Devonian-Pennsylvanian Paleogeographic Reconstructions (based on Paleobiogeography) of the Arctic Alaska Terrane and its relation to Sedimentary-Hosted Ore Deposits

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Final Report

By

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Abstract: This report provides an overview of Arctic Alaska terrane faunas and floras of Devonian to Pennsylvanian age in order to better constrain speculation as to the paleogeographic origin of the terrane, host to World Class sedimentary-hosted mineral deposits. At present the two most popular models for origin of this terrane 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.

Devonian marine faunas show a strongly consistent Siberian affinity. 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.

In summary, this overview of paleobiogeographic affinities of the Arctic Alaska terrane Devonian-Pennsylvanian age 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 held resolve the paleogeographic origin of this terrane.

In view of the strong evidence indicating an origin of the Arctic Alaska terrane from Siberia (or associated peri-cratonic Siberian terrane), it would appear best to model sedimentary-hosted mineral deposits from this region after well-studied Siberian occurrences, rather than with analogues in western North America. This appears to especially applicable to Sedex Zn-Pb-Ag deposits in the western Brooks Range (hosted primarily in the Mississippian-Pennsylvanian age Kuna Formation of the Lisburne Group)

On-going research continues by the investigator and is focused on the development of paleogeographic maps for numerous time slices through the Devonian-Pennsylvanian strata of the western Brooks Range.

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 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 (primarly 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. Additional abstracts have also been published which relate to the paleobiogeographic affinities of Arctic Alaska terrane faunas (Blodgett, 2000, Blodgett and Clough, 2007, in press; Blodgett and others, 2002b; Clough and Blodgett, 2002, 2006, and 2007a, b; Dumoulin and Harris, 2006; Silberling, 1970) as well as one earlier paper (Dumoulin and others, 1998). Another paper opposing the counterclockwise rotational origin of the Arctic Alaska terrane is Lane (1997).

Support for the earlier popular model of the origin of the Arctic Alaska terrane by rifting and counterclockwise rotation away from the Canadian Arctic Islands (the so-called "Windshield-Wiper Model" can be found in Carey (1958), Tailleur (1969a, b, 1973), Tailleur and Brosgé (1970), Newman and others (1979), Grantz and May (1983), Grantz and others (1982, 1988, 1990), Mull (1984), Mayfield and others (1988), Lawver and Scotese (1990), and Lawver and others (2002).

Sources for this data compilation include a complete inventory of published papers and abstracts on Arctic Alaska terrane paleontology and stratigraphy 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, and A.J. Boucot.

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.

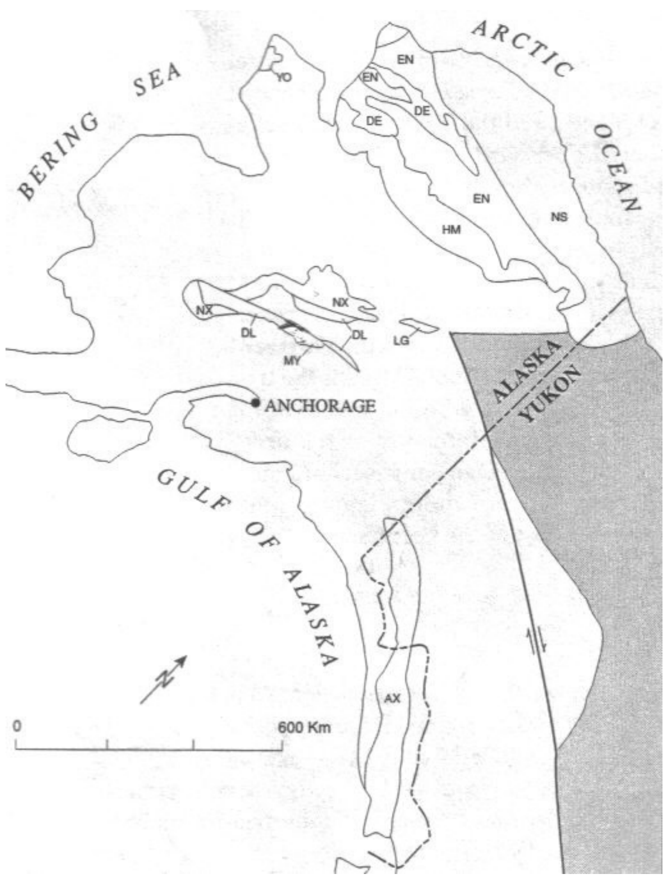

Figure 1. Map showing distribution of Arctic Alaska terrane (and its subterranes) as well as other accreted terranes of southern Alaska which show paleobiogeographic affinity with the Arctic Alaska terrane. Arctic Alaska terrane: HM—Hammond subterrane, DE—De Long subterrane, EN—Endicott Mountains subterrane, 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).

