrader, 1902). The other division, the Endicott Group was also established by Tailleux and others (1967), and consisted of a more northerly developed succession of fine to coarse-grained clastic rocks of Devonian-Mississippian age, including the Hunt Fork Shale (named by Chapman and others, 1964), the Kanayut Conglomerate, Noatak Sandstone, Kekiktuk Conglomerate, and Kayak Shale.

In the northeastern Brooks Range, Dutro (1970) established the Nanook Limestone (type section is in the Shublik Mountains). He recognized 8 informal members, the uppermost of which (member 8) yielded corals thought at the time to indicate a Middle Devonian, possibly Eifelian age. The age of Nanook was significantly revised by Blodgett and others (1986a, b, 1988b) who showed that member 8 included Cambrian and Ordovician age strata as well. The Devonian beds formerly ascribed to the Nanook Limestone were later separated into their own new distinct formation, designated as the Mount Copleston Limestone by Blodgett and others (1992a).

Brachiopods - Lower and Middle Devonian brachiopods have been reported, described and/or illustrated from a number of localities in Arctic Alaska terrane. Emsian (late Early Devonian) age brachiopods have been reported as present in the Mount Copleston Limestone in the Mt. Michelson C-3 and C-4 quadrangles (Blodgett and others, 1986a, 1992a). Unfortunately, the taxa recovered from so far (the genus *Schizophoria*, ambocoelids, and chonetids) to the level they have been identified so far are not key diagnostic paleobiogeographic indices.

Baxter and Blodgett (1994) named a new species of the genus *Droharhynchia*, *D. rzhonsitskayae*, from the Eifelian (early Middle Devonian) age strata of the upper part of the Cheeneetuk Limestone of the McGrath A-5 quadrangle (west-central Alaska), belonging to the Nixon Fork subterrane of the Farewell terrane, which has now been long considered to be of Siberian origin (Blodgett and Brease, 1997; Blodgett, 1998; Blodgett and Boucot, 1999; Garcia-Alcalde and Blodgett, 2001; Frýda and Blodgett, 2004). Baxter and Blodgett (1994) also recognized this species to be present in coeval strata of the Baird Group, exposed in the Howard Pass B-5 quadrangle. It is noteworthy that several co-occurring species were also recognized in the Baird Group collection to be present in the Cheeneetuk Limestone, suggesting very strong faunal linkage (none of these species have been recognized in North American cratonic rocks) between the Farewell and Arctic Alaska terranes during Eifelian time.

Popov and others (1994) established a new species of lingulid brachiopod, *Bicarinatina kongakutensis*, from the Ulunagarat Formation in Demarcation Point A-4 quadrangle. This genus is known during the Eifelian and Givetian only from occurrences in the Baltica continent (or Eastern European Plate of others). No occurrences of this distinctive large lingulid brachiopod have yet been observed in Laurentia (cratonic North America).

The widespread, predominately Givetian (late Middle Devonian) age brachiopod genus *Stringocephalus* has been noted from several places in the Arctic Alaska terrane: 1.) from the Punupkahkroak Mountains in the De Long Mountains A-3 quadrangle (Blodgett and Dutro, 1992; Blodgett and others, 1988a) and also in a single report (no illustration) in the Howard Pass quadrangle (Perkins, 1971). The De Long Mountains occurrence was described in detail by Blodgett and Dutro (1992) who identified these specimens under the name *Stringocephalus* (*Stringocephalus*) cf. (*S.*) (*S.*) *noctua* Crickmay (Figs. 8.1-8). The nominate species is a western Canadian taxon known from cratonic North America, but similar appearing taxa are also present in Russia and western Europe. Also co-occurring with the *Stringocephalus* in the De Long Mountains quadrangle is another stringocephalid identified by Blodgett and Dutro as *Geranocephalus*? sp.

Famennian brachiopods have been described in the literature from two separate localities in Arctic Alaska: 1). Dutro and others (1994) and 2.) Sartenaer (1969). Sartenaer (1969) described and illustrated a number of Late Upper Devonian (Famennian) rhynchonellid brachiopods from western Canada. One of the species he established therein was *Eoparaphorhynchus maclareni* Sartenaer, from the Northwest Territories. He also indicated that the 42 specimens identified by J.T. Dutro, Jr. as *Leiorhynchus* cf. *L. seversoni* and *L. sp.* (in Sable and Dutro, 1961) belonged to the new species. However, he did note that “this Alaskan population differs somewhat from the type material by having a larger proportion of individuals with 2/1 median costae. These median costae are strongly elevated. If further material from other localities in Alaska should corroborate such difference, the possibility of geographic subspecies may have to be considered.”

Gastropods – Virtually no formal systematic work has been done with Devonian gastropods of the Arctic Alaska terrane, which is unfortunate, as this group has proved to be among the most paleobiogeographically distinctive faunal group in Devonian strata of other accreted terranes of Alaska (Blodgett, 1992; Blodgett and others, 2002a, 2003). The only Devonian gastropod described to date from this terrane is *Ulungarotoechia heidelbergeri* Blodgett and Cook, 2002 (shown in Fig. 9C), from Eifelian age strata of the Ulunagarat Formation of Anderson (1991) in the Demarcation Point A-4 quadrangle. This new genus and species belongs to the family Cheeneetnukiidae Blodgett and Cook, 2002, representatives of which are common throughout the Middle Devonian (both Eifelian and Givetian) of Eurasia [Germany, Australia, Malaysia (unpublished data of R.B. Blodgett)] but have not yet been described from cratonic North America. The genus *Manitobiella* Blodgett and Frýda is represented by a single species in the early Givetian strata of the Baird Group in the De Long Mountains A-3 quadrangle. This genus is an Old World Realm taxon found in both Eifelian and Givetian strata of North America, and appears to be closely related to the Givetian age genus *Scalitina* found in Europe. Unpublished Middle Devonian gastropods are also found in collections of Amoco Petroleum Co.

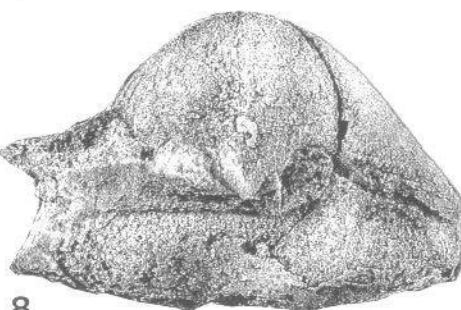
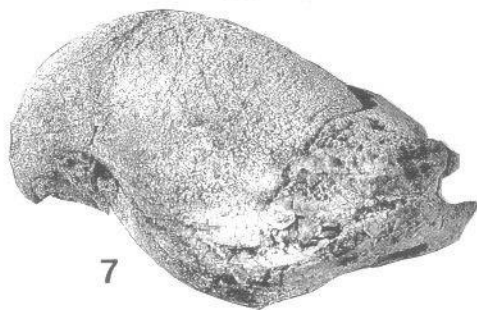
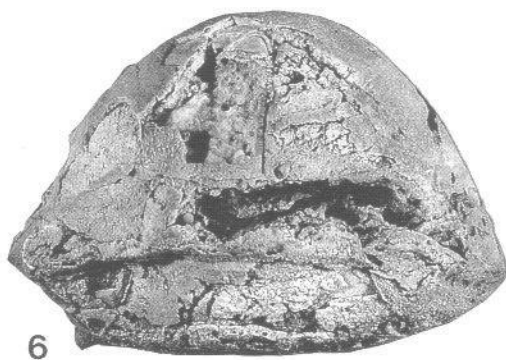
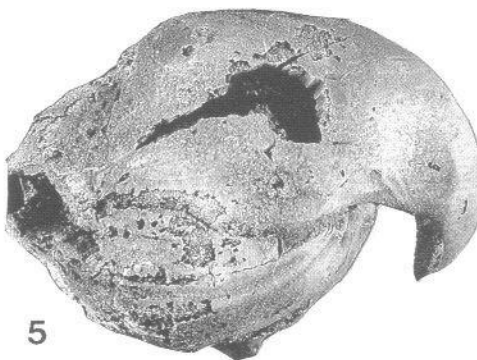
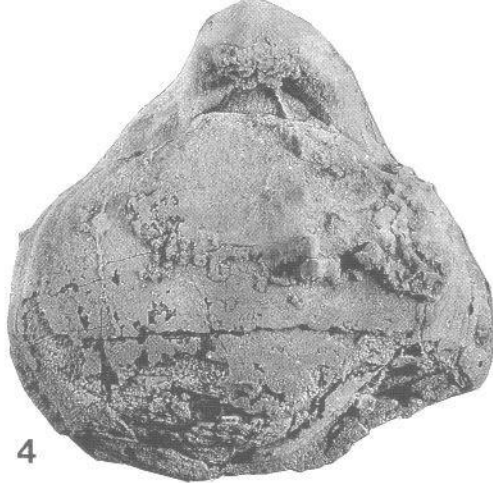
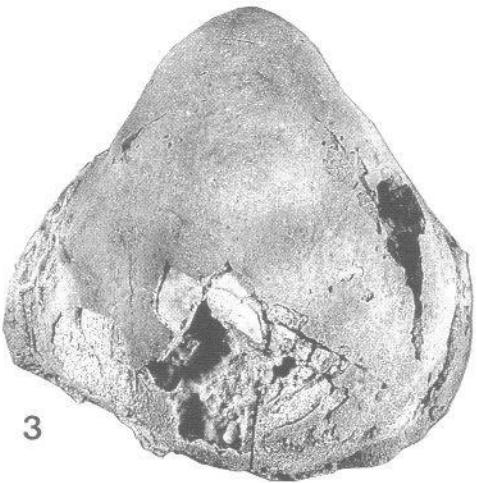
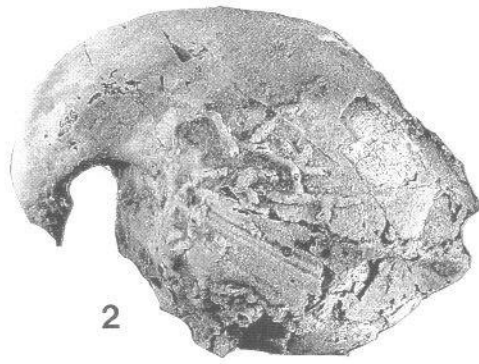


Figure 8 (on previous page). *Stringocephalus* (*Stringocephalus*) cf. *S. (S.) noctua* Crickmay from exposures of the Baird Group on the west side of Punupkahkroak Mountain, De Long Mountains A-3 quadrangle (from Blodgett and Dutro, 1992)

which were collected along Trail Creek in the Misheguk Mountain quadrangle from Baird Group exposures. The preservation of this material was superb, but unfortunately, the sample size was too small to be biogeographically significant.

Corals – Oliver and others (1975) provided faunal lists and illustrations of many rugose and tabulate corals found in Devonian strata of Arctic Alaska (as well as the rest of the State). Collections were listed from the western Brooks Range (from the Skajit? Limestone, the Eli Limestone, and Kugururok Formation), the Cosmos Hills area, from the central and eastern Brooks Range (Skajit Limestone and several unnamed formations), and the Nanook Limestone (these beds are now placed in the Mount Copleston Limestone) in the Shublik Mountains. No paleobiogeographic conclusions were stated by the above authors, but personal inspection of the listed genera indicates that these are of a generalized Old World Realm character. I believe these collections in the hands of the specialist working with western North American coral faunas (i.e., Alan E.H. Pedder, retired Geological Survey of Canada paleontologist) could do much for refinement of the biogeographic character of the Arctic Alaskan Devonian coral faunas. He is currently working on other accreted terrane coral faunas from the Farewell and Alexander terrane. Unfortunately, the late William A. Oliver, Jr. (formerly of the U.S. Geological Survey), responsible for most of the Devonian coral identifications of Alaskan material, was primarily interested in the study of Devonian coral faunas of eastern North America, and did Alaskan work only on a routine courtesy basis for Alaskan field workers, so that his identifications were primarily to provide genus-level identifications and age control where possible.

Calcareous algae – The dasycladacean alga genus *Coelotrochium* is a common floral associate of in Eifelian (early Middle Devonian) gastropod communities in various accreted Alaskan terranes (Farewell, Alexander, Livengood, and Arctic Alaska) (Poncet and Blodgett, 1987; Blodgett, 1992; Blodgett and others, 2002a; Blodgett and Cook, 2002). All of these terranes are now considered to be derived from or near the Siberian paleocontinent and subsequently accreted to the western margin of North America (Blodgett, 1998, 2000; Blodgett and Boucot, 1999; Blodgett and Brease, 1997; Blodgett and others, 2002a, b, 2003).

The presence of *Coelotrochium* in the Arctic Alaska terrane is known from only a single occurrence in the Ulungarat Formation (named by Anderson, 1991) in the Demarcation Point A-4 quadrangle (Blodgett in Anderson, 1993; Blodgett and Cook, 2003 –see Figs. 9C-D for illustrations of this species). The abundance of *Coelotrochium* in Eifelian near-shore (lagoonal) environments in many different accreted terranes makes it an easily identifiable guide fossil for strata of this age. It is unknown anywhere in cratonic rocks of North America, and this absence appears to be real. Due to its abundance and utility, I have sent samples of this alga to many other Devonian paleontologists and stratigraphers

working on western North American rocks, and none have ever reported as having seen this unusual hexagonally symmetrical green alga in strata with which they are familiar.

Outside of Alaska, this genus is known only from the Old World, and is commonly reported from late Emsian-late Eifelian age rocks of Germany (Siegfried Rietschel, 1981, written commun.) and in the late Eifelian of Belgium (Mamet and Preat, 1992).

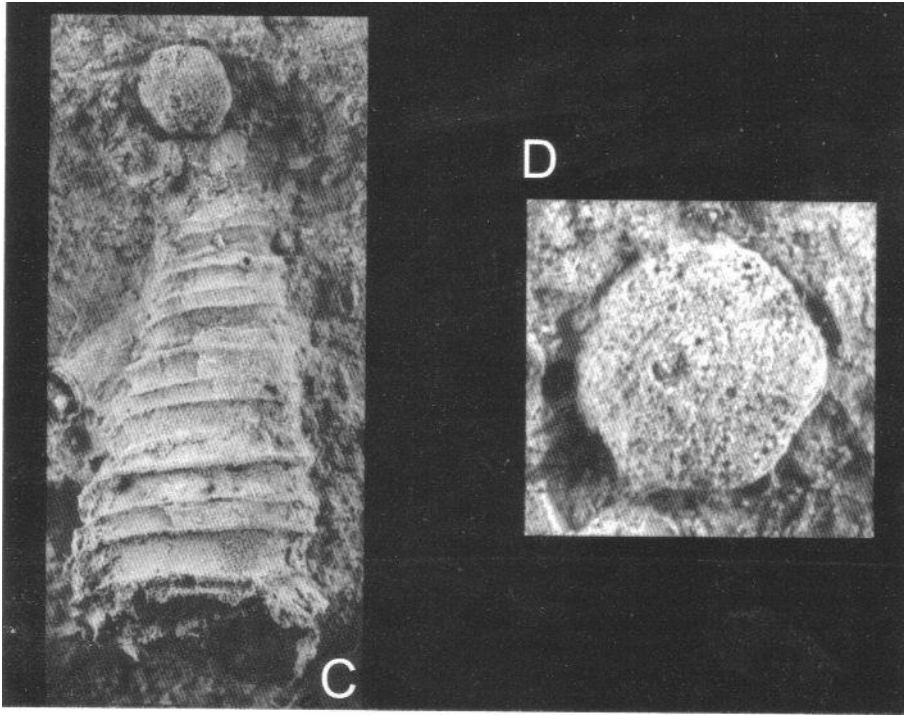


Figure 9. *Coelotrochium* sp., a calcareous green alga (same specimen shown in D is visible above the gastropod *Ulungarotoechia heidelbergeri* Blodgett and Cook in C), commonly found in Eifelian age shallow-water gastropod-dominated communities in Alaska's accreted terranes (i.e. Farewell, Alexander, Livengood, and Arctic Alaska terranes). The specimen shown here is from the Ulungarat Formation (of Anderson, 1991) in the Demarcation A-4 quadrangle, northeast Brooks Range (photos from Blodgett and Cook, 2002).

Conodonts – Discussion and/or illustrations of Devonian conodonts of the Arctic Alaska terrane appear in the following publications: Blodgett and others (1988b), Dumoulin and Harris (1987, 1994), and **Moore and others (1997)**. [what paper is this????] Although Devonian conodonts present great potential for broad correlation over great distances, their extremely cosmopolitan character during this time interval make them not germane to helping resolve the paleogeographic position of the Arctic Alaska terrane during Devonian time.

Summary of Devonian paleobiogeographic affinities of Arctic Alaska terrane:

Despite the relative abundance of Devonian exposures throughout much of Arctic Alaska, little in-depth paleontological studies have been conducted to date on these faunas. Emsian (late Early Devonian) faunas rich in brachiopods, corals, trilobites and gastropods are known from the Mt. Copleston Limestone in the Shublik Mountains and in the Trail Creek area of the Misheguk Mountains quadrangle. Unfortunately, only small fossil collections have been made to date, none of which has yielded biogeographically significant conclusions. Eifelian (early Middle Devonian) brachiopods and algae indicate strongly non-Laurentian (non-cratonic North American) affinities of the Arctic Alaska terrane. Affinities are seen both with the Farewell terrane of southwestern Alaska (which is Siberian in origin) as well as with Baltica. Givetian stringocephalid brachiopods from the Arctic Alaska terrane indicate generalized Old World Realm affinities both to North America and Eurasia. Famennian brachiopods are known from the Arctic Alaska terrane, but seemingly are quite cosmopolitan in character, reflecting the generally cosmopolitan nature of brachiopod faunas globally during the Famennian.

Recommendations for future study: A number of areas for future investigations on Devonian paleobiogeography of the Arctic Alaska terrane can be listed as follows:

- 1.) The area around Punupkahkroak Mountain, De Long Mountains A-3 quadrangle, western Brooks Range. Baird Group exposures are well exposed in this area (see Blodgett and Dutro, 1992) and upper Middle Devonian (Givetian) strata there contain abundant horizons of silicified and non-silicified fossils. An intense collecting program would undoubtedly yield many localities of varying ages and faunal character. Emphasis would be given to work downsection from documented Givetian age sites to locate older Devonian horizons (especially Emsian), when global endemism was higher.
- 2.) A detailed examination of Devonian exposures in the Trail Creek area, Misheguk Mountain A-4 and A-5 quadrangles. Collections by Amoco from Baird Group strata exposed there indicate that Eifelian and possibly Emsian age collections with excellent silicification can be obtained. The Emsian is especially critical as this time interval (407.0-397.5 Ma) represents the acme of global endemism recognized during the Devonian.
- 3.) I would highly recommend further collecting in beds of the Mt. Copleston Limestone (Emsian) from the Shublik Mountains, Mt. Michelson C-3 and C-4 quadrangles. The Emsian as note above is the height of global endemism within the Devonian, and enlarged collections of brachiopods, corals, trilobites may well prove to show strong biogeographic signals. Previous collections made by the author in this unit were strongly limited by time and size, and he firmly believes that several days of intensive collection in this unit would bear fruit in this regard.