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.

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 Tailleur 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 Kugururok Formation (named by Sable and Dutro (1961)), the Eli Limestone (named by Tailleur and others, 1967), and the Skajit Limestone (which had been named by Schrader, 1902). The other division, the Endicott Group was also established by Tailleur 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 Cheeneetnuk 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 Cheeneetnuk 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. 2.1-2.8). 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-occuring 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 corrobate such difference, the possibility of geographic subspecies may have to be considered."

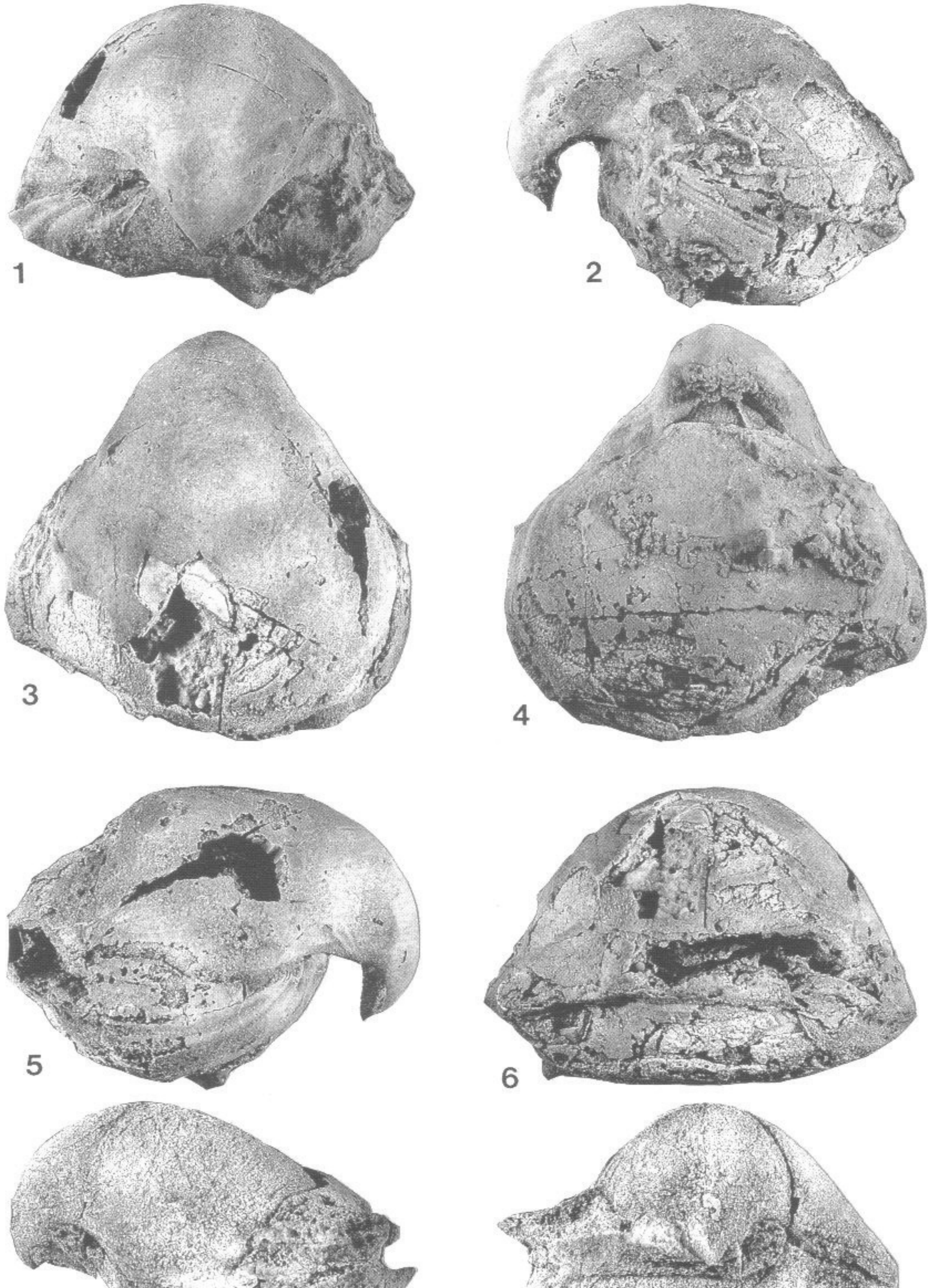
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Figure 2 (on previous page). ***Stringocephalus* (*Stringocephalus*) cf. *S.* (*S.*) *noctua* Crickmay from exposures of the Baird Group on the west side of Punupkahkroak Mountain, De Long Mountains A-3 quadrangle (from Blodgett and Dutro, 1992)**