MISSISSIPPIAN

The Mississippian stratal sequence of the Arctic Alaska terrane consists of the Endicott Group and much of the overlying Lisburne Group, the latter being the most areally extensive mappable lithostratigraphic unit in the terrane (see Fig. 10 for distribution of

Mississippian age strata in northern Alaska). The Lisburne Group is extremely abundant in megafossils, most notable being colonial rugose corals, followed by solitary rugose corals, brachiopods, bryozoans, as well as abundant crinoid columnals, similar to other Mississippian carbonate sequences found globally. The Mississippian is commonly conceived as representing acme of the crinoid diversity and abundance. The first widely distributed publication presenting a megafossil zonation for the Mississippian was that of Bowsher and Dutro (1957), although they had previously published a USGS report (constituting a sort of “gray literature”) in 1950, which contained an earlier version of this zonation and well as many fossil plates (39 in total). This megafossil zonation was presented and revised in several succeeding publications (Yochelson and Dutro, 1960; Dutro, 1979, 1985, and 1987). Figure 11 presents a summation of the megafossil zonation of the Arctic Alaska as used in Dutro (1987).

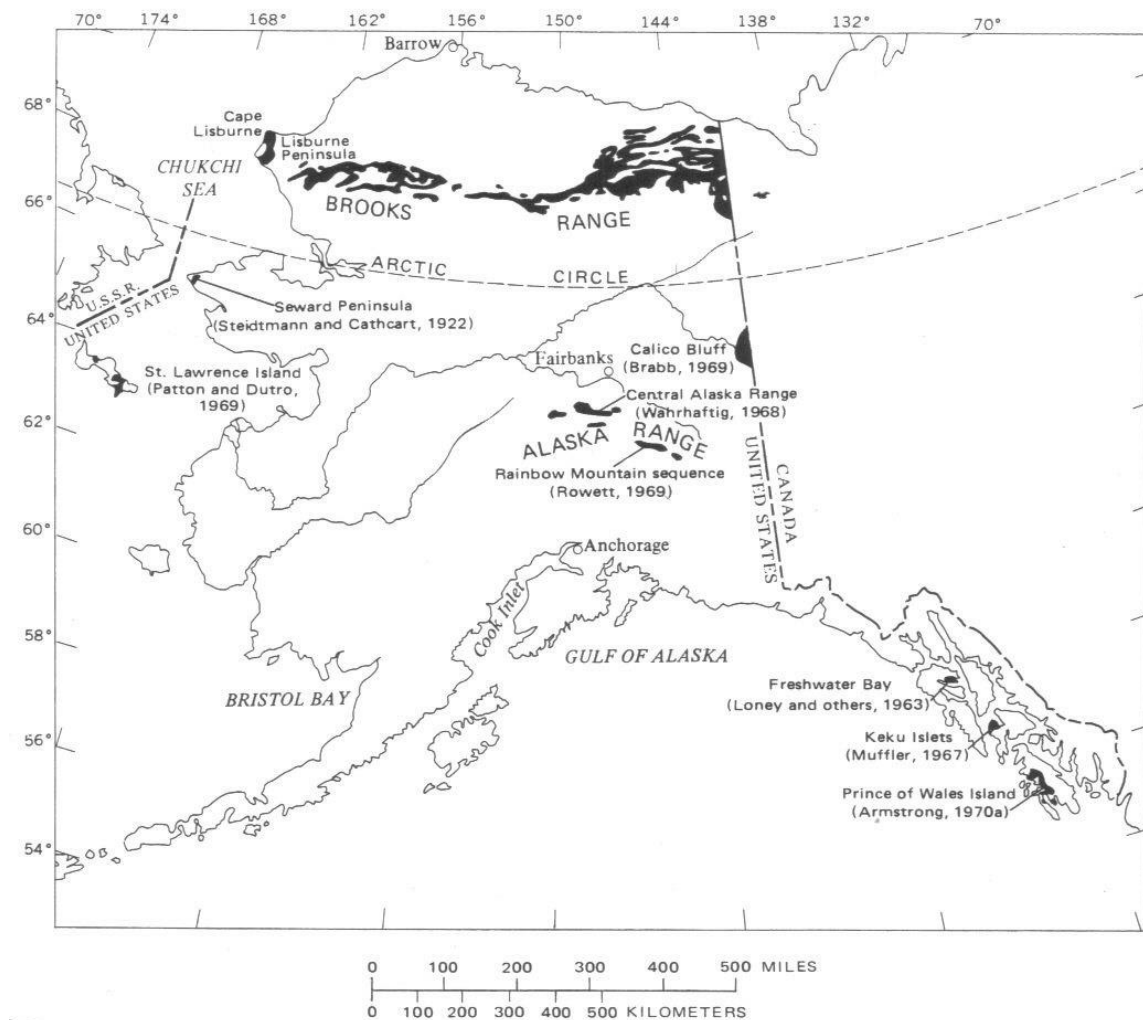


Figure 10. Map showing distribution of Carboniferous rocks in Alaska (from Armstrong, 1975b).

Dutro (1979) presented an overview on the stratigraphy, fossil biota, and history of research on Mississippian strata of Alaska. From the decade of the 1970's on, most of the biostratigraphic framework for the Carboniferous Lisburne Group (as well as the

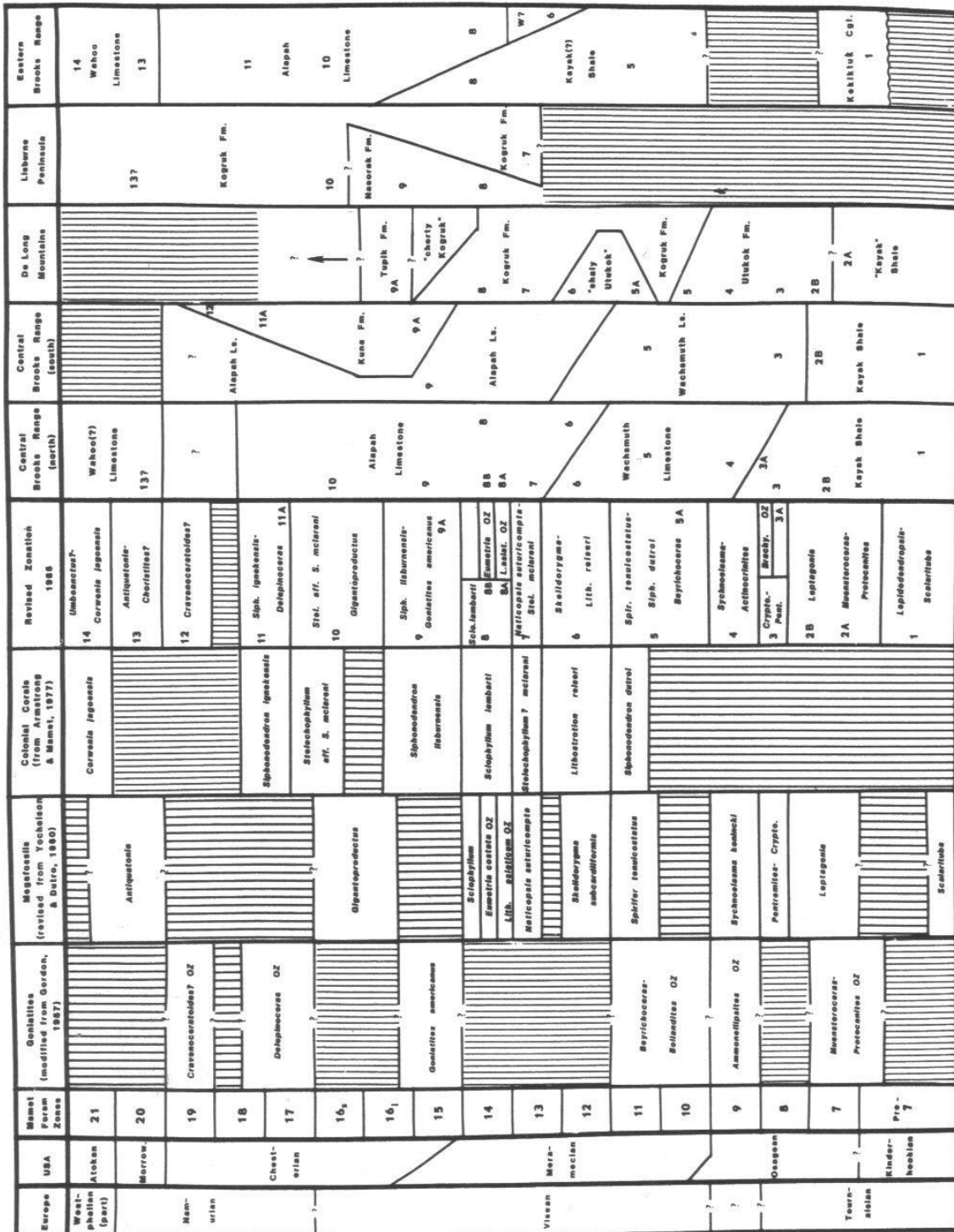


Figure 11. Chart (from Dutro, 1987) showing megafossil zonation for Mississippian strata of northern Alaska.

underlying Endicott Group) has relied on the microfossil assemblage zones that were compiled by Bernard L. Mamet (Armstrong and others, 1970, 1971; Mamet and Armstrong, 1972; Mamet and Skipp, 1970). Even more recently, zonation of the Lisburne Group has come to rely almost wholly upon conodonts (Dumoulin and Harris, 1993, 1997; Dumoulin and others, 1993; Krumhardt and others, 1994). The current trend to rely wholly upon any single faunal/flora group in the Lisburne is considered to be a troublesome trend in the opinion of the writer. No single biotic group should be used exclusively in a stratigraphic interval associated with as many facies changes as occur in the Lisburne Group. Conodonts are an excellent tool in regional biostratigraphy, but in my experience, they have limited paleoecological (and paleobiogeographic) information compared to megafossils, and like all biotic groups are restricted by environmental tolerances so that they can be absent in lengthy stratigraphic intervals, especially in near-shore, environmentally stressed settings. I believe future investigations in the Lisburne should utilize all fossil biotic groups present, be they conodonts, Foraminifera, or megafossils.

Stratigraphic overviews of the Mississippian strata of Arctic Alaska can be found in Armstrong (1975b), Dutro (1979 and 1987) and Dumoulin and others (2004).

Foraminifera – Foraminifera have been more intensely studied and reported on than any other single group of fossil faunal or floral group from the Mississippian of Arctic Alaska. The following papers have addressed various aspects of Arctic Alaska terrane Mississippian foraminiferid faunas [Armstrong (1970b), Armstrong and Mamet (1970, 1974, 1976, 1977, and 1994); Armstrong and others (1970a, b, 1971); Baesemann and others (1998); Bird and Mamet (1981, 1983); Bowsher and Dutro (1950); Carr and Mamet (1987); Mamet (1970, 1976); Mamet and Armstrong (1972); Mamet and Mason (1970); and Mamet and Skipp (1970)]. A number of publications cover the paleobiogeographic framework for Arctic Mississippian foraminifer faunas (i.e., Mamet and Skipp, 1970; Ross, 1973; Mamet, 1976). Mamet and Mason (1970), Bird and Mamet (1981, 1983) Armstrong and Mamet (1970, 1994) noted that the Arctic Alaska Lisburne foraminiferids belong to the Taimyr-Alaska Realm (in some papers referred to as the Alaska-Taimyr Realm), correlated with a temperate warm environment and considered by Mamet (1976) to represent one of three realms he recognized in the northern hemisphere. The other two realms were: 1.) the Tethyan Realm, characterized by a rich fauna, high to very high species diversity; and 2.) the Kuznets and North American Realm also with a rich fauna but with lower species diversity than the former realm. Papers providing taxonomic description and/or biostratigraphic (or paleoecologic) discussion of Mississippian foraminiferid faunas of the Arctic Alaska terrane include Mamet (1976), Armstrong and Mamet (1970), Mamet and Armstrong (1972).

Corals - Mississippian rugose corals, like the co-occurring Foraminifera and algae, have received the greatest amount of taxonomic study amongst the Mississippian fossil biota of the Arctic Alaska terrane. This is part due to their extreme abundance amongst the

Lisburne Group megafauna. Corals are abundant in the Alapah Limestone and the upper part of Wahoo Limestone, but quite rare in the lower Wachsmuth Limestone according to Armstrong and Mamet (1994). Their relatively high degree of study may also be due to the fact they are the most easily recognizable fossil group in the field. Rugose corals are relatively uncommon to unknown locally in the clastic-dominated Endicott Group, while as noted above they are most commonly recognized and collected megafossil group in the overlying Lisburne Group. Published taxonomic and biostratigraphic studies of Lisburne Group corals include Armstrong (1970a,b, 1972, 1973a,b,c, and 1975a,b,c), Armstrong and Mamet (1970 and 1977), Duncan *in* Bowsher and Dutro (1950), Dutro and Armstrong (1970), Harker and McLaren (1950), Mamet and Armstrong (1972) and Sando (1977). Mississippian corals from the Lisburne Group occur primarily in Meramecian age strata, being much rarer or absent in Osagean and Chesterian age strata. Armstrong (1975b, p. 45) attributed this to regional temperature or salinity changes that possibly inhibited their growth.

E.W. (Wayne) Bamber, retired Geological Survey of Canada paleontologist (speciality is Late Paleozoic corals), indicated to me (oral communication, July 7, 2006) that the Mississippian coral fauna of the Brooks Range merely represented an extension of the Western Canadian Cordillera coral faunas, sharing many species in common with those of the Rundle Group of Alberta.

Sando and Bamber (1985, p. 1) commented that areas of coral-bearing Mississippian rocks in northern and southeastern Alaska, the northern Yukon, northwestern Washington, central Oregon, and northern California were in different zoogeographic provinces during Mississippian time.

Dorothy Hill (1973, p. 140) in her survey of Lower Carboniferous coral global biogeography, noted some alliance of the Siberian Arctic Mississippian coral faunas with those of North America, as stated here in quotes:

“The recognition of “North American” genera in northeastern Siberian and in the Taymyr implies open migration routes between North America and Polar U.S.S.R. during the Lower Carboniferous.”

Brachiopods – The earliest and most definitive work on Arctic Alaska terrane Mississippian brachiopods is that of Bowsher and Dutro (1950), which contained lengthy faunal lists and many photographs of Mississippian brachiopods from this region. Unfortunately, this “publication” appeared as an internal USGS open-file report, which never received general circulation, and thus, remains virtually unknown to modern day Brooks Range workers as well as Mississippian brachiopodologists!!!! Mississippian brachiopods from the Arctic Alaska terrane have been illustrated in only one officially recognized publication (Mull and others, 1997), which dealt with specimens from the Kayak Shale, in the western Endicott Mountains (Howard Pass Quadrangle). These brachiopods included several species that are conspecific with forms known from western Canada. Very little has been published on the nature of the rich brachiopod found in the Lisburne Group, other than small scattered comments, usually in the form of written statements by J.T. Dutro, Jr., as to character (i.e., Sable and Dutro, 1961, p. 592) of

brachiopods found in specific area or stratigraphic interval. Bowsher and Dutro (1957) provided the first officially published megafossil zonation of the Lisburne Group, but brachiopods play only a minor role in this zonal scheme, with only one zone, the *Gigantoproductus striato-sulcatus* (Schwetzhoff) zone, being established (*ibid*, fig. 4 and p. 6) for strata in the upper part (fine-grained limestone and chert nodule members) of the Alapah Formation of the Lisburne Group in the Shainin Lake area of the central Brooks Range. They recognized this zone to rest above an interval of the lower two-thirds of the Alapah Limestone characterized by lithostrotionoid corals. This same brachiopod zone was also recognized in Yochelson and Dutro (1960, fig. 24). Members of the genus *Gigantoproductus* have also been reported from upper Lisburne strata on St. Lawrence Island (E&R report by J.T. Dutro Jr. and W.J. Sando, dated 10/22/1968, to W.W. Patton, Jr.). The genus *Gigantoproductus* is a well-known and widespread Mississippian (Visean-Namurian) brachiopod genus found in Eurasia (western Europe, Russian Platform, Kazakhstan) as well as North Africa. The species *G. striatosulcatus* (Schwetzhoff) is known from the Russian Platform (Sarycheva and Sokolskaya, 1952). The genus is unknown in cratonic rocks of North America, but is known from Nova Scotia (Adams, 1978), an accreted terrane affiliated with northwestern Europe, notably Ireland and northern England during Mississippian time, as well as in Arctic Alaska. Gordon (1957, p. 16) believed that the beds containing *Gigantoproductus* in the central part of the Brooks Range (lying above the black chert and shale member of the Lisburne) were probably equivalent in age with the *Goniatites granosus* (P₂) goniatite zone. He noted that the *Gigantoproductus*-bearing beds lie above the highest occurrence of lithostrotionoid corals. Dutro (1979, fig. 2) shows the two informal members of the Alapah containing *Gigantoproductus* to correspond to Mamet's foraminiferal zone 16_{inf}, while in the same publication the *Gigantoproductus* zone is shown corresponding to Mamet's microfossil zones 16_{inf} and 16_{sup}; both zones indicate an early Chesterian age in terms of the North American mid-continent series.

Bowsher and Dutro (1950) noted and illustrated the following brachiopods from the upper part of the Kayak Shale. This publication preceded the formal establishment of the Kayak Shale by Bowsher and Dutro (1957), and in this earlier publication the unit was considered part of the Noatak Formation. From their argillaceous limestone member they recognized two separate zones (Alpha and Beta zones). In the Alpha zone they recognized only a small number of brachiopod species: *Leptaena analoga* (Phillips), *Camarotoechia* cf. *C. tuta* (Miller), *Spirifer* cf. *S. platynotus* Weller, *Spirifer* aff. *S. tornacensis* de Koninck and *Rhipidomella tenuicostata* Weller. In the Beta zone they reported the occurrence of the following brachiopods: *Chonetes* cf. *C. gregarius* Weller, *Productella* cf. *P. pyxidata* (Hall), *Buxtonia belliplicatus* (Branson), *Linoproductus ovatus*, *Avonia* cf. *A. pustulifera* (Moore), *Pustula* cf. *P. echinata* (Moore), *Dielasma?* *choteauensis*, *Spirifer* aff. *S. biplicatus* Hall, *Spirifer louisianensis?*, *Spirifer* cf. *S. platynotus*, *Spirifer striatiformis* Meek, *Spirifer* aff. *S. tornacensis* de Koninck, *Syringothyris halli* Winchell, *Cleiothyridana* aff. *C. glenparkensis* Weller and *Composita lewisensis*. From the uppermost member, the red limestone member (of Osagian age) they reported the following brachiopods: *Buxtonia?* cf. *B. choteauensis* Branson, *Allorhynchus heteropsis*, *Spirifer* cf. *S. biplicatus* Hall, *Spirifer* cf. *S. missouriensis* Swallow, *Spirifer latior?*, *Spirifer louisianensis*, *Spirifer osagensis*, *Spirifer striatiformis*

Meek, *Brachythyris choteauensis* Weller, *Brachythyris peculiaris* (Shumard), *Pseudosyrinx missouriensis*, and *Syringothyris halli* Winchell. These Kayak Shale faunas from the central Brooks Range are currently correlated with the Tournaisian (Kinderhookian-Osagian) according to Dutro (1987). Nearly all the Kayak species are the same or compared with North American species (especially mid-Continent forms), but a few species based on western European species are also present [notably *Leptaena analoga* (Phillips) (now placed in the genus *Leptagonia*) and *Spirifer tornacensis* de Koninck].