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 palebiogeographically 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. 3C), from Eifelian age strata of the Ulungarat 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, 1999, 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. 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

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.

3C-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 symmetical green alga in strata with which they are familiar.

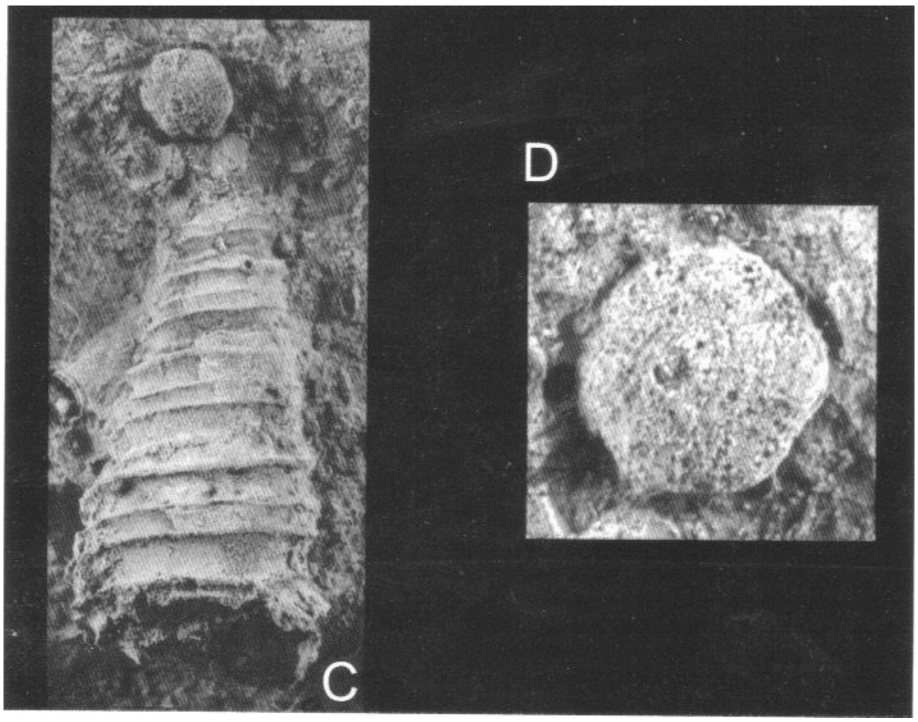

Figure 3. *Coelotrochium* sp., a calcareous green alga (same specimen shown in D is visible above the gastropod *Ulungarotoechia heidelbergeri* Blodgett and Cook in C), commonly found in Eifelian age shallow-water gastropod-dominated communities in Alaska's accreted terranes (i.e. Farewell, Alexander, Livengood, and Arctic Alaska terranes). The specimens 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).

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).

Conodonts – Discussion and/or illustrations of Devonian conodonts of the Arctic Alaska terrane appear in the following publications: Blodgett and others (1988b) and Dumoulin and Harris (1987, 1994). 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 and the north flank of Bastille Mountain (type section of the Kugururok Formation, Misheguk Mountain B-4 quadrangle. 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. 4 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 "field guide"(constituting a sort of "gray literature") in 1949, 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 5 presents a summation of the megafossil zonation of the Arctic Alaska as used in Dutro (1987).

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 underlying Endicott Group) has relied on the microfossil assemblage zones that were compiled by Bernard L. Mamet (Armstrong and others, 1970a, b, 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 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.

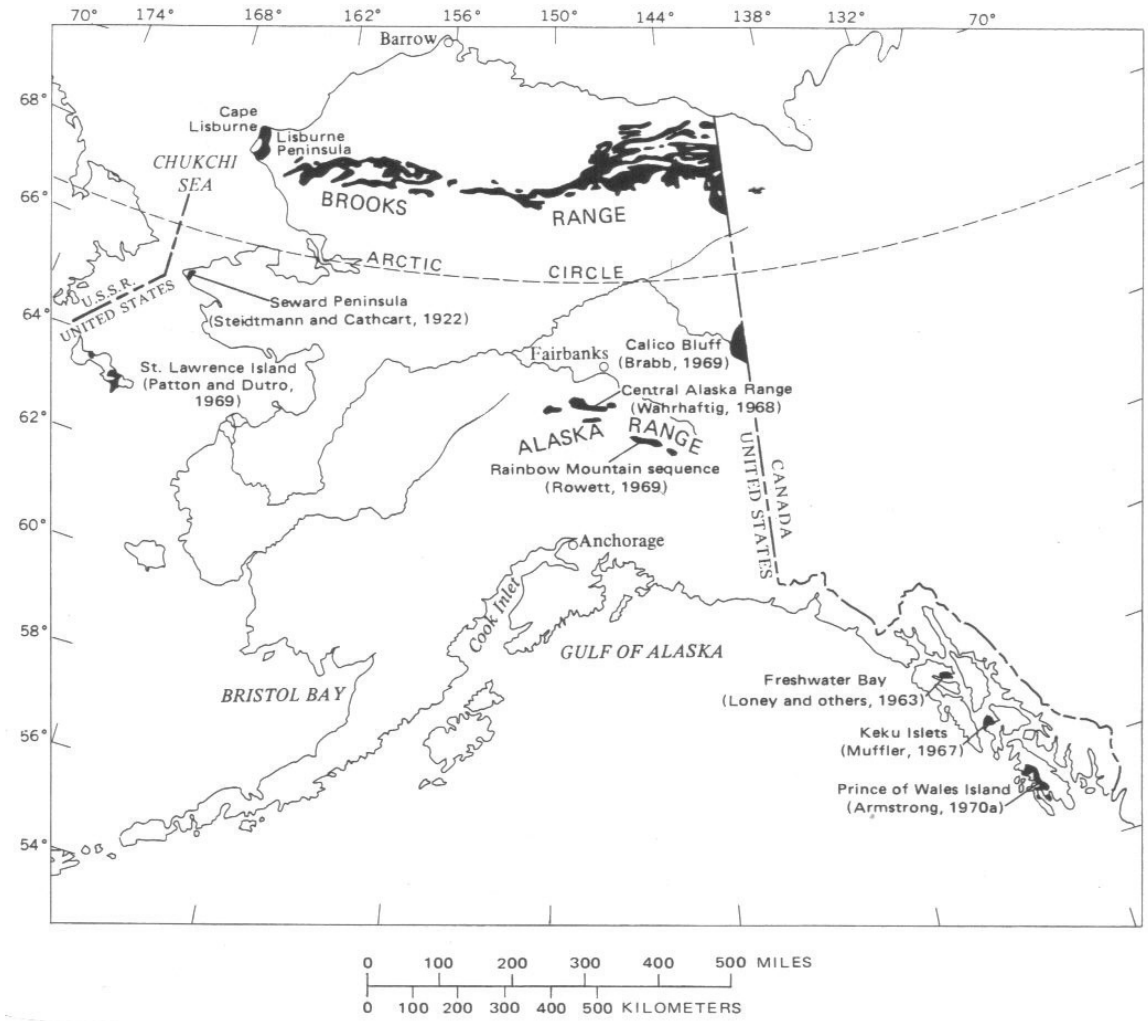

Figure 4. Map showing distribution of Carboniferous rocks in Alaska (from Armstrong, 1975b).