Bowsher and Dutro (1950) assigned the following brachiopods to their zonal scheme for the Lisburne. For the Wachsmuth member they recognized four lithologic zones. The first zone contains: *Moorefieldia* sp. A, *Camarotoechia* aff. *C. mutata* (Hall), *Reticulariina*? cf. *R. mundulus* (Rowley), *Cyrtina* cf. *C. neogenes* Hall and Clarke, *Tylothyris novamexicana* (Miller), *Torynifera* aff. *T. pseudolineata*, *Spirifer* cf. *S. shepardi* Weller, *Spirifer* aff. *S. subaequalis* Hall, *Spirifer* aff. *S. missouriensis* Swallow, *Spirifer* sp. E., *Martinia*? sp. indet., *Brachythyris* aff. *B. suborbicularis* Hall, *Cleiothyridina* cf. *C. tenuilineata* (Rowley), *Selenella*? sp. A, *Strophalosia*? spp. A and B, *Buxtonia* cf. *B. viminalis* (White), *Rhipidomella dimunitiva* (Rowley), and *Dimegalasma latior* (Weller). No fossils (brachiopods or otherwise) were listed from their second lithologic zone within the Wachsmuth. Their third lithologic zone contains the following brachiopods: *Camarotoechia* cf. *C. elegantula* Rowley, *Chonetes burlingtonensis* Weller, *Chonetes logani* Norwood and Pratten, *Dictyoclostus burlingtonensis*, *Spirifer* spp. A, B, and C, *Spirifer tenuicostatus* Hall, *Spirifer* aff. *S. keokuk* Hall, *Spirifer rostellatus* Hall, *Orthotetes keokuk* Hall, *Streptorhynchus* sp. A, *Leptaena analoga* (Phillips), *Krotovia* sp. A, *Dielasma* cf. *D. burlingtonensis* (White), and *Pseudosyrinx* aff. *P. missouriensis* Weller. Their fourth (and uppermost) lithologic zone contains the following brachiopods: *Camarotoechia* aff. *C. tuta* (Miller), *Camarotoechia bisinuata* (Rowley), *Acanthaspira* sp. A, *Spirifer* sp. B., *Spirifer* sp. F, *Spirifer keokuk* Hall, *Spirifer* cf. *floydensis* Weller, *Spirifer tenuicostatus* Hall, *Brachythyris suborbicularis* Hall, *Athyris lamellosa* (Levielle), *Athyris* sp. B, *Chonetes* cf. *logani* Norwood and Pratten, *Dictyoclostus* aff. *D. burlingtonensis* (Hall), *Buxtonia* cf. *B. viminalis*? (White), *Echinoconchus* sp. A, *Pseudosyrinx* aff. *P. missouriensis* Weller, *Centronelloidea* aff. *C. rowleyi* (Worthen), *Dielasmella*? cf. *D. compressa* Weller, and *Composita pentagonia* Weller. Virtually all of the species listed from the Wachsmuth, either as named species or compared with (cf. or aff.), were established in the upper Mississippi Valley region (especially Iowa and Missouri), with the exception of two named species: *Leptaena analoga* (Phillips) [now placed in the genus *Leptagonia*] and *Athyris lamellosa* (Levielle) [now placed in the genus *Actinoconchus*]. Both of the latter two species were originally defined in western Europe, but are now recognized as widespread, nearly cosmopolitan species in Lower Carboniferous faunas throughout much of the world.

Bowsher and Dutro (1950) recognized ten lithologic zones in their Alapah member (now Alapah Limestone) of the Lisburne. In the first lithologic zone the only brachiopod noted was *Echinoconchus* sp. indet., otherwise the fauna reported was dominated by gastropods which was later assigned to the *Naticopsis suturicompta* zone by Yochelson and Dutro (1960). The following brachiopods were reported from the second lithologic zone:

Allorhynchus? cf. *A. acutiplicatus* Weller, *Brachythyris* cf. *B. altonensis* Weller, “*Spirifer*” cf. *S. leidy* Norwood and Pratten, *Reticularia setigera* (Hall), *Krotovia* spp. A and B, *Overtonia* sp. B, *Buxtonia* cf. *B. muirwoodi* Paeckelmann, *Avonia* cf. *spinocardinata* Bell, *Linoproductus* cf. *L. lyelli* (Verneuil), *Linoproductus* sp., *Pustula* sp. A, *Rhipidomella* sp. indet., *Spiriferina* aff. *S. verneuili* Bell, *Girtyella indianensis* (Girty), *Hartella* aff. *H. gibbosa* Bell, *Dielasma* cf. *D. milviformis* Bell, *Composita* cf. *C. subquadrata* (Hall), *Athyris*? sp., *Cleiothyridina* cf. *C. hirsuta* (Hall), and *Composita* sp. indet. The following brachiopods were listed from the third lithologic zone: *Spirifer bifurcatus* Hall, *Spirifer*? sp. indet., *Reticularia setigera* (Hall), *Avonia* cf. *A. spinocardinata* Bell, and *Eumetria costata* (Hall); and from the fourth lithologic zone they listed the following: *Pugnoides ottumwa* (White), *Moorefieldella*? sp. indet., *Leiorhynchus* sp. A, *Tetracamera* sp. indet., *Spirifer* sp. G., *Buxtonia*? cf. *B. muirwoodi*? Paeckelmann and *Hustedia* sp. A. The following brachiopods were listed from the fifth lithologic zone: *Moorefieldella* sp. A, *Productella* sp. A, *Overtonia* cf. *O. fimbriatus* Sowerby, *Overtonia* sp. C, *Buxtonia* sp. indet., *Productus productus* (Martin), *Dictyoclostus*? cf. *subfasciculatus* (Bell), *Dictyoclostus* aff. *D. fliegeli* Paeckelmann, *Echinoconchus* sp. A, *Echinoconchus* cf. *E. genevievensis* Weller, and *Schizophoria* sp. B.; from the sixth lithologic zone they cited only *Munella*? *adonis* Bell, but they mentioned that most of the fossils from the underlying fifth zone were also present, and that there may be no real reason to paleontologically separate these zones. From their seventh lithologic zone they listed the following brachiopods: *Gigantella* cf. *G. latissimus* (Sowerby), *Echinoconchus* cf. *E. genevievensis* Weller, and *Echinoconchus biseriatus* (Hall), and from the eighth lithologic zone they listed the following: *Gigantella striato-sulcatus* (Schwetzoff), *Dictyoclostus inflatus* (McChesney), *Echinoconchus* sp. A?, and *Productus* cf. *P. garwoodi* Muir-Wood. From the ninth lithologic zone they listed the following brachiopods: rhynchonellid brachiopod, *Stenoschisma* sp. indet., *Tetracamera arctirostra* (Swallow), *Fusella triangularis* (Sowerby), *Choristites*? sp. A, *Daviesiella*? sp. indet. and *Dictyoclostus* cf. *D. hindi* (Muir-Wood); no fossils (brachiopods or otherwise) were listed from their tenth lithologic zone. Like the underlying Wachsmuth, the brachiopods listed from the Alapah are dominated by North American mid-Continent taxa, but the percentage of European (or Eurasian) forms is somewhat larger.

Mamet and Bamber (1979, p. 43) note the presence of *Anthracospirifer leidy* (Norwood and Pratten) in the Alapah Limestone. This is a widespread, characteristic species found in uppermost Meramecian and Chesterian of the Rocky Mountains and is also known from the Chesterian of the Mississippian Valley region. Bowsher and Dutro (1950, pl. 17, figs. 17-20) provided the only illustration of this species from the Alapah Limestone, which they identified as “*Spirifer*” cf. *S. leidy* Norwood and Pratten and listed as occurring in their “Second lithologic zone”, being considered by them as among the most important zone fossils for this interval.

Two species of *Gigantella* (now *Gigantoproductus*) were recognized by Bowsher and Dutro (1950) in the Alapah Limestone. These were *Gigantella* cf. *G. latissimus* (Sowerby) (shown on their Pl. 27, figs. 4-6) from the “Seventh lithologic zone” and *Gigantella striato-sulcatus* (Schwetzoff) [shown on Pl. 26, figs. 1-3 (shown herein as Fig. 12.1-3) and Pl. 27, figs. 1-3, 7-8] from their “Eighth lithologic zone”. The latter species,

originally established from the Russian Platform by Schwetzoff, was abundant enough to be designated as the *Gigantoproductus striato-sulcatus* Zone by Bowsher and Dutro (1957) ([n latter revisions simply listed as the *Gigantoproductus* Zone in Yochelson and Dutro (1960) and Dutro (1987)]. The former species, *Productus latissimus* Sowerby by original designation, was subsequently made the type species of the genus *Latiproductus* Sarycheva and LeGrand, 1977, being removed from the family Gigantoproductidae and placed by its authors in the family Semiplanidae Sarycheva. The stratigraphic range of the type species is cited as late Visean-Serpukhovian (being more abundant in the Serpukhovian, rarer in the late Visean) by Litvinovich and Vorontsova (1983). The reported Alaskan occurrence to this species occurrence is the only known citation to this species in North America, otherwise found throughout much of Russia (Russian Platform), Kazakhstan, western Europe, and northern Africa.

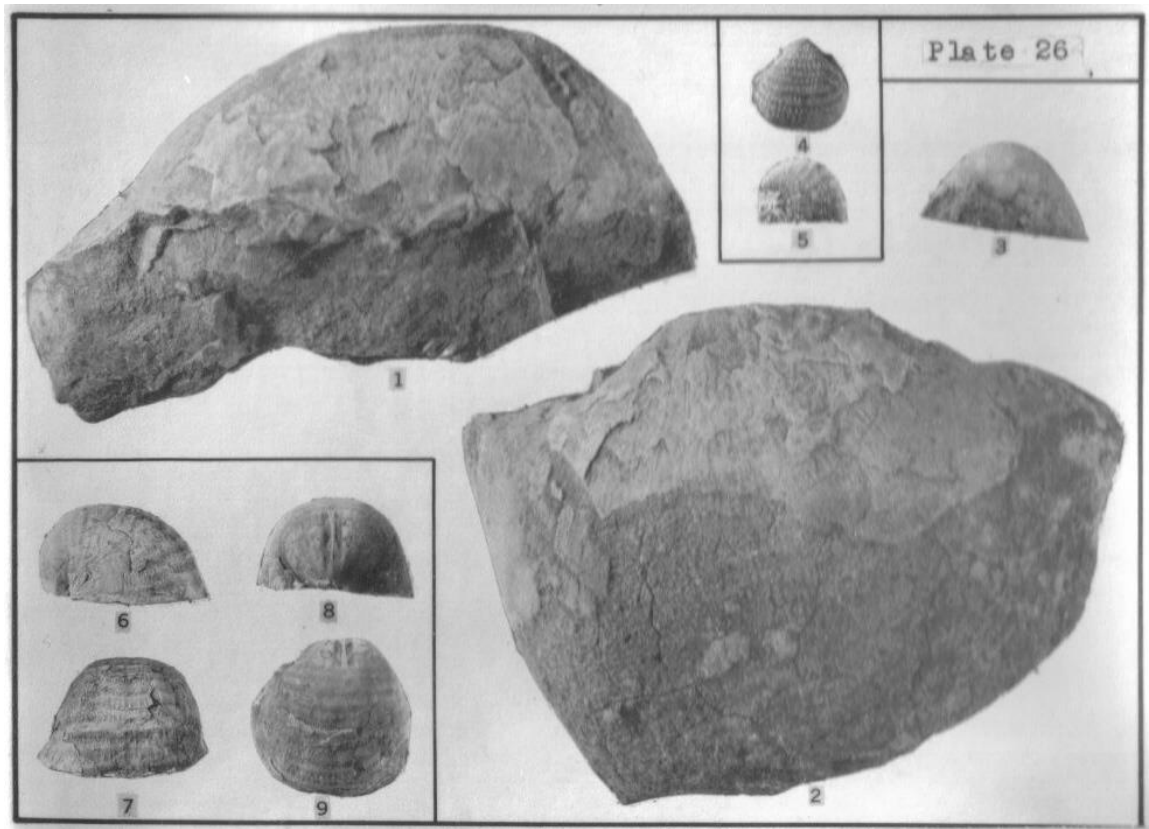


Figure 12. Views 1-3 show specimens assigned to the species *Gigantella striato-sulcatus* (Schwetzoff) by Bowsher and Dutro (1950). These specimens (now placed in the genus *Gigantoproductus*) were collected along the Canning River by E. de K. Leffingwell from his locality 26X (=USGS locality 7138-green) (photo from Bowsher and Dutro, 1950, Pl. 26)

Fragmentary specimens, most probably belonging to the genus *Gigantoproductus* are also reported from Lisburne Group equivalent beds on St. Lawrence Island (E&R report by J.T. Dutro, Jr. and W.J. Sando, dated 10/22/1968, to W.W. Patton, Jr.). The authors of

this report suggested a possibly early Chester age for this horizon, correlative with the *Gigantoproductus* Zone of the central Brooks Range.

John L. Carter in Mull and others (1997) provided faunal lists and illustrations of Kinderhookian to possibly early Osagean (early Tournaisian) brachiopods from the Kayak Shale in the Howard Pass quadrangle. These included a number of species: *Ovatia prolata* Carter; *Piloricilla desmetensis* Carter, *Pustula morrocreekensis* Carter, *Seminucella parva* Carter, *Spinocarinfra parviformis* (Girty), *Composita immatura* (Girty), *Calvustrigus rutherfordi* (Warren). Many of these species were previously established or recognized in the Banff Formation (part of the North American craton) in western Alberta (Carter, 1977).

Only one source of photographic coverage of Lisburne Group brachiopods exist, namely Bowsher and Dutro (1950), which consists of an informal “gray literature” publication of the U.S. Geological Survey containing 39 photographic plates of megafossils, mostly brachiopods, rugose corals, tabulate corals, gastropods, bivalves, crinoids, and blastoids. Unfortunately this work was not further massaged into a formal publication at the level of a USGS Professional Paper, and remains almost wholly unknown to most geologists working on Alaskan Carboniferous paleontology and stratigraphy. In the writer’s opinion, further study of the brachiopods from the Endicott and Lisburne Groups remains perhaps the most lucrative sources of paleobiogeographic information to be garnered for the Mississippian of the Arctic Alaska terrane.

As stated above, the writer believes that much paleobiogeographic information could be ascertained from an intensive taxonomic study of the Mississippian brachiopod fauna of the Arctic Alaska terrane. Unfortunately, despite numerous, large collections being made from the Lisburne Group over the course of the past 60+ years by USGS field parties, these collections have come under the “protection” of J.T. (Tom) Dutro, Jr., a Survey paleontologist whose primary specialization has been Upper Paleozoic Brachiopoda. They have become his personal fiefdom, and no other brachiopod specialists have been allowed to work with or study these collections. As a former colleague of his in the Branch of Paleontology & Stratigraphy of the USGS, I must confess that my observations of his work habits left much to be desired. Tom does not have a large library of Carboniferous brachiopod literature (especially Russian literature), and I observed him many times trying to fit brachiopod collections submitted for identification into a select few large monographs he had in his office. In the case of Mississippian brachiopods from northern Alaska, he almost exclusively used the classic monograph of Weller (1914) on Mississippian brachiopod faunas from the upper Mississippi Valley, and typically tried to tie them to taxa therein by direct species identification or a very high degree of similarity (i.e., cf. or aff.). This is a very dangerous approach in studying a new fauna (straight-jacketing a fauna into a classic fauna known elsewhere), and I observed no effort by Dutro to compare the Alaska Mississippian materials with faunas described elsewhere from the western U.S., western Canada, Canadian Arctic Islands, Siberia, or the Russian Platform. The only exception was the identification of gigantoproductid brachiopods (i.e. *Gigantoproductus striato-sulcatus* (Schwetzoff)), previously reported from the Russian Platform, in the central Brooks Range by Bowsher and Dutro (1950),

and again it should be noted that this identification was done by the senior author, Arthur Bowsher.

The dominance of Arctic Alaska terrane Mississippian brachiopod fauna by species previously named in the Mississippi Valley region of North America, especially more so in the early Mississippian, is not all that surprising as apparently a similar trend can be noted in Tournaisian (earliest Mississippian) brachiopods described by Nalivkin (1979) from the Urals. A close inspection of the systematic paleontology section of this large work shows a curious admixture of western European and mid-continent North American species, probably reflecting the more cosmopolitan character of early Mississippian faunas, as compared to that of the later Mississippian. I would seriously consider the taxonomic conclusions of D.V. Nalivkin to be most sound, as he was one of the premier paleontologists (and a highly regarded geologist as well) of the former Soviet Union.

Bryozoa – Duncan *in* Bowsher and Dutro (1950) discussed and illustrated many bryozoan species from the Lisburne Group, but no discussion has yet been published as to the paleobiogeographic affinities of these faunas.

Gastropods - Mississippian gastropods from the Arctic Alaska terrane were described by Yochelson and Dutro (1960) from the Kayak Shale and the Lisburne Group. A number of taxa were established in this study, including: *Straparollus* (*Euomphalus*) *brooksensis* n. sp., *Turbonellina?* *lata* n. sp., *Mourlonia minuta* n. sp. (later renamed *Mourlonia sablei* by Yochelson and Dutro, 1963), *Nodospira ornata* n. gen., n. sp., *Bembexia?* *inumbilicata* n. sp., and *Naticopsis* (*Naticopsis*) *suturicompta* n. sp. None of these new taxa have been recognized elsewhere in North America, although one previously named species, *Anematina rockymontanum* (Shimer) was recognized which previously was established from Lake Minnewanka area near Banff, Alberta. All of the other named species would appear to be endemic to the Arctic Alaska terrane, although recently at least one species, *Naticopsis* (*Naticopsis*) *suturicompta*, has been recognized as being present in the Russian Platform. The latter species is relatively abundant in the lowermost part (in the shaly limestone member) of the Upper Mississippian Alapah Limestone, given its name as the basalmost recognized faunal zone in the Alapah (see Yochelson and Dutro, 1960, fig. 24). This same zone had earlier been established by Bowsher and Dutro (1957, fig. 4 and p. 6) under the name *Naticopsis howi* Dawson zone, but was subsequently changed by Yochelson and Dutro (1960) to the *Naticopsis* (*Naticopsis*) *suturicompta* zone when they recognized the Alaskan specimens represented a new, different species. Other literature on Mississippian gastropods of Arctic Alaska include Yochelson and Dutro (1958), consisting of an abstract summarizing the same data presented at greater length by Yochelson and Dutro (1960), as well as the photographic atlas of Mississippian fossils by Bowsher and Dutro (1950), which contains photographs of several gastropod species occurring in the Lisburne Group.

In summary, the Mississippian gastropod fauna of Arctic Alaska gives mixed biogeographic signals, primarily represented by endemic species known only to the terrane, but also showing some sharing of one species with western Canada and another with the Russian Platform (part of the Baltica continent). It should be emphasized,

however, that global studies of fossil gastropods throughout the Paleozoic are still in its infancy during many time intervals, and until further monographic coverage is obtained for many parts of the globe, comparison of northern Alaska's Mississippian gastropods poses some problems.

In addition, Yochelson (1966) established a new species of the genus *Nordospira*, *N. vostokovae* n. sp. (=New genus? B Yochelson and Dutro, 1960, p. 139-140, pl. 14, figs. 26, 27), based on specimens USGS locality 13215-PC in the Kiligwa River valley, lat. 68°35'N., long. 158°20'W., Howard Pass C-5 quadrangle. This locality is within the Nuka Formation of Tailleux and Sable (1963), and was formerly thought to be Permian (Word) in age (Yochelson, 1966, p. 33). However, this age should be regarded with suspicion, as the bulk of the Nuka Formation has now yielded conodonts that indicate an age straddling the Mississippian-Pennsylvanian boundary.

Trilobites - Mississippian trilobites from the Arctic Alaska terrane have been described in only two papers [Chamberlain (1977) and Hahn and Hahn (1993)], although other specimens were illustrated (but not described) in Bowsher and Dutro (1950). Chamberlain (1977) described and illustrated two Mississippian taxa from the Arctic Alaska terrane. The first species, *Griffithides* (*Griffithides*) *megalops* n. sp., was collected by Ken Bird along a tributary to the Kelly River from calcareous shale probably belonging to the Kogruk Formation (Sable and Dutro, 1961) of the Lisburne Group. Chamberlain suggested that the most similar species to the new species is *G. (G.) acanthiceps* Woodward, 1883 from the Carboniferous of Great Britain. The second species described by Chamberlain, *Griffithides* (*Metaphillipsia*) *?bufo* (Meek & Worthen), probably of Meramecian age from dark calcareous and siliceous shale of the Nuka Formation at Nuka Ridge from the De Long Mountains, represents a taxon previously known only from the Mid-Continent region of North America. *Griffithides* (*Griffithides*) *megalops* n. sp. from the Lisburne Group, probably Kogruk Formation, also in the De Long Mountains. In contrast to the putative North American mid-continent affinities of the first species, Chamberlain (1977, p. 759) noted that the subgenus *Griffithides* (*Griffithides*) [to which the second species belonged] was known only from Eurasia until this publication (Alaska being its only occurrence in North America).

Hahn and Hahn (1993) reviewed all known Permo-Carboniferous trilobites known to them from Alaska. They reassigned (*ibid*, p. 142) both of Chamberlain's species from northwestern Alaska to the subgenus *Griffithides* (*Particeps*), questionably in the case of *G. (P.?) megalops*, and without question in the case of *G. (P.) ?bufo*. They recognized the Nuka Formation occurrence of *G. (P.) ?bufo* as possibly representing an "American" element amongst the trilobites, depending if the determination of the material from Nuka Ridge as *G. bufo* was correct. Hahn and Hahn additionally described and illustrated two trilobite pygidia they identified as *Linguaphillipsia* sp. indet., from probable basal Mississippian strata in the Demarcation Point quadrangle, northeastern Brooks Range. The locality given in their paper (90A-59B) indicates to the writer that these specimens were collected by Arlene Anderson (then a Ph.D. Student at University of Alaska, Fairbanks), who had passed them initially on to me, upon which I turned them over to the Hahns, in recognition of their internationally recognized expertise on Permo-

Carboniferous trilobites. Of paleobiogeographic importance to these authors was the fact that the Eurasian genus *Linguaphillipsia* was unknown up to this time in North America.

Ostracodes – Only two publications have appeared on Mississippian ostracodes from the Arctic Alaska terrane: Sohn (1971) that described Late Mississippian ostracodes from the Alapah Limestone and Sohn (1988) that described Early Mississippian (Tournaisian) ostracodes from the Lisburne test well. Neither publication included any conclusions concerning the paleobiogeographic affinities of these faunas.

Crinoids – Crinoids from the Lisburne Group were illustrated by Bowsher and Dutro (1950), but have never been the subject of a definitive taxonomic study.

Blastoids – Blastoids from the Lisburne Group were illustrated by Bowsher and Dutro (1950), but like the crinoids have not yet been the subject of taxonomic study.

Cephalopods – References to Alaskan cephalopod (mostly goniatite) faunas from Arctic Alaska can be found in Gordon (1955, 1957, and 1971) and Bowsher and Dutro (1950). Gordon (1957) beautifully summarized the taxonomic content and biostratigraphy of Mississippian cephalopods (including both ammonoids and nautiloids) from northern and eastern Alaska. His study was based on previously acquired USGS collections, which were greatly increased in volume by the USGS geologists working in exploration of Naval Petroleum Reserve No. 4 from 1945 to 1953. Many of the described species were new, but he noted that the species identified as *Goniatites crenistria* Phillips (the cited Alaskan occurrences of this species were later transferred to *Goniatites americanus* Gordon, 1971, a species which was subsequently recognized to range from northern Alaska to northern Arkansas), *G. cf. G. granosus* Portlock, *G. cf. G. sphaericus* (Sowerby), and *Beyrichoceras micronotum* (Phillips) appear to be identical to the named British species. Regarding the affinities of the ammonoids, Gordon (1957, p. 2) stated:

“One of the most striking features of the goniatite fauna, taken as a whole, is the relative abundance of *Beyrichoceras* and the closely related *Bollandites*. They are common in England, but rather uncommon on the continent of Europe and in North Africa. In the United States only one specimen of *Beyrichoceras* has thus far been described (Miller, 1947). The relative abundance of these genera in Alaskan rocks of Mississippian age emphasizes the boreal aspect of the fauna.”

Obviously, he recognized that the ammonoid fauna in general to be quite different from that known at that time from the conterminous U.S. It is also worthy to mention that among Gordon’s named species of ammonoids, none were found to be shared with the fauna from Eagle-Circle district of east-central Alaska (part of cratonic North America), while two species of nautiloids (*Rayonnoceras rangifer* Gordon and *Adnatoceras alaskense* Gordon) was found in both Arctic Alaska and the Eagle-Circle district. However, a large part of the faunal dissimilarity may be due to the differing time intervals represented by sampling in these two areas (see Gordon, 1957, Table 2; the Eagle-Circle district being slightly younger than those of northern Alaska).

Bivalves – Several bivalve species from the Lisburne Group were illustrated in Bowsher and Dutro (1950), but no definitive study has yet been undertaken from bivalves from the Mississippian of the Arctic Alaska terrane.

Conodonts – Publications dealing with Mississippian age conodonts from the Arctic Alaska terrane include Carr and Mamet (1987), Lane and Ressmeyer (1987), Murchey and others (1988a,b), Mull and others (1997), Krumhardt and others (1994), Dumoulin and Harris (1993, 1997), Dumoulin and others (1993, 1994, and 2004), and Blome and others (1998). Unfortunately, their overall cosmopolitan distribution during the Mississippian makes them not very useful in determining paleobiogeographic affinities in this interval.

Plants – Dutro (1979, p. DD8-DD9)) noted that plant fragments are present in dark shales near the base of the Mississippian throughout the Brooks Range. Using the identifications of S.H. Mamay (USGS paleobotanist), Dutro presented a combined list of this floral assemblage, noting that it includes: *Lepidodendropsis* sp., *Calamites* sp., *Stigmara* cf. *S. ficoides* Sternberg, *Lepidodendron* cf. *L. veltheimii* Sternberg, *Lepidophyllum* sp., *Lepidostrobus* sp., *Rhodea vespertina* Read, and *Triphyllopteris* sp. Citing Mamay (written commun., 1970), this assemblage was considered to represent Floral Zone 2 of Read and Mamay (1964).

Mississippian age plants from the Kurupa Lake area (Howard Pass quadrangle) have been documented by Spicer and Thomas (1987) and Thomas and Spicer (1986) to have strong Siberian (Angaran) floral affinities.

Pollen – References to pollen from Mississippian strata of the Arctic Alaska terrane are found in Ravn (1991, 1992). Ravn (1991) provided a detailed taxonomic study of miospores from the Kekiktuk Formation and concluded that the mioflora he recovered showed strong similarities to described miofloras from northwestern Canada as well as Spitsbergen. In a recent conversation, he indicated to me that the same similarities exist as well with miofloras known now from the Mississippian of Arctic margin of Siberia (R.L. Ravn, personal commun., 2006).

Algae – References to Mississippian algae from the Arctic Alaska terrane can be found in Armstrong and Mamet (1994), Carr and Mamet (1987), and Mamet and de Batz (1989). Mamet and de Batz (1989) provide an excellent overview of both Mississippian and Pennsylvanian microfloras from the Lisburne Group exposures in the Sadlerochit Mountains. The latter authors noted only a minor development of algae in the late Viséan, denoted by scattered *Stacheiinae* (mostly *Stacheoides*), followed by a somewhat richer microflora in the early Namurian with *Archaeolithophyllum*, *Cuneiphyucus* and *Asphaltina*. They also noted that the Mississippian algal flora was typical of the Taimyr-Alaska Realm (which Mamet had earlier used for contemporaneous foraminiferid assemblages). They considered the Mississippian algal flora to be more temperate in character, as opposed to the warmer floral assemblages they observed in the overlying Pennsylvanian strata of the Wahoo Limestone.

Radiolaria – Mississippian age radiolarians from the Arctic Alaska terrane are listed or discussed in Blome and others (1998) and Murchey and others (1981, 1988a, b). However, no paleobiogeographic conclusions can be ascertained from this group as of yet that helps in resolving the paleogeographic origins of this terrane.

Reefs – Reef deposits are lacking from the thick carbonate successions of the Lisburne Group (Armstrong and Mamet, 1970, Armstrong, 1975, and Dumoulin and Harris, 2006), differing from age equivalent carbonate rocks of the Canadian Arctic Islands (Sverdrup Basin), where they are well developed (see Beauchamp, 1993). If the Windshield-Wiper model was true, then one would expect their development in Arctic Alaska as well as in the Canadian Arctic Islands.

Summary of Mississippian paleobiogeographic affinities of Arctic Alaska terrane:

Despite having the greatest amount of published paleontological information available of all the geological systems in the Arctic Alaska terrane, sorting out its paleobiogeographic affinities are more difficult here than in most systems, due to the fact that the general level of paleobiogeographic differentiation is so low during the Mississippian. Compared to the Devonian (one of the most intensively studied intervals for biogeography), there are only a few published summaries of Mississippian global paleobiogeography [i.e., Hill (1973) – on corals; Korn and others, 2005 – on ammonoids; Ross (1973) on Foraminifera; Raymond and others (1985) – on megafossil plants; and Clayton (1985) and Van der Zwan (1981) on pollen]. Among marine invertebrates, the overall picture for the early Mississippian is one of very wide cosmopolitan distribution of most genera, and even of some species. This condition seems to continue the same general high of global cosmopolitanism similarly observed in the latest Devonian (Fammenian). Endemism appears to increase upward as one enters the middle and late Mississippian (late Visean-early Namurian), as Korn and others (2005, p. 356) have argued: “Mississippian ammonoid faunas demonstrate increasing provincialism during the younger part of the subsystem.”

The similarities noted among Early Mississippian brachiopods from Arctic Alaska with both those of North American and the northern portion of the former Soviet Union should come as no shock, in light of the comments by Dorothy Hill (1973, p. 140 – then the world’s leading experts on Carboniferous corals) on Mississippian corals from Siberia:

“The recognition of “North American” genera in northeastern Siberian and in the Taymyr implies open migration routes between North America and Polar U.S.S.R. during the Lower Carboniferous.”

Later Mississippian faunas from Arctic Alaska do evidence some strong cases of Eurasian affinities, as noted by presence of gigantoproductid brachiopods in the Alapah Limestone as well as by the presence of Angaran (or Siberian)-like floras in the Kurupa Lake region.

Recommendations for future study:

- 1.) Brachiopods remain amongst the most poorly known faunal elements in the richly diverse Mississippian fauna known from the Arctic Alaska terrane. Future concentrated collection and identification of brachiopod elements from both the Endicott Group and overlying Lisburne Group should provide much most insight into the biogeographic affinities of Arctic Alaska during the Lower Carboniferous. Brachiopods tend to be more endemic overall, in comparison to other more widely distributed faunal groups such as corals, Foraminifera, and conodonts, which form the vast bulk of our current knowledge for this terrane (especially for the Lisburne Group). Another faunal group, even more prone to provincialism, is the gastropods. Emphasis should likewise be given to their collection and future study in terms of biogeographic analysis. However, unlike brachiopods, gastropods tend to be restricted primarily to nearshore, inner shelf habitats, so one should specifically seek out such environments for their sampling. Another problem plaguing the study of Mississippian gastropods is the lack of adequate monographic or systematic study of gastropod throughout much of this time interval in other parts of the Circum-Arctic. Few monographs or published papers exist on this particular faunal group in the Lower Carboniferous of Siberia or the Russian Platform, so in order to make such a study, future investigators should attempt to get direct access to Russian material in various repositories to make adequate comparisons.
- 2.) An excellent brachiopod fauna was found by the writer during summer field work in 1987 in the Shublik Mountains within a sequence of flaggy sandstone rubble beds situated on a flat-topped mesa in the SW1/4, NW1/4, SW1/4 Sec. 16, T. 2 N., R. 27 E., Mt. Michelson C-3 quadrangle (Lat. 69°31'33" N, Long. 145° 31'44"). The material was preserved as cast and molds, but the details of the shell exteriors and interiors were quite superb. I distinctly remember many alate (winged) spiriferoid brachiopods at this locality, and was so impressed with the material that lay about that I made a small cairn to be collected at some future time. This material was from the basal Endicott Group, and most likely represented rubble of the Early Mississippian Kekiktuk Conglomerate or less likely a sandy horizon in the overlying Kayak Shale. No brachiopod faunas have ever been reported from the dominantly non-marine Kekiktuk Conglomerate, though brachiopods have been observed rarely in thin-section (LePain, 1993). This fauna is extremely important as it will provide a much firmer date on the age of the Kekiktuk Conglomerate (presently based on plant remains and palynomorph data), and may have important paleobiogeographic implications as well. Unfortunately, I did not realize the importance of this fauna at that time, or I would have carried out some of the material to my base camp.

PENNSYLVANIAN

Dutro (1979) presented an overview on the stratigraphy, fossil biota, and history of research on Pennsylvanian strata of Alaska. Pennsylvanian carbonates are well exposed in the northeastern part of the Brooks Range, where they are represented by the Wahoo

Limestone (Brosigé and others, 1962) that locally forms the uppermost part of the Lisburne Group.

Corals – References to Pennsylvanian coral assemblages of the Arctic Alaska terrane are found in the following sources: Armstrong (1970b, 1972b, 1975a,b,c), Dutro and Armstrong (1970), and Mamet and Armstrong (1972). Regarding Pennsylvanian corals of Arctic Alaska, Armstrong (1972b, p. 3) reported that:

“Rugose corals are known only from beds of Atoka age of the Wahoo Limestone; as yet none has been found in beds of Morrow age. The corals are represented by two new species, *Corwenia jagoensis* n. sp. and *Lithostrotionella wahooensis* n. sp. The most closely related corals are *Lithostrotionella orboensis* Groot (1963) from the upper Moscovian of Spain and *Petalaxis mohikana* Fomichev (1953) from the upper Moscovian of the Donetz Basin, U.S.S.R. *Corwenia jagoensis* n. sp. shows close similarity to the upper Moscovian corals *Corwenia symmetrica* (Dobroljubova) from Spain and Moscow and Donetz Basins of U.S.S.R. Taxa similar to *L. wahooensis* have not been described from Pennsylvanian age sediments of the Cordilleran region of North America. The apparent closer relationship of the two Atokan Wahoo corals to forms described from Eurasia is probably due to the lack of detailed systematic studies of Pennsylvanian colonial corals from the Cordilleran of North America.”

A similar conclusion to that above was also given in Armstrong (1975b). Both of the Wahoo Limestone corals occur in large numbers in certain horizons, and their growth habit and spatial relationship within these beds suggested that the individual colonies lived separately from one another and did not form biostromal or biohermal masses (Armstrong, 1972b, p. 9). The paucity or lack of corals in Morrowan age rocks (as also in Osagean and Chesterian strata of the Mississippian) of Arctic Alaska was attributed by Armstrong (1975b, p. 45) to regional temperature or salinity changes that possibly inhibited their growth.

Brachiopods – Pennsylvanian age brachiopods are very poorly documented from the Arctic Alaska terrane. No illustrations or taxonomic descriptions exist for Pennsylvanian brachiopods from Arctic Alaska. Dutro (1987, p. 363) recognized an *Antiquatonia-Choristites* Assemblage Zone, which he characterized as follows:

“Widely scattered occurrences of large brachiopods in the uppermost few meters of the thick-bedded carbonates of the Lisburne Group in the central Brooks Range indicate an Early Pennsylvanian age. *Choristites* occurs at Nanushuk Lake and *Antiquatonia* is found in the Atigun Gorge area. Probable representatives of this zone also occur in the lower Wahoo Limestone of the eastern Brooks Range and at the top of the Kogruk Formation of the Lisburne Peninsula. Foraminifers of Mamet Foraminifer Zone 20 characterize this interval.”

In addition to this published record cited above, J.T. Dutro, Jr. and David Bieler in an internal USGS E&R fossil report to R.L. Detterman dated January 25, 1971 noted the presence in the Wahoo Limestone in the Mt. Michelson A-5 quadrangle of a number of brachiopod species previously reported from Moscovian age strata in Spitzbergen by Gobbett (1964). These taxa included: *Wellerella* sp., *Laevicamera* cf. *L. arctica* (Holtedahl), *Linoproductus* spp., *Juresania* sp., *Reticulatia*? sp., *Choristites* cf. *C.*

aliforme (Gobbett), *Choristites* sp., *Cleiothyridina* sp., and *Rhynchopora?* sp. (see Appendix B). They also noted that similar species have been reported from the Moscovian of northern Russia.