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), Amstrong 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 (1949); Carr and Mamet (1987); Mamet (1970, 1976); Mamet and Armstrong (1972); Mamet and Mason

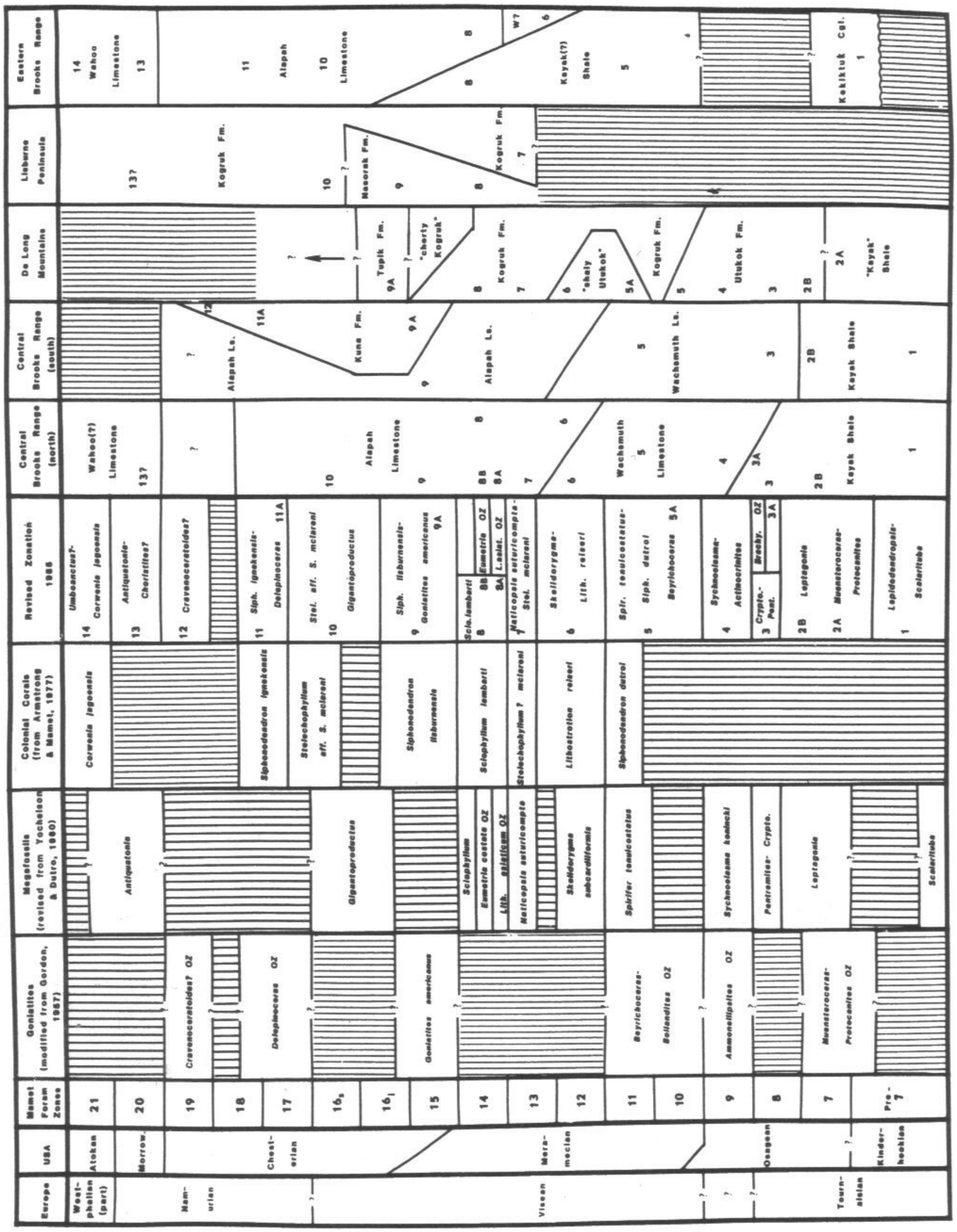

Figure 5. Chart (from Dutro, 1987) showing megafossil zonation for Mississippian strata of northern Alaska.