Foraminifera (including Fusulinids) – Pennsylvanian age smaller Foraminifera from Arctic Alaska have received considerable study [Armstrong (1970b); Armstrong and Mamet (1970); Armstrong and others (1970, b); Baesemann and others (1998); Bird (1977); Carr and Mamet (1987); Mamet (1970); and Mamet and Armstrong (1972)]. No definitive published comments are extant that I am aware that help resolve the paleogeographic origins of the Arctic Alaska terrane based on its contained Pennsylvanian Foraminifera. However, Paul Brenckle (formerly Amoco's Upper Paleozoic foram expert) mentioned to me that protofusulinids show up in the Pennsylvanian of Arctic Alaska in early Atokan strata of the Wahoo Formation, namely two genera: *Pseudostaffella* and *Eoschubertella*, but noted that they occur no higher (P. Brenckle, oral commun., August 2006). Otherwise, fusulinids are not known from Pennsylvanian age strata of Arctic Alaska. However, in contrast, fusulinids are common to locally abundant in Pennsylvanian strata of the Canadian Arctic Islands. The relative lack of Pennsylvanian age fusulinids is matched only in the Northern Hemisphere by Siberia [forming the Eastern Arctic Province of Ustritskii (1971)]. The relative absence of fusulinids in the Arctic Alaska makes an alliance with Siberia, rather the Canadian Arctic Islands, seemingly more likely.

Algae – References to Pennsylvanian algae from the Arctic Alaska terrane can be found in Armstrong and Mamet (1994), Bird (1977), and Mamet and de Batz (1989). Mamet and de Batz (1989) provide an excellent overview of both Mississippian and Pennsylvanian microfloras from the Lisburne Group exposures in the Sadlerochit Mountains. They noted that the basal Pennsylvanian strata in the Wahoo Limestone are characterized by *Masloviporidium* and the first appearance of dasycladacean algae in the Lisburne [associated with a stratigraphically upward warming climatic trend also noted by Armstrong and Mamet (1994)]. Even higher, in Mamet's microfossil zone 21, they report the occurrence of abundant *Donezella*, which form seven levels of algal bafflestones (with attendant good porosities!), succeeded in turn by levels of high energy *Osagia* oncolites. Mamet and de Batz assign the Pennsylvanian microflora to the Taimyr-Alaska Realm (defined earlier by Mamet for foraminifers), but note that this microflora is warmer than that found in the underlying Mississippian strata.

Summary of Pennsylvanian paleobiogeographic affinities of Arctic Alaska terrane:

Unlike the underlying Mississippian rocks, Pennsylvanian strata of the Arctic Alaska terrane have yielded a limited fauna of more distinctly Eurasian (and non-North American) character. This is well demonstrated by the rugose corals and to a lesser degree by the brachiopods. The limited diversity and abundance of fusulinids in the Arctic Alaska terrane suggest stronger affinities with Siberia, rather than with the Canadian Arctic Islands.

Recommendations for future study:

- 1.) Armstrong (1972b, p. 3) commented that the Pennsylvanian colonial corals from the Wahoo Limestone show much stronger affinities with Eurasian faunas, rather than with contemporaneous faunas from North America, and suggested that this might be due to the lack on published studies on coral faunas of this age from North America. Since that statement, more work has been done on North American Pennsylvanian corals, the most notable being the work of Bamber and Fedorowski (1998) on Pennsylvanian rugosans from Ellesmere Island in the Canadian Arctic Islands. A renewed study of the original material at the species level may useful to further evaluate the paleobiogeographic affinities between the Arctic Alaska terrane coral faunas with those of Arctic Canada. It should be noted that Bamber and Fedorowski (1998) also noted affinities of their studied faunas with those of Spain, the Russian Platform (Donets Basin and Moscow Basin, also northern Urals), Spitsbergen and the western U.S. (similar in part to the findings reported by Armstrong, 1972b, 1975b).
- 2.) A systematic study of Pennsylvanian age brachiopods from the upper part of the Wahoo Limestone is in order. From my personal experience, brachiopods are one of the most biogeographic sensitive groups (superseded by gastropods). Unfortunately only limited faunal lists exists for the Wahoo brachiopod faunas of this age (mostly from unpublished, internal USGS E&R reports). Significant sized collections from this interval are deposited in the USGS collections housed at the Smithsonian Institution in Washington, D.C., and these would provide an ample starting part for such a study. Comparative studies on contemporaneous brachiopod faunas from others parts of the Circum-Arctic have already been completed, i.e. Russian Arctic: Abramov (1970), Abramov and Grigoreva (1983), Ustritskii (1971), Ustritskii and Chernyak (1963); Canadian Arctic Islands: Carter and Poletaev (1998); and the cratonic portion of Yukon Territory: Bamber and Waterhouse (1970).

PERMIAN

Permian strata are widespread throughout the Arctic Alaska terrane (Fig. 13) and stratigraphic units which have yielded significant fossil biota include the Siksikpuk Formation (Lower Permian), a dominantly clastic marine unit that accumulated not too distant from an emergent land area that to the north (Patton, 1957; Patton and TAILLEUR, 1964), the Sadlerochit Group, as well as the part of the Nuka Formation as originally established (TAILLEUR and others, 1958; TAILLEUR and SABLE, 1963).

Bivalves – Dutro and Silberling (1988) mention the presence of *Atomodesma* prisms reported the lower part of the Ikiakpaurak Member of the Echooka Fm. at a depth of 4,221-4,229 m (13,848-13,874 ft) in the Inigok well.

Brachiopods – Dutro in Patton (1957, p. 42) noted that the the basal part of the type section of the Siksikpuk Formation contains a “small spiriferoid brachiopod referred tentatively to the genus *Spiriferella*. This genus is found in Permian rocks of Russia, India, Oregon, and west Texas and is present in collections of Permian fossils elsewhere in Alaska.”

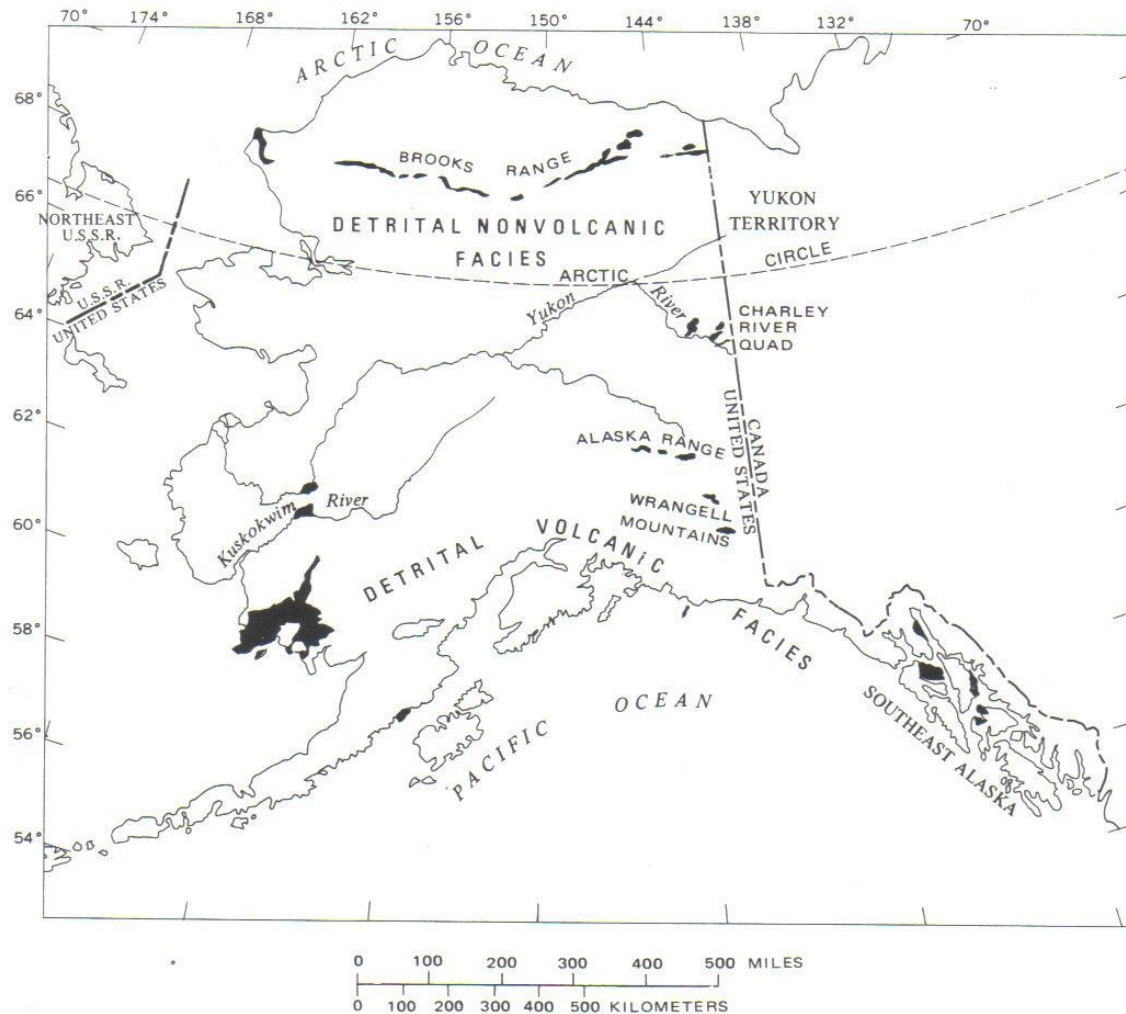


Figure 13. Distribution of surface exposures of Permian rocks and principal lithofacies (from Rowett, 1975a).

Brachiopod faunas of probable late Permian age were noted by Tailleux and others (1958) near the top of an Upper Paleozoic rock sequence exposed at Nuka Ridge in the DeLong Mountains Quadrangle. These were characterized by following genera: *Licharewia*, *Spiriferella*, *Spirigerella*, *Horridonia*, and *Waagenoconcha*. Dutro (1961) provided a more detailed faunal list of brachiopods for this interval, including abundant specimens of the genus *Licharewia*, as well as: *Derbyia* sp., *Linoproductus* sp., *Stephanoviella* sp., *Waagenoconcha* aff. *W. payeri* (Toula), *Antiquatonia* spp., *Kochiproductus* cf. *K. freboldi* (Stepanow), *Horridonia* cf. *H. horrida* (Sowerby), *Muirwoodia* cf. *M. greenlandica* Dunbar, *Choristites* spp., *Neospirifer* sp., *Spiriferella* cf. *S. keilhavii* (von Buch), *Spiriferella* sp., *Stenoscisma* sp., *Squamularia* sp., *Spirigerella* sp., *Rhynchopora* cf. *R. kochi* Dunbar, and *Dielasma* spp. Dutro considered the assemblage to be typical of Permian faunas found elsewhere in the Arctic (the so-called Arctic Permian fauna) and indicative of an early Late Permian age (probably a Kazanian equivalent). The spiriferoid

genus *Licharewia* was also noted by Dutro to be considered a guide to the Upper Permian of the USSR.

Corals – Helen Duncan (*in* Patton, 1957, p. 42) was quoted as follows concerning corals recovered from the basal 50 feet of the Siksikuk Formation:

“A very few horn corals, mainly pleurophyllid types, were found in the formation. A composite list of the corals obtained at three localities includes *Allotropiophyllum* sp. undet., *Euryphyllum* sp. undet., *Sochkineophyllum* cf. *S. artiense* (Soshkina), *Tachylasma* sp. undet., and *Ufimia?* sp. undet. The corals provide somewhat better evidence than the other elements in the faunule for assignment of the formation to the Permian system. *Tachylasma*, *Euryphyllum*, and *Allotropiophyllum* (s.s.) have been recorded only from the Permian in other parts of the world. The specimens of *Sochkineophyllum* are comparable to *S. artiense* (Soshkina), which occurs in the Artinskian of the Urals. *Ufimia* ranges into the Carboniferous but is more common in Permian rocks. The genera of corals here reported from the Siksikuk formation have also been identified in collections from Permian formations in other parts of Alaska. So far, comparable assemblages have not been identified from rocks that are older than Permian.”

Rowett (1975a, b) presented an overview of Permian corals from all over Alaska. Rowett (1975a, p. 62) provided the following discussion of Permian coral faunas from Arctic Alaska:

“In the far-western Brooks Range (fig. 20, area 1, Lisburne Peninsula), only a few polycoid corals are known, including *Tachylasma* and *Ufimia*. In the western Brooks Range (fig. 20, area 2, De Long Mountains), the coral faunas are more varied and include representatives of the Metriophyllidae (*Stereocorypha*), Laccophyllidae (*Amplexocarinia*), Hapsiphyllidae (*Amplexizaphrentis*), and Cyathopsidae (*Hornsundia*). In the central Brooks Range (fig. 20, area 3) both polycoid corals (*Sochkineophyllum* and *Tachylasma*) and hapsiphyllid corals (*Allotropiophyllum* and *Euryphyllum*) are present. This is the type area of the Siksikuk Formation. Corals from the extreme northeastern part of the Brooks Range (Sadlerochit Formation) (fig. 20, area 4) are uncommon and represent only the Metriophyllidae (*Duplophyllum*) and Polycoididae (*Pseudobradiphyllum*). Summarizing for this region, the coral faunas are strongly dominated by small, simple, nondissected corals that occur in clastic, commonly argillaceous nearshore marine facies.”

Rowett (1975a, p. 64) in summation noted:

“in general, genera of Asiatic origin are concentrated in northern and central Alaska.”

Fusulinids – Dutro and Silberling (1988) noted the first and only record of Permian fusulinids from northern Alaska. These specimens occur at a depth of 4,279 m (14,040 ft) in the Inigok well and were identified by R.C. Douglass as *Pseudofusulinella* sp. aff. *P. valkenburghae* Petocz. This species was established by Petocz (1970) from his Zone B (correlated with the Wolfcampian) in the central Alaska Range, from rocks now considered to belong to the Wrangellia terrane. This near total dearth of fusulinids in the Permian of the Arctic Alaska appears to be quite significant. I know that fusulinids are relatively common in Arctic Canada up through much of the Early Permian, so their absence in the numerous coeval collections from Arctic Alaska is puzzling. In going

through the major biogeographic publication by Ustritskii (1971) on Carboniferous biogeography of the Arctic entitled "Biostratigrafiya verkhnego paleozoi arktiki", I see that he also notes a near total death (or extreme rarity) of fusulinids in his Eastern Arctic Province (which includes Siberia and the isolated cratonic blocks in NE Siberia - when fusulinids do show up, he reports them there primarily from the Taimyr Peninsula), while he reported them as being common in his Western Arctic Province (including Russian Platform, Novaya Zemlya, Spitsbergen and East Greenland). In this regard, a Siberian origin of Arctic Alaska makes more sense than from the Canadian Arctic Islands.

Gastropods – Permian gastropods were first noted in the Permian of Arctic Alaska in the naming paper for the Siksikpuk Formation (Patton, 1957). Ellis Yochelson was quoted therein (ibid, p. 42) as noting that most of the specimens from the basal part of the formation can be referred to the genus *Straparollus*, and that all of these specimens represent a single unnamed species (subsequently named *Straparollus (Euomphalus) alaskensis* n. sp. by Yochelson and Dutro (1960)). Yochelson and Dutro (1960) undertook a detailed study of Permian gastropods from northern Alaska (all belonging to the Arctic Alaska terrane). Material for this study was derived from the Siksikpuk, Sadlerochit, and a then unnamed Permian formation (later named the Nuka Formation). Euomphalaceans were noted as comprising two-thirds of the Permian gastropod fauna, including two new species: *Straparollus (Euomphalus) alaskensis* and *Amphiscapha (Cylicoscapha) grada*. *Straparollus (Euomphalus) alaskensis* Yochelson and Dutro is present in all three formations. Pleurotomariaceans comprise much of the remainder of the fauna and included the new species *Mourlonia? reloba*, as well as many other types that are poorly preserved. Although the sample size of Permian gastropods from the Arctic Alaska terrane remains too small for full assessment of its affinities, it is worthy to note that none of the typical species for this interval [*Straparollus (Euomphalus) alaskensis*, *Amphiscapha (Cylicoscapha) grada*, *Mourlonia? reloba*, and *Glabrocingulum (Glabrocingulum)* sp.] are now known from the well documented Permian gastropod faunas of the southwestern United States (the so-called tropical Grandian Province of Yancey, 1975), suggesting that some degree of endemism for the northern Alaskan fauna.

Summary of Permian paleobiogeographic affinities of Arctic Alaska terrane:

Some significant differences both in fauna and climatically sensitive sediments exist between Lower Permian (pre-late Artinskian) rocks of the Arctic Alaska terrane and those of the Canadian Arctic Archipelago. Fusulinids are abundant in the Canadian Islands up until early Artinskian time (Thorsteinsson and Tozer, 1970), after which they no longer present. In contrast, fusulinids of Permian age in the Arctic Alaska terrane are known from only a single occurrence in a core from the Inigok Well. There a single species of Wolfcampian age is reported, closely related to a species previously described from the Wrangellia terrane, representing a form not known from the Canadian Arctic Islands. Evaporites and thicker bedded and more pure limestone are also present in the earliest Permian of the Canadian Arctic Islands (Sverdrup Basin), while at the same time in Arctic Alaska evaporites are totally unreported and limestone, when present, occurs in very thin beds, commonly very impure (highly argillaceous or arenaceous). The presence

of evaporites and fusulinids suggest that the marine waters of the Sverdrup Basin were somewhat warmer than those that bathed Arctic Alaska. If the counterclockwise rotational model for the Arctic Alaska was true, one would expect more of less similar conditions. In contrast, northeastern Siberia (as well as most of the Siberian continent) was situated in a much higher paleolatitude (60-90° N) in most current paleogeographic reconstructions for this time interval (see Fig. 14) and deriving Arctic Alaska by rifting from here (rather than from the Canadian Arctic Islands) makes much more sense from the viewpoint of paleobiogeography and climatically sensitive sediment types.

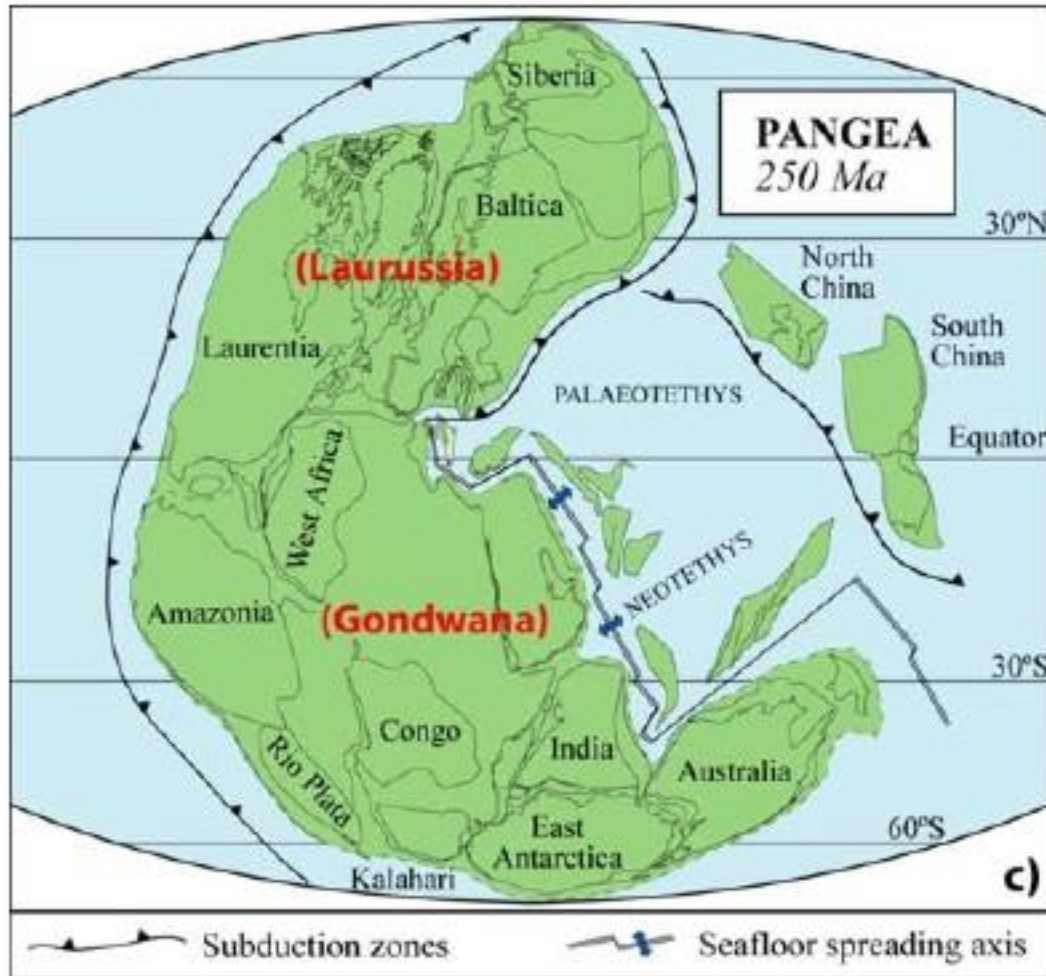


Figure 14. Global reconstruction of Late Permian paleogeography. Note the extreme high latitude position of northeastern Siberia compared to that of the Canadian Arctic Islands (from Torsvik, 2003).

Recommendations for future study:

The single most important item that I feel could be addressed to help resolve the paleogeographic origin of the Arctic Alaska terrane from a Permian perspective would be an intensive new taxonomic review of its contained Permian brachiopod faunas.

Brachiopods are the most common faunal element found in the Permian strata of this terrane, and we now have a considerable amount of published literature (especially from the Russian and Siberian Arctic) to use for comparison. As mentioned above, the major study of paleobiogeography of circum-Arctic Permian brachiopods by Ustritskii (1971) would be a major guiding force in such a study. It would now be relatively easy to distinguish the affinities of our Arctic Alaska faunas, be they with Ustritskii's Eastern Arctic Province (including Siberia) or with his Western Arctic Province (including the northern Russian Platform, Spitsbergen, eastern Greenland, and the Canadian Arctic Islands). Nearly all extant Permian brachiopod collections from northern Alaska are deposited in the USGS collections currently housed in the Smithsonian Institution, and should still be available for study at this time.

TRIASSIC

Triassic strata are widespread across the most of the Arctic Alaska terrane and include a number of stratigraphic units. Detterman and others (1975) provide an excellent overview of Triassic stratigraphy and biostratigraphy for the northeastern Brooks Range, including the following stratigraphic units (from bottom to top): the Lower Triassic Ivishak Formation (Kavik, Ledge Sandstone, and Fire Creek Siltstone Members), the Middle-Upper Triassic Shublik Formation, and overlying Upper Triassic (upper Norian) Karen Creek Sandstone. Mull and others (1982) established the Otuk Formation (Early Triassic-Middle Jurassic in age), the Triassic portion of which appears to represent a more off-shore, distal equivalent of shallower-water Triassic strata represented in surficial outcrops in the northeastern Brooks Range. Much of what was formerly mapped as "cherty" or western facies rocks of the Shublik Formation in the western and central Brooks Range is now placed in the Otuk Formation. The Middle to Late Triassic (early Anisian-late Norian) Shublik Formation is especially notable for being the most richly fossiliferous stratigraphic unit in northern Alaska, rivaled only in fossil abundance (but still in a secondary position) by the Permo-Carboniferous Lisburne Group. The Middle and Upper Triassic strata of both the Shublik Formation and Otuk Formation are especially rich in the remains of the pseudoplanktonic bivalve genera *Daonella*, *Halobia*, and *Monotis*. In fact, it is difficult to land on a single outcrop of middle or late Norian age in Arctic Alaska and not walk away with numerous bags bearing the genus *Monotis*.

Ammonites – Despite their presence in the Triassic strata of the Arctic Alaska terrane, no definitive statements as to the paleobiogeographic affinities of these faunal elements are to be found in the published literature. Antiquated faunal lists of Triassic ammonites are to be found in Martin (1926), and more up to date taxonomic listings can be found in Detterman and others (1975 – the identifications being by N.M. Silberling). The faunal lists from the Lower Triassic beds of the Ivishak Formation listed by Silberling can only be noted as representing relatively high northern paleolatitude assemblages one would expect from other regions of present-day Circum-Arctic, and the same could be said for the limited ammonites listed from Middle and Late Triassic beds of the Shublik Formation.

Brachiopods – Middle and Late Triassic brachiopods are unusually common in the Shublik and Otuk Formations of the Arctic Alaska terrane. Faunal lists showing their presence in Upper Triassic (from rocks now assigned to the Shublik Formation) are to be found in Leffingwell (1919) and Martin (1926), but it should be noted that the generic names were rather broadly conceived at that time and their proper generic assignment will undoubtedly change pending a more detailed, modern study of the same collections. Sandy and Blodgett (2002) in a preliminary study of these older collections, and especially of new collections made by Blodgett from the Otuk Formation, made the following conclusions:

“Cold-water, high-latitude brachiopods are present in the Arctic Alaska terrane, and common in Ladinian-Norian strata of the Shublik and Otuk formations, as well as in probable late Norian-Rhaetian strata of the Sag River Sandstone. Genera found in the Shublik and Otuk formation include *Piarorhynchia*, *Spiriferina*, *Ochotathyris*, and allied to *Aulacothyroides*. The brachiopod fauna of the Shublik and Otuk formations show strong affinities with those of northeastern Russia, showing a high degree of similarity to forms described by Dagys (1965). The limited, probably late Norian-Rhaetian age brachiopod fauna the Sag River Sandstone includes a poorly preserved rhynchonellid brachiopod identified as cf. *Tetrahynchia*.”

The strong affinities of the Middle-Late Triassic brachiopod faunas of the Arctic Alaska terrane with those of northeastern Siberia is not surprising, especially in light of similar findings with coeval ostracodes and some bivalve groups (see discussions below under those respective groups). No close similarities are known with published faunas from the Canadian Arctic Islands (Logan, 1967), although this single study focused on Carnian age faunas, and our knowledge of older and younger Triassic brachiopod faunas from this region still need to be filled in.

Bivalves – Late Triassic bivalves are extremely abundant in the Arctic Alaska terrane, and lengthy faunal lists were provided by early workers (Leffingwell, 1919; Martin, 1926). Subsequently, Late Triassic bivalves from this terrane have been subject to more formal taxonomic and biostratigraphic study (Grant-Mackie and Silberling, 1990; McRoberts, 1992, 1997; Silberling, 1963, 1970, 1985; Silberling and others, 1997; Detterman and others, 1975).

Silberling (1985) is a publication devoted wholly to biogeographic significance of the Upper Triassic (Norian) bivalve genus *Monotis* in Circum-Pacific accreted terranes. In this study he recognized five general types (denoted A-E) of monotid faunas (see Fig. 15). The Arctic Alaska terrane occurrences were assigned to Fauna C, found in northeastern British Columbia, northern Alaska, and northeastern Siberia (South Anyui fold belt and Sikhote Alin), and Japan. Fauna C was recognized by Silberling to be the most taxonomically diverse and geographically widespread of the five *Monotis* faunas. Monotids from the Canadian Arctic Islands were assigned by Silberling to his Fauna D, and on this basis he suggested that the counterclockwise rotation of Arctic Alaska (terrane) away from the northwestern continental margin of Canada was made unlikely (*ibid*, p. 67). He did suggest, however, that before he totally discarded this option, he would like to see this same view confirmed on the basis of biogeographic evidence from other faunal groups. The assignment of monotids from the northernmost part (represented

by the Verkhoyansk fold belt and Kolyma and Omolon massifs) of northeastern Siberia was uncertain to him, and he suggested assignment of this area to an undifferentiated C-D fauna.

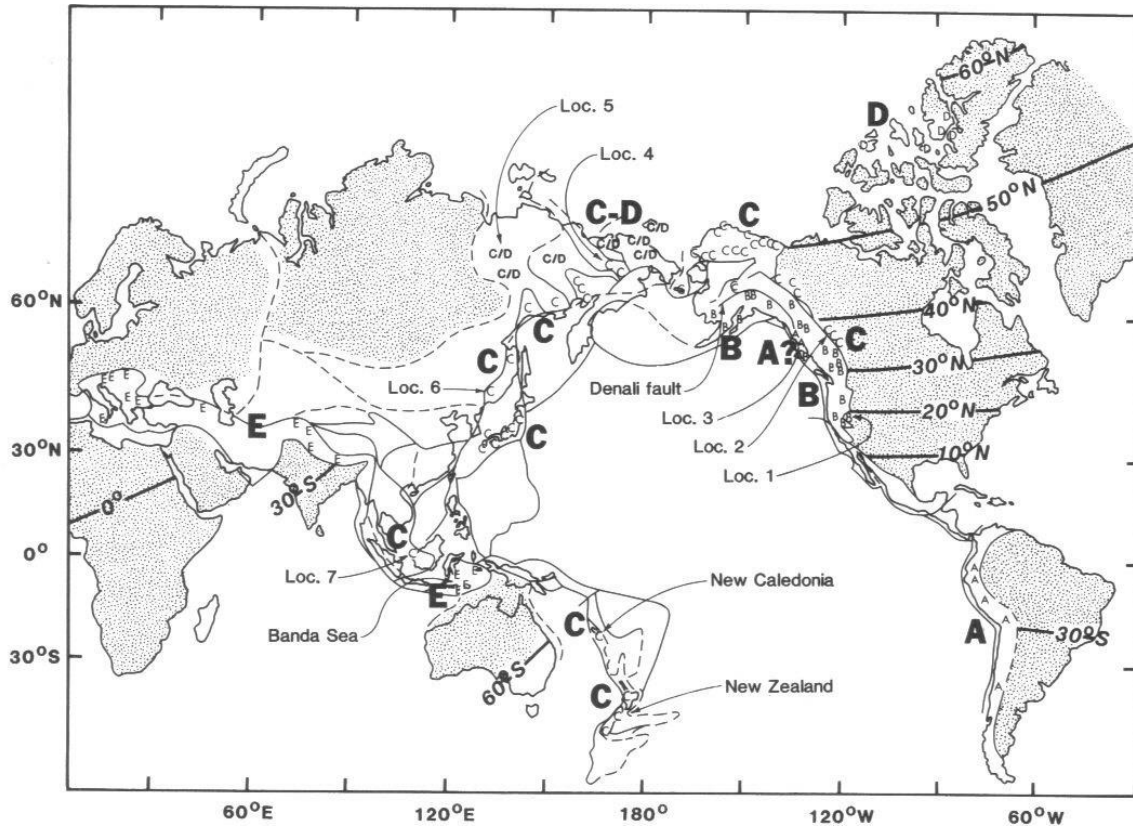


Figure 15: World distribution of *Monotis* faunas A through E (from Silberling, 1985)

Grant-Mackie and Silberling (1990) presented preliminary new information on Upper Triassic *Monotis* species based on their then new collaboration on the group. They recognized two northeastern Siberian species of late Norian age from two of Alaska's accreted terranes. Neither species had previously been reported outside of Siberia: 1.) *Monotis* (*Entomonotis*) *pachypleura* Teller from the beds belonging to (and possibly slightly above) the Columbianus Zone in the Otuk Formation of the Arctic Alaska terrane and 2.) *Monotis* (*Entomonotis*) *anjuensis* Butschkov and Efimova from the Nixon Fork subterrane of the Farewell terrane in the Medfra quadrangle of west-central Alaska.

Silberling and others (1997) provided yet another more exhaustive study of the distribution of the bivalve *Monotis* in Upper Triassic (middle and late Norian) rocks of Alaska. They recognized that the Arctic Alaska terrane contained monotid faunas representing middle, possibly high-middle, northern paleolatitudes, and that these faunas included most of the same species and subspecies and about the same diversity level

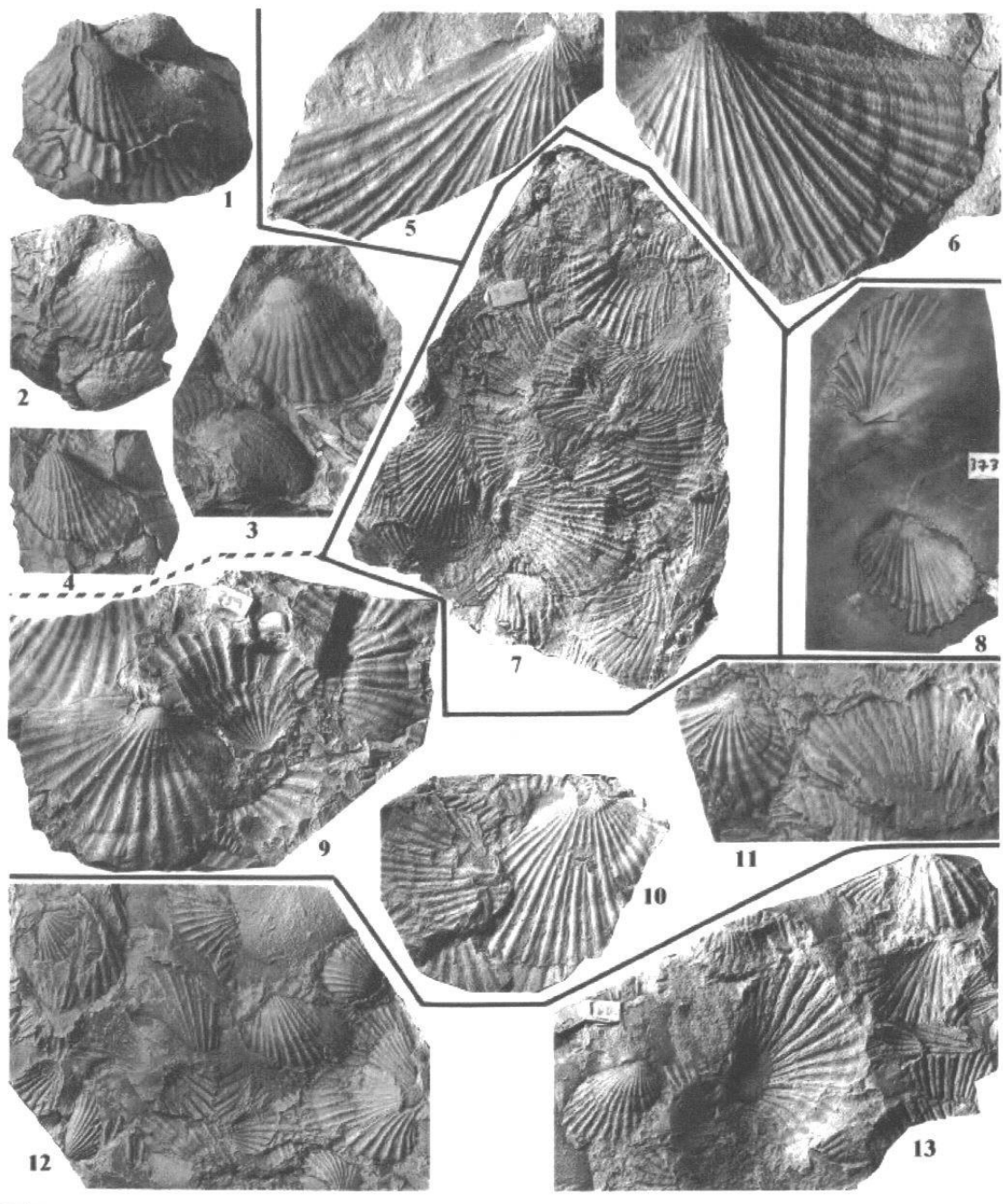


Figure 16. Views of various species of the Upper Triassic *bivalve* *Monotis* which are common in the Arctic Alaska terrane: 1-4, 9-11. *Monotis* (*Entomonotis*) *pachypleura*; 5-6. *Monotis* (*Pacimonotis*) *subcircularis*; 7, *Monotis* (*Eomonotis*) *?typica*; and 8, 12-13. *Monotis* (*Entomonotis*) *ochotica ochotica*. (from Silberling and others, 1997, Plate 9).

throughout the terrane (Silberling and others, 1997, p. 8). They also noted that the following species occur in profusion: *Monotis (Entomonotis) ochotica ochotica* (Figs. 16.8 16.12-13), *M. (Pacimonotis) subcircularis* (Figs. 16.5-6), *M. (Eomonotis) pinensis*, *M. (Eomonotis) obtusicastrata*, and *M. (Eomonotis) typica* (Fig. 16.7); while *Monotis (Entomonotis) pachypleura* (Figs. 16.1-4, 9-11) is well represented only in the western exposures of the Otuk Formation. Known from only one locality in the Arctic Alaska terrane is a monotid they identified as *M. (Eomonotis) aff. M. (Eo.) anjuensis*. Of the monotid species listed immediately above, *Monotis (Entomonotis) ochotica ochotica*, *M. (Eomonotis) obtusicastrata*, *Monotis (Entomonotis) pachypleura*, and *M. (Eomonotis) aff. M. (Eo.) anjuensis* are unknown from the Canadian Arctic Islands (where one would expect their presence if the “windshield wiper” model was true), but are typical of northeastern Siberia [and in a few cases also in accreted terranes of southwestern Alaska (such as the Nixon Fork and Goodnews)] and to a lesser degree western Canada.

McRoberts (1992) reviewed the then known distribution of the Late Triassic representatives of the oyster genus *Gryphaea* from North America. He recognized two species in the Shublik Formation in the northeastern Brooks Range: *Gryphaea (Gryphaea) arcuataeformis* Kiparisova and *G. cf. Gryphaea (Gryphaea) keilhaui* Böhm. The former species was noted by McRoberts to occur in northeastern Oregon, northeastern British Columbia, northeastern Brooks Range, the Canadian Arctic Islands and northeast Siberia (where it was originally described), while the second taxon was reported as being known from the northeastern Brooks Range, northeastern Siberia (Omolon River area), Spitsbergen and the Canadian Arctic Islands. [Note by R.B. Blodgett – Detterman and others (1975, p. 43) also report an even higher occurrence of *Gryphaea keilhaui* Böhm from the late Norian age Karen Creek Sandstone, which immediately overlies the Shublik Formation].

Corals and Hydrozoans - Warm-water elements such as scleractinian corals and hydrozoans (i.e., the widespread Norian genus *Heterastridium*) have not been found in Upper Triassic strata of the Arctic Alaska terrane, suggesting that this terrane (unlike the accreted terranes of southern Alaska of tropical origin) was situated in a relatively cool-water, temperate setting.