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(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-occuring 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, 1972a, 1973a,b,c, and 1975a,b,c), Armstrong and Mamet (1970 and 1977), Duncan *in* Bowsher and Dutro (1949), 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 (1949), which contained lengthy faunal lists and many photographs of Mississippian brachiopods from this region. Unfortunately, this “publication” appeared as an internal USGS field guide, 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* (P_2) 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 (1949) 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 brachopod 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, *Brachythyis choteauensis* Weller, *Brachythyris pecularis* (Shumard), *Pseudosyrinx missouriensis*, and *Syringothyris halli* Winchell. These Kayak Shale faunas from the central Brooks Range are currently correlated with the Tournaisian (Kinderhookian-Osagian) acccording 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 (1949) 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* Norword 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 cosmoplitan species in Lower Carboniferous faunas throughout much of the world.

Bowsher and Dutro (1949) 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. leidyi* 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 eight 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 leidyi* (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 (1949, pl. 17, figs. 17-20) provided the only illustration of this species from the Alapah Limestone, which they identifed as "*Spirifer*" cf. *S. leidyi* 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 (1949) 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. 6.1-6.3) 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.

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, *Spinocarinifer*a *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).

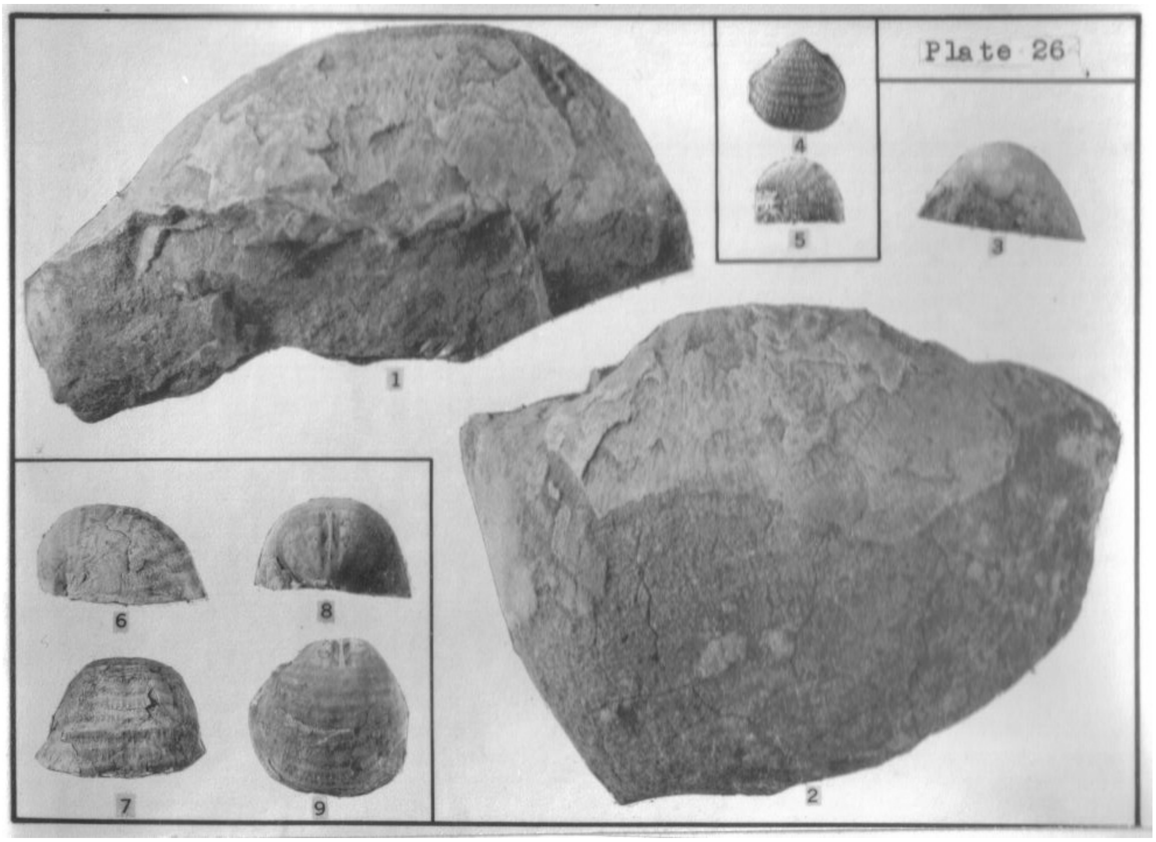

Figure 6. Views 1-3 show specimens assigned to the species *Gigantella striato-sulcatus* (Schwetzoff) by Bowsher and Dutro (1949). These specimens (now placed in the genus *Gigantoproductus*) were collected along the Canning River by E. de K. Leffingwell from his locality 26X (=USGS locality 7138-green) (photo from Bowsher and Dutro, 1949, Pl. 26)