Foraminifera – The first Triassic Foraminifera to be described from North America were from Arctic Alaska (Tappan, 1951a, b), and the study by Tappan (1951b) remains a major monographic source of knowledge for this group. Subsequent published studies on Triassic foraminiferid biotas from the Arctic Alaska terrane include Bergquist (1960, 1966, 1970). To date, no published synthesis has yet appeared in print to my knowledge relating to the paleobiogeographic affinities of Arctic Alaska Triassic Foraminifera in relation to other coeval biotas around the world.

Gastropods – Gastropods are poorly represented in the Upper Triassic of the Arctic Alaska. Martin (1926) listed only four identifiable forms (identified by T.W. Stanton) from the Shublik Formation: *Pleurotomaria*, *Pleurotomaria?*, *Natica?*, and undetermined gastropods (small). The common use of the question mark after the genus name suggests that the examined material was very poorly preserved. I had the opportunity several

years ago to examine the USGS Triassic megafossil collections that are reposit in a USGS storage facility in Denver. My hurried examination of the Arctic Alaska collections revealed no Triassic gastropods with preserved shell material; all specimens I observed consisted of indeterminate internal molds (steinkerns). This is unfortunate, as gastropods have proven to be the most definitive paleobiogeographic indicator in Upper Triassic shallow marine facies rocks of the accreted terranes of southern Alaska (Blodgett and Frýda, 2001; Blodgett and others, 2003, 2005; Frýda and Blodgett, 2001).

Ostracodes – Four publications have been issued which deal with Middle and Late Triassic age ostracode faunas from the Arctic Alaska terrane (Sohn, 1964, 1984a, 1984b, 1987). As a point of fact, Sohn (1964) study was the first paper to chronicle marine Triassic ostracodes in North America. Sohn (1987) provided an overview of all known Triassic ostracodes from Arctic Alaska, most of which were derived from the reference section of the Shublik Formation designated by Detterman and others (1975) near Fire Creek in the Mt. Michaelson quadrangle. Both Middle and Late Triassic age ostracode faunas were documented by Sohn in this paper. In terms of paleobiogeographic affinities of the Shublik ostracodes, he noted (ibid, p. C1) that:

“Related genera have been recorded from the Middle Triassic of the Primor’ye Zoogeographical Province of the Pacific Realm and from the Middle and Upper Triassic in the Tethyan Zoogeographical Province of Eurasia.”

The close affinities with Primor’ye (part of maritime eastern Siberia) is intriguing in light of the eastern Siberian affinities noted above by the Late Triassic brachiopods, and to a lesser degree by the bivalves. Sohn (1984b, 1987) also noted the strong contrast between in diversity and generic content of Triassic ostracode assemblages from Arctic Alaska terrane those from Nevada (from strata more or less in-situ with respect to the North American craton) and warmer water accreted terranes such as Stikinia from western Canada (based on material from Lime Peak, Yukon Territory). The Nevadan and Stikinia collections were noted as being more diverse and generically quite different from those of Arctic Alaska.

Radiolaria – Publications dealing with Triassic radiolarian faunas of the Arctic Alaska terrane include Blome (1987), Blome and Reed (1986), Blome and others (1988), Reed and Blome (1986), and Swain (1981). Blome (1987) summarized radiolarian faunas known from the Upper Triassic and Jurassic of the Brooks Range (Arctic Alaska terrane), considering them to be quite distinct paleogeographically from all other Cordilleran terranes (he believed the latter to be of a more southern origin), summarizing them as follows (ibid, p. 377):

“Early to middle Karnian Brooks Range faunas are characterized by abundant species belonging to the genus *Pseudostylosphaera*. Species of *Eptingium* are abundant in faunas from the Brooks Range, but are nearly absent in other Cordilleran faunas. Low-paleolatitude late Karnian to late middle Norian radiolarian faunas are characterized by abundant (ave. 8 species per 200 specimens counted) species of the genus *Capnodoce* whereas Brooks Range equivalents are *Capnodoce*-poor in both abundance and diversity values. In contrast, species belonging to the genus *Capnuhosphaera* are more abundant in Brooks are more abundant in

Brooks Range faunal assemblages.” “Low-latitude accreted terranes, such as “Wrangellia,” contain abundant and diverse late Norian species of the genera *Ferresium* and *Pantanellium*, whereas late Norian Brooks Range faunas are relatively ferresid- and pantanellid-poor.” “Overall, the Brooks Range radiolarian faunas contain different species, and in most cases, less abundant species for several generic groups compared to generic abundances for other coeval Cordilleran faunas.”

Ichthyosaurs – The presence of abundant vertebrate bone material in the Shublik Formation has long been noted (Leffingwell, 1919; Martin, 1926; Patton and TAILLEUR, 1964). Most of this bone material now appears to be attributable to ichthyosaurs, a major Mesozoic group of marine reptiles. TAILLEUR and others (1973) documented the presence of a well-preserved skeleton in the Brooks Range [note: this skeleton was recently removed from the outcrop and is now deposited in the University of Alaska Museum in Fairbanks] and DETTERMAN and others (1975) made the following comment regarding ichthyosaur and bone remains recovered during their study of the Shublik Formation:

“Numerous vertebrate fragments were found in the limestone member on the north side of Ignek Valley near the west end of the Sadlerochit Mountains. According to C.A. Repenning of the USGS, these bones represent the ichthyosaur family Shastosauridae (written commun., 1972). Unidentifiable bone fragments are present in other collections from the member.”

Pisces (Fish) – The presence of the Early-Middle Triassic paleoniscoid fish genus *Boreosomus*, represented by a few bone fragments, in the Killik-Itkillik Rivers region has been noted several times in the literature (Kummel *in* Reeside and others, 1957; Patton and TAILLEUR, 1964, p. 437; and DETTERMAN and others, 1975, p. 14). This occurrence was in beds of unit 11 of the shale member of the Shublik Formation on Tiglukpuk Creek [this occurrence is now placed in the Otuk Formation of Mull and others (1982)] according to Patton and TAILLEUR (1964), as was thought to be of Middle Triassic age, though it was also considered to possibly be of Early Triassic in part. The genus *Boreosomus* is presently known from Lower and Middle Triassic (Induan-Ladinian) strata, and is seemingly common in the Circum-Arctic Triassic, being known from eastern Greenland and Spitsbergen, but is also known from Madagascar (Carroll, 1988). According to D.H. Dunkle *in* Patton and TAILLEUR (1964, p. 437):

“Collection 53APa118 is the incomplete and macerated skeleton of the marine paleoniscoid fish *Boreosomus*. This individual does not show the detailed structural features upon which specific definitions within this genus have been based and for convenience it can be tentatively referred to the genotype species *B. arcticus* Stensio.”

The genotype species referred to, *Boreosomus arcticus* Stensio, was established on the basis of Early Triassic age material from east Greenland. Other fish remains have been noted in the Shublik and/or Otuk Formation (i.e., Patton and TAILLEUR, 1964, p. 436), and possibly would be of significant paleobiogeographic implications pending their study.

Summary of Triassic paleobiogeographic affinities of Arctic Alaska terrane:

The complete absence of scleractinian corals and the hydrozoan genus *Heterastridium* (extremely common in tropical marine waters of the Upper Triassic) indicate that during Triassic time the Arctic Alaska terrane was situated in a relatively high-latitude, temperate to cool-water setting. Studies made to date on Middle and Late Triassic bivalve, brachiopod, and to a lesser degree ostracode faunas from Arctic Alaska indicate that this terrane was more closely associated with northeastern Siberia, rather than with the Canadian Arctic Islands. Silberling (1985), in fact, made a strong case that the Windshield Wiper model (counter-clockwise rotation away from the Canadian Arctic) was untenable based on the general character of the monotid faunas he recognized in the Circum-Pacific region.

Recommendations for future study:

- 1.) The Shublik Formation is the most richly fossiliferous stratigraphic unit in the Arctic Alaska terrane (Detterman and others, 1975, p. 16). Despite a number of published papers on certain portions of the megafauna, many faunal groups remain to be inventoried, described, and photographed for documentation from this unit. Whilst the bivalves have been studied in terms of such widespread biogeographically widespread groups such as the monotids and halobiids (both thought to have existed pseudoplanktonic life modes), other more endemic groups (excepting the gryphaeids studied by McRoberts) remain for intensive study. Vast collections made by the USGS are now housed in their Denver Warehouse and are available for study by interested geoscientists. These collections include both surficial samples and much material extracted from NPRA cores. I was particularly impressed during a visit to this facility that bivalve-dominated near-shore facies collections were present in borehole material from the Barrow Arch. Although I was not particularly interested at the time (my purpose was then to gather Triassic gastropods), I noted many familiar forms which I believe represent common Upper Triassic taxa (Norian-Rhaetian) in Japan and eastern Siberia. In light of the eastern Siberian affinities mentioned for both the Late Triassic brachiopod and ostracode faunas, studies other groups (i.e, the bivalves mentioned here and the ichthyosaurs mentioned below) may have significant paleogeographic implications.
- 4.) An intensive taxonomic study of Upper Triassic brachiopods from both the Shublik and Otuk Formations should be undertaken. I have gathered together currently available USGS collections (from Denver) as well as my own extensive collections from the Otuk Formation and have passed these on to Dr. Michael R. Sandy, University of Dayton, Dayton, Ohio for study. A preliminary study (Sandy and Blodgett, 2002) resulted in a published abstract. Work done to date with these faunas show an uncanny resemblance with coeval faunas described by Dagys (1965) from northeastern Siberia, which I believe is accord with biogeographic data garnered from Triassic ostracodes and some bivalve groups. Concerted efforts should be made to encourage further work by Michael Sandy on

the Middle-Late Triassic brachiopods of the Arctic Alaska terrane. As noted above, he has considerable material at his disposal, and the only other possibility of additional study on his part would be a trip to visit the Geological Survey of Canada collections in Ottawa (possibly also Vancouver, B.C.) to examine counterpart Triassic collections from the Canadian Arctic Islands.

- 5.) Ichthyosaur bones (mostly isolated bones, but also partial to nearly complete skeletons) are known from a number of sites in Upper Triassic strata of the Shublik Formation across the length of Brooks Range (most of the material is derived from the Shublik Mountains area (Mt. Michaelson quadrangle), but bones are also noted in the western Brooks Range near Bombardment Creek in the Wiseman D-2 quadrangle (M. Churkin, Jr., oral communication, 1984). Considerable knowledge now exists on the distribution of this fossil marine reptile group, and a systematic survey of all available material from Arctic Alaska would be a useful study from a paleobiogeographic point of view. Some recent work has been conducted on Alaskan ichthyosaur material, unfortunately only from the Alexander terrane of southeastern Alaska (Adams, 2006), which was situated in a much more southerly (equatorial position) than the Arctic Alaska terrane. It is recommended that a highly competent specialist in the taxonomy of this group take the charge in such a study, two primary candidates who come to mind are: 1.) Dr. Olivier Rieppel at the Field Museum in Chicago (he has already expressed an interest in such a project); and 2.) Dr. Ryosuke Motani at the University of California at Davis, Calif. Material for this study reposes primarily in the USGS Triassic collections housed at the USGS storage facility in Denver, CO., but additional material (a partially complete skeleton) is present now in the collections of the University of Alaska Fairbanks.

JURASSIC

Jurassic rocks are relatively well known from surficial exposures (Fig. 17) across the length of northern Alaska (Imlay, 1950; Imlay and Detterman, 1983) and several elements of its fossil biota have received considerable study, notably bivalves, ammonites, and crinoids. The most thorough overview of Jurassic stratigraphy of the Arctic Alaska can be found in Imlay and Detterman, 1973, p. 9 and 14, 16, also Fig. 11). An earlier review of Jurassic stratigraphy of Arctic Alaska can also be found in Imlay (1955, p. 70-73). Virtually all our current knowledge of the Jurassic of Alaska is due to immense outpouring of work by the USGS paleontologist, Ralph W. Imlay (now deceased), and who specialized in Jurassic and Lower Cretaceous faunas of North America.

Ammonites – Description and/or discussion of Jurassic ammonite faunas of the Arctic Alaska terrane are found in the following publications: Imlay (1955, 1976, 1981a ,b, 1984); Imlay and Detterman (1973); Callomon (1984); Taylor and others (1984), and Howarth (1973).

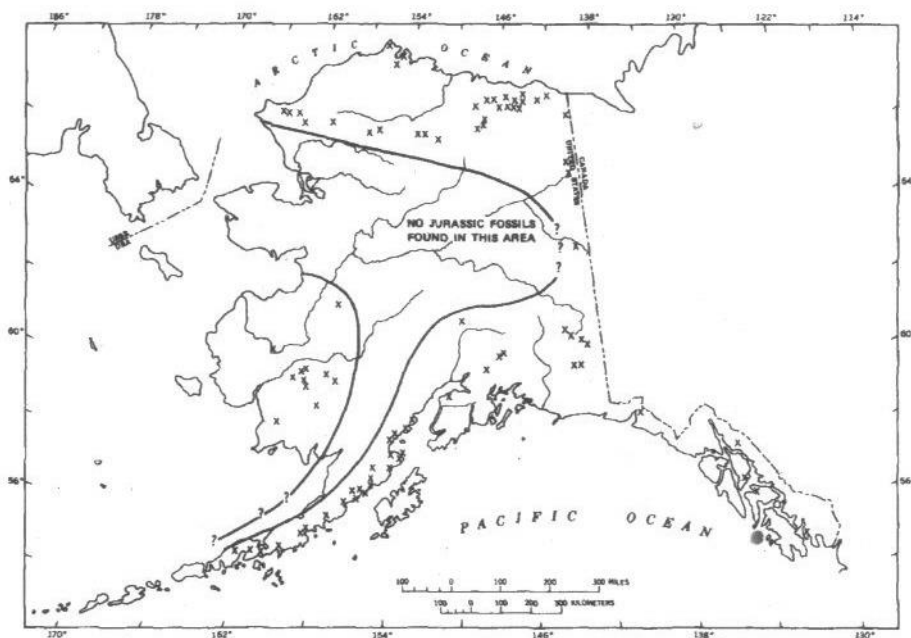


Figure 17. Distribution of Jurassic fossils in Alaska of all stages (from Imlay and Detterman, 1973)

Imlay (1981b) provided a comprehensive review of known ammonite faunas from the Lower Jurassic of Alaska. He noted that outcrops in northern Alaska are typically poorly exposed and sparsely fossiliferous, but did yield ammonites of Pliensbachian and Toarcian age, and perhaps even Sinemurian age. In contrast, the Lower Jurassic found in the subsurface of northern Alaska (along the coastal plain) differed from those in the surface in “containing minor amounts of glauconitic sandstone, by being somewhat more fossiliferous, and by containing ammonites representing all Lower Jurassic stages” (*ibid*, p. 5). He also noted these subsurface beds did not yield any ammonites of middle Sinemurian to middle Pliensbachian age, or late Toarcian. In terms of paleobiogeography, Imlay (1981a, p. 18) stated that:

“No distinct ammonite faunal province existed in Alaska during most of Early Jurassic time, as shown by the remarkable resemblance of most of the ammonites present to those elsewhere in the world. During late Pliensbachian time, a close tie with northern Europe is shown by the presence of *Amaltheus* in northern Alaska and in the Talkeetna Mountains of southern Alaska.”

Imlay (1976) provided a detailed summary of then current knowledge of Middle Jurassic ammonite faunas from northern Alaska. He recognized that the both the Bajocian and Bathonian faunas were closely similar to those in northern Canada and probably lived in the same faunal province. He also noted that some common species were shared in common with faunas of the same age (both Bajocian and Bathonian) from southern Alaska, indicating some connection between the marine seaways of both regions, although he also indicated that the northern Alaskan faunas were less varied in terms of diversity.

Imlay (1981b) summarized knowledge on Late Jurassic ammonite faunas from throughout the state of Alaska. He recognized Late Jurassic ammonites in northern Alaska are found only in the Mt. Michelson quadrangle (in the Kingak Shale) from the East Fork of the Shaviovik River eastward about 40 miles (64 kilometers) to Fire Creek. Few ammonite taxa of Late Jurassic were recognized (see Table 4 therein), but those specifically mentioned included the subgenus *Cardioceras* (*Scarburgiceras*) from Ignek Mesa, the subgenera *Amoeboceras* (*Prionodoceras*) and *Amoeboceras* (*Amoebites*) from the Canning River area, as well as the genera *Phylloceras* and *Partschiceras*. No paleobiogeographic affinities for the Arctic Alaska Late Jurassic ammonite fauna was indicated in this publication.

Bivalves – Publications dealing directly with Jurassic bivalve faunas of the Arctic Alaska terrane include Imlay (1955, 1959, 1967, 1970), Detterman and others (1975) and Reiser (1970).

Imlay (1967) described a new species of the monotid genus *Otapiria*, *O. tailleuri*, originally considered to be from beds of Toarcian-early Bajocian (late Early Jurassic-earliest Middle Jurassic) age in the northern foothills of the Brooks Range. Subsequently, its age has been refined, and is more recently considered to be of Sinemurian age (Imlay and Detterman, 1973, p. 17; Detterman and others, 1975, p. 19; Imlay, 1981a, p. 4). This species is rather widespread across the length of the Brooks Range (Fig. 18) and is an easily recognizable index fossil (Fig. 19) in northern Alaska. Its occurrence in the northern foothills of the Brooks Range is unusual in that it almost always associated with an organic shale interval that directly overlies Upper Triassic beds of the Shublik Formation, with most of the intervening underlying Lower Jurassic seemingly absent. The genus *Otapiria* is biogeographically significant and has a fairly wide distribution in the Upper Triassic and Early Jurassic of the Circum-Pacific region (represented by at 9-10 species), where it was essentially restricted (Damborenea and others, 1992), being known from western South America, New Zealand, northern Alaska, and the Northeast and Far-East of Russia. The Brooks Range occurrences of *O. tailleuri*, like that of other members of this genus (Hallam, 1977, p. 62) is typically in huge numbers, covering whole bedding places, associated with ammonites but little other fauna, suggestive of an opportunistic adaptive strategy. *Otapiria tailleuri* Imlay is morphologically closest to two other species of this genus: *O. limaeformis* Zakharov, 1962, from North-East Siberia and the type species of *Otapiria*, *O. marshalli* (Trechmann) from New Zealand. Outside of the Arctic Alaska terrane occurrences, *O. tailleuri* has been noted in the literature only in western Canada, where it was reported from Sinemurian age strata of the Fernie Formation in British Columbia (Aberhan, 1998) and in early Sinemurian strata of the central Omolon Massif in northeastern Siberia (Sey and others, 1992, p. 238). Terry Poulton, Geological Survey of Canada paleontologist, confirms preliminary identifications (mostly unpublished) of this genus in Lower Jurassic rocks of southeastern British Columbia, northeastern British Columbia (Ferne Formation, many occurrences), Queen Charlotte Islands (one occurrence), and in northern Yukon Territory in rocks that represent the eastern terminus of the Arctic Alaska terrane [see Poulton (1991 for Yukon Territory occurrence)]. The genus *Otapira* has not yet been reported from the Canadian

Arctic Islands (confirmed by Poulton), and its extreme abundance in the Lower Jurassic of the Arctic Alaska terrane would seemingly require its appearance in the Canadian Arctic Islands if the Windshield-Wiper model was true!

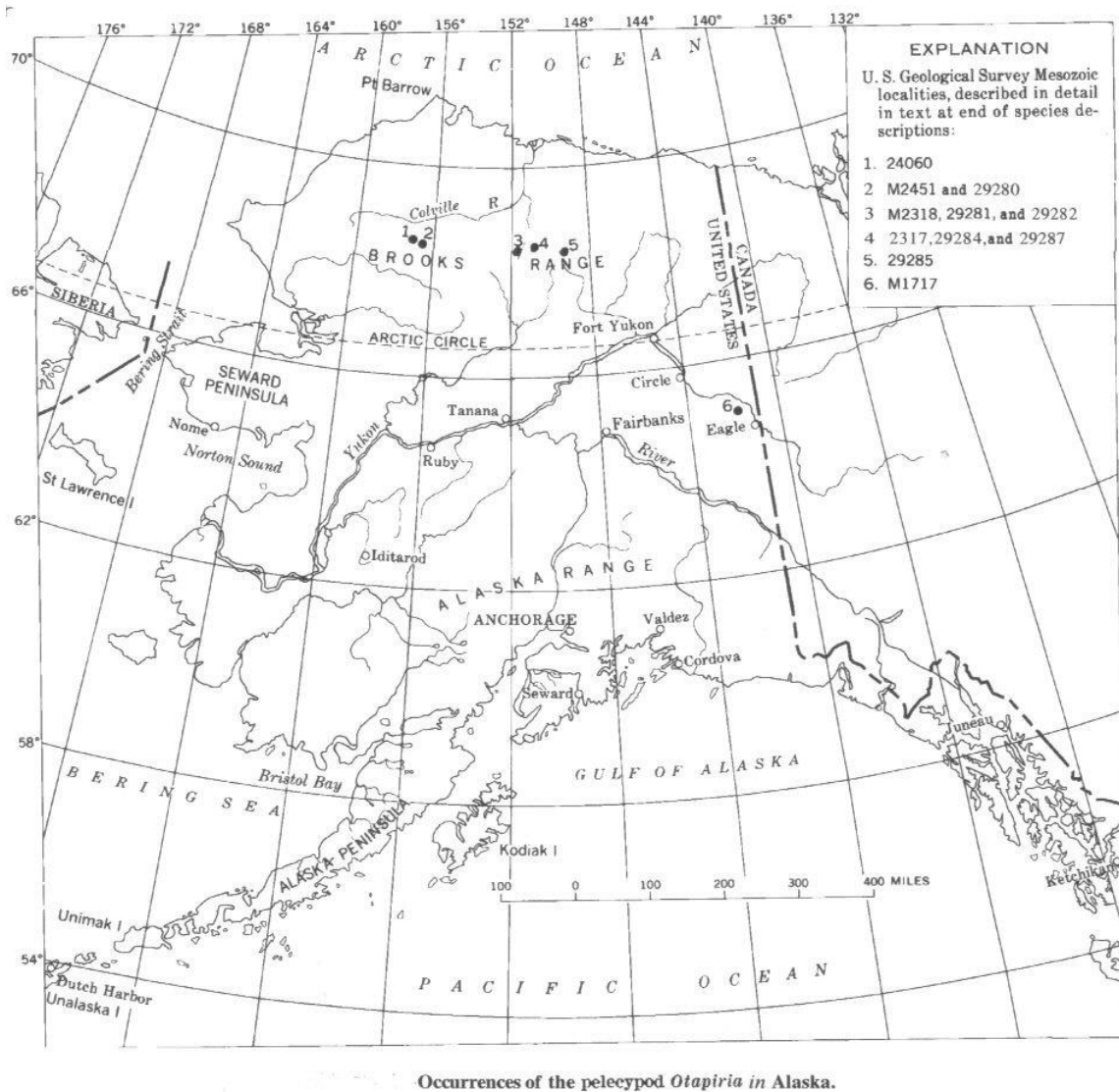


Figure 18. Occurrence of the bivalve *Otapiria tailleuri* Imlay, 1967 in northern Alaska (according to Imlay, 1967). This species is now known from many more new localities (see Alaska Paleontological Website: www.alaskafossil.org)

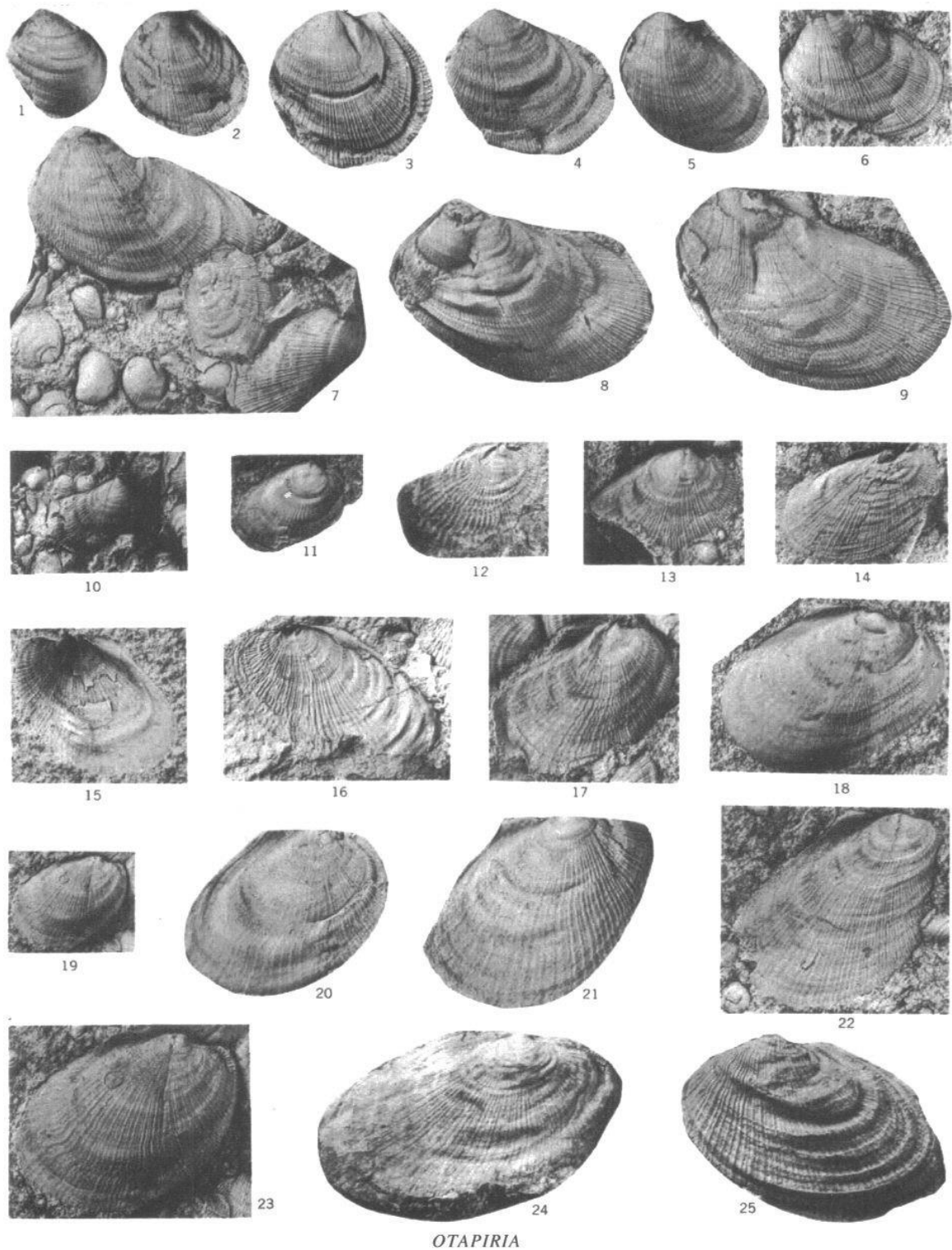


Figure 19. Various views of *Otapiria tailleuri* Imlay, 1967, an important index fossil in Sinemurian (Early Jurassic) strata of the Arctic Alaska terrane (from Imlay, 1967, Plate 1)

Imlay (1959) in his now classic study of the bivalve genus *Aucella* (now referred to as *Buchia*) illustrated a number of specimens from the Arctic Alaska terrane, including *Buchia rugosa* (Fischer) and *Buchia mosquensis* (von Buch). The bivalve *Buchia* dominated shelfal communities of the Upper Jurassic of Boreal Realm of the high-latitude regions of the northern Hemisphere. Unfortunately the widespread distribution of *Buchia* species in the Boreal Realm precludes its use of paleobiogeographic differentiation of Circum-Arctic terranes.

Imlay (1955) provided limited discussion of bivalves from Jurassic strata of the Kingak Shale within the Arctic Alaska terrane, notably *Gryphaea* cf. *G. cymbium* Lamarck from the Lower Jurassic (illustrated on Pl. 8, figs. 2-4), *Posidonia* cf. *P. ornata* Quenstedt from the basal Middle Jurassic (illustrated on Pl. 10, fig. 21 therein), the lower Middle Jurassic (Bajocian) species *Inoceramus lucifer* Eichwald (discussed, but not illustrated by Arctic Alaskan specimens), as well as several species of *Buchia* (referred therein to the genus *Aucella*) from the Upper Jurassic.

Corals – Jurassic age corals are unknown anywhere in the Arctic Alaska terrane, suggesting a moderately cool high-latitude paleogeographic setting. In contrast, scleractinian corals are present in limited numbers within Lower Jurassic strata of accreted terranes of southern Alaska (notably the Peninsular terrane). No scleractinian corals are known from Jurassic rocks younger than the Early Jurassic.

Echinoderms – Springer (1925) described a new variety of the crinoid genus *Pentacrinus* from the Lower Jurassic of the northeastern Brooks Range (Kingak Shale), *Pentacrinus subangularis* var. *alaska*, which is now known from a number of sites. Further discussion on the distribution and occurrence of *Pentacrinus* in northern Alaska (Arctic Alaska terrane) can be found in Leffingwell (1919), Imlay (1955, 1967), and Detterman and others (1975). The genus *Pentacrinus* is extremely widespread in the Jurassic, and has no significant paleobiogeographic implications for this study.

Foraminifera – Tappan (1955) provided a magnificent study of North Slope Jurassic Foraminifera, with over 111 species described including the first Lower Jurassic taxa to be established from the Western Hemisphere. Further studies referring to Jurassic foraminiferid faunas of the Jurassic of the Arctic Alaska terrane include: Bergquist (1970), Mickey and Haga (1987); Reifentstahl and Plumb (1993); and Witmer and others (1981). No paleobiogeographic studies have yet been issued to my knowledge pertaining to Jurassic foraminiferid faunas of Alaska or North America.

Radiolaria – References to Jurassic radiolarian faunas of the Arctic Alaska terrane can be found in Blome (1987), Blome and Reed (1986), and Blome and others (1988). As with the early Late Triassic radiolarian fauna discussed earlier, Blome (1987, p. 375) likewise considered the Arctic Alaska terrane Jurassic radiolarian flora to be very different from coeval faunas in other parts of the western Cordillera.

Summary of Jurassic paleobiogeographic affinities of Arctic Alaska terrane:

Ammonite faunas from the Arctic Alaska terrane are too cosmopolitan (widespread regionally) to definitively tie down the paleogeographic position of this terrane for most of the Jurassic. However, Middle Jurassic ammonite faunas of Arctic Alaska terrane were more or less similar to those northern Canada (Imlay, 1976), in passive agreement with the view that the Brooks Range was starting to form from the collision of the Arctic Alaska terrane with terranes to the south. Upper Jurassic faunas (ammonites and bivalves) from the Arctic Alaska terrane are of a generalized Boreal region character (dominated by the widespread distribution of the bivalve genus *Buchia*). The strongest line for faunal differentiation comes from the Lower Jurassic (Sinemurian) bivalve *Otapiria tailleuri* Imlay, 1973, which is widespread across the length of Arctic Alaska. This distinctive species is not known anywhere in the Canadian Arctic Islands (confirmed by phone conversation with Terry Poulton, Geological Survey of Canada paleontologist, 8/17/06), and hence, is not compatible with the Windshield-Wiper model of counterclockwise of the Arctic Alaska terrane. The species is closest morphologically with a coeval species from northeastern Siberia (*Otapiria limaeformis* Zakharov, 1962). Only one occurrence of *O. tailleuri* is documented by illustrated material in the literature outside of the Arctic Alaska terrane – that by Aberhan (1998) from the Fernie Formation (on the cratonic margin of western North America) in British Columbia. The species is also reported to be present in early Sinemurian age strata in the Omolon Massif of northeastern Siberia (Sey and others, 1992). Hence, the limited information at hand suggests strong faunal linkages of the Arctic Alaska terrane Lower Jurassic bivalve fauna with that of northeastern Siberia and western Canada. Based on the evidence from *Otapiria*, the paleogeographic position of Arctic Alaska terrane during the Early Jurassic would thus appear to be tied closely to northeastern Siberia, or in a position between northeastern Siberia and northwestern Canada, but not in the Canadian Arctic Islands.

Recommendations for future study: Due to the cool-water character of the Boreal Realm Upper Jurassic fauna which resulted in a more or less undifferentiated, low diversity fauna found throughout the Circum-Arctic region, little future work can be suggested for the Upper Jurassic, or for that matter even with the Middle Jurassic.

However, the Lower Jurassic still provides evidence of considerable faunal differentiation in the Circum-Arctic and adjoining regions, especially with the bivalve faunas. Hence, I would recommend a intensive search for Lower Jurassic bivalves from both surficial outcrops and core materials. Much work has been done during the past several decades with Early Jurassic (and also Late Triassic) bivalve faunas from the Circum-Pacific region (western Canada, Japan, but especially in northeast Siberia), so that we now have a good census of shelfal bivalve communities and taxa for this interval. Bivalves have varying levels of larval dispersal, but in general are much less widely distributed than ammonites, making the former group more useful for use in paleobiogeographic applications in modeling past paleogeographies. Hence, I think a detailed census of bivalves from Lower Jurassic strata of the Arctic Alaska terrane would be most useful in throwing further light on where this terrane was at during the Early Jurassic. Such a study should entail a trip to examine the USGS Lower Jurassic fossil

collections in the National Museum of Natural History (curated by R.W. Imlay), as well as an intensive search of core materials at the Geologic Materials Center in Eagle River, Alaska. The South Barrow Test Well #12 yielded a large number of Lower Jurassic bivalves such *Otapiria tailleuri* Imlay (mostly), but other bivalves such as *Eopecten*, *Eopecten?*, and *Lima?* sp. were also reported in an E&R report (dated 01/29/1975) by R.W. Imlay to Irv L. Tailleux. In terms of resampling surficial outcrops, Gil Mull (oral communication, August 2006) recommends visiting the highly condensed Lower Jurassic section exposed along Cobblestone Creek in the Chandler Lake C-1 quadrangle.

EARLY CRETACEOUS

Ammonites – Ammonites were rare throughout much of the Early Cretaceous of the Arctic Alaska terrane, making their first reappearance (since the Valanginian) in Albian time (Imlay, 1961; Callomon, 1984, p. 167). Only two ammonite genera or subgenera *Phylloceras* (*Phylloceras*) and *Lytoceras* were reported by Imlay (1961) from the pre-Albian Lower Cretaceous of northern Alaska. Their nearly complete absence in the Berriasian and Valanginian suggests to the writer that the marine waters of this region were too cold to support diverse ammonite populations. In marked contrast, Neocomian age strata of the Canadian Arctic Island (northern Sverdrup Basin) contain a relatively rich succession of ammonites, their faunal succession being summarized by Jeletzky (1973). Albian ammonites from northern Alaska (Arctic Alaska terrane) were noted by Imlay (1961, p. 12) to include many species (referring to both ammonites and bivalves) that “were originally described from northeastern British Columbia and northern Alberta. The same fauna is widespread in the Yukon basin of central Alaska.” Taxa previously recognized in the Albian of the western Canadian provinces (Alberta and northeastern British Columbia) included *Beudanticeras* (*Grantziceras*) *affine* (Whiteaves), *Subarcthioplites bellii* (McLearn), *Gastropolites kingi* McLearn, and *Paragastropolites spiekeri* (McLearn). In addition, however, a number of new endemic ammonite taxa (both genera and species) were established by Imlay (1961). Overall, the high degree of similarity of the Early Cretaceous ammonites and bivalves of Arctic Alaska with those found to the east in cratonic Canada is in accordance with the Arctic Alaska terrane time having already accreted or being in the process of collision by this time.

Bivalves – Publications dealing with Early Cretaceous bivalve faunas of the Arctic Alaska terrane include: Imlay (1959, 1961), Elder (1992, 2001), and Elder and others (1991). Imlay (1961) described and illustrated four species of the genus *Buchia* (referred to as the genus *Aucella* therein) occurring in the Berriasian-Valanginian age Okpikruak Formation: *Buchia okensis* Pavlow, *Buchia subokensis* Pavlow, *Buchia sublaevis* Keyserling, and *Buchia crassicollis* (Keyserling). These four species, which virtually dominate the megafauna of the Okpikruak Formation to exclusion of nearly all other taxa, are widespread in throughout Circum-Arctic early Early Cretaceous Boreal faunas and are found in Circum-Arctic portions of Russia and Siberia, the Canadian Arctic Islands, and western Canada as far south as British Columbia. As with the aforementioned Albian ammonite faunas of the Arctic Alaska terrane, Imlay also noted the Albian bivalves of the same area were very similar to those (especially during the middle Albian) of northeastern British Columbia and Alberta, sharing many of the same named species (i.e.,

Yoldia kissoumi McLearn, *Dicranodonta dowlingi* McLearn, *Astarte portana* McLearn, *Tancredia stelcki* McLearn, *Pleuromya sikanni* McLearn, *Panope? kissoumi* (McLearn), *Panope? elongatissima* (McLearn), *Goniomya matonabbei* McLearn, *Thracia stelcki* McLearn, *Oxytoma camselli* McLearn and *Aucellina dowlingi* McLearn). Imlay also noted similarities to the Albian faunas of Greenland, northern Russia, and northern Siberia.

The strongly shared taxonomic content of Early Cretaceous bivalve faunas of the Arctic Alaska terrane is in concord with the predominant view that that this terrane was either in the process of accreting or had already accreted with much of the rest of Alaska by this time.

Summary of Early Cretaceous paleobiogeographic affinities of Arctic Alaska terrane:

The available evidence from the numerous collections of Lower Cretaceous fossil fauna from Arctic Alaska terrane strongly indicate that it was more or less in its present-day geographic orientation. Virtually no faunal differentiation separates it from those known to east in the northern Yukon and further to southeast down the Interior Seaway.

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