Only one source of photographic coverage of Lisburne Group brachiopods exist, that of Bowsher and Dutro (1949), 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.

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 (1949) 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* (*Naticopis*) *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) 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 (1949), which contains photographs of several gastropod species occuring 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. 68º35'N., long. 158º20'W., Howard Pass C-5 quadrangle. This locality is within the

Nuka Formation of Tailleur and Sable (1963), and was formerly thought 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 (1949). 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 (1949), but have never been the subject of a definitive taxonomic study.

Blastoids – Blastoids from the Lisburne Group were illustrated by Bowsher and Dutro (1949), 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 (1949). 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 continerminous 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 (1949), 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., *Stigmaria* 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 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 Visean, denoted by scattered Stacheiinae (mostly *Stacheoides*), followed by a somewhat richer microflora in the early Namurian with *Archaeolithophyllum*, *Cuneiphycus* 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 Missississippian (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 provicialism, 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. 69º31'33" N, Long. 145º 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 (Brosgé 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 wahooenensis* 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. 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 Pennyslvanian 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).

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APPENDIX

Publications that resulted from this Mineral Resources External Research Program-funded study.

Manuscript (nearly completed that resulted from this project [Grant 06HQGR0199]):

> Blodgett, R.B., in preparation, A paleobiogeographic study of Paleozoic-Early Cretaceous fossil fauna and flora of the Arctic Alaska terrane: 92 MS pages (single-spaced), slated for publication in the Alaska Division of Geological & Geophysical Surveys Professional Interpretative Report series. [Manuscript essentially complete, waiting to get some obscure Russian (Soviet) references through interlibrary loan need to fill in gaps for Carboniferous studies comparing Arctic Alaska with NE Siberia]

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Abstracts resulting from this study:

Blodgett, R.B., and Clough, J.G., 2007, Paleozoic-Triassic paleobiogeographic signals from the Arctic Alaska terrane of northern Alaska indicate Siberian origins [abs.]: NGF Abstracts and Proceedings of the Geological Society of Norway [including The Fifth International Conference on Arctic Margins (ICAM 5), Tromso, Norway], Number 2, 2007, p. 229.

Clough, J.G., and Blodgett, R.B., 2007, Siberian connection of Arctic Alaska based on paleobiogeography, sedimentology and geochronology: Implications for Circum-Arctic reconstructions [abs.]: NGF Abstracts and Proceedings of the Geological Society of Norway [including The Fifth International Conference on Arctic Margins (ICAM 5), Tromso, Norway], Number 2, 2007, p. 111.

Clough, J.G., and Blodgett, R.B., 2007, Siberian Origins of Neoproterozoic to Upper Triassic Rocks of Arctic Alaska [abs.]: Eos Trans. AGU, v. 88, (52), Fall Meeting (San Francisco , December 2007) Suppl., Abstracts.

Blodgett, R.B., and Clough, J.G., in press, Paleozoic-Triassic biogeographic affinities of fossil biota from the Arctic Alaska plate indicate an origin from Siberia (rather than from the Canadian Arctic Islands) [abs.]: Geological Society of America Abstracts with Programs, combined Cordilleran/Rocky Mountain sections meeting, Reno, Nevada, March 2008.

The below abstract obliquely dealt with data derived from this study (data derived from this study used in several slides presented during this Power-Point presentation).

Blodgett, R.B., and Zhang, Ning, 2007, Regionally-based paleontological databases – two examples of web-based archiving of USGS fossil data from Alaska and the Great Basin [abs.]: Geological Society of America Abstracts with Programs (National Meeting in Denver), v. 39, no. 6, p. 294.