CONODONT BIOSTRATIGRAPHY AND BIOFACIES OF THE WAHOO LIMESTONE (CARBONIFEROUS), EASTERN SADLEROCHIT MOUNTAINS, BROOKS RANGE, ALASKA

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ABSTRACT

The Wahoo Limestone is the youngest formation of the Lisburne Group (chiefly Carboniferous) in northeasternmost Alaska. Systematic sampling for microlithofacies and conodont analysis at a relatively continuous section (~262 m thick) in the eastern Sadlerochit Mountains shows that existing Carboniferous conodont zonations are not readily applicable because most zonal indicators are absent. The following zones and faunal intervals were recognized: Upper *Rhachistognathus muricatus* Subzone (latest Chesterian); *Declinognathodus noduliferus-Rhachistognathus primus* Zone (earliest Morrowan); *Rhachistognathus minutus* Fauna (Morrowan); and an *Idiognathodus* Fauna (late Morrowan and (or) early Atokan). The Mississippian-Pennsylvanian boundary is at 55 m above the base of the Wahoo. Established foraminiferal biostratigraphy is inconsistent with respect to conodont-based time-rock boundaries in the study section.

The Mississippian part of the Wahoo Limestone was deposited under near restricted to normal-marine conditions in a chiefly open-platform to open-marine setting; it produces a chiefly cavusgnathid biofacies. The Pennsylvanian part of the Wahoo was deposited under predominantly normal-marine, high-energy conditions characterized by migrating ooid shoals; it produces a chiefly rhachistognathid biofacies. Abraded conodonts and bioclasts and mixed assemblages indicate considerable postmortem hydraulic mixing across the Pennsylvanian carbonate platform.

INTRODUCTION

A section of the Wahoo Limestone in the eastern Sadlerochit Mountains (Fig.1) was studied to: (1) establish a conodont biostratigraphic framework for the formation in the Arctic National Wildlife Refuge (ANWR); (2) determine the position of the Mississippian-Pennsylvanian boundary; (3) integrate conodont biofacies with microlithofacies studies; and (4) compare conodont and foraminiferal biostratigraphic data.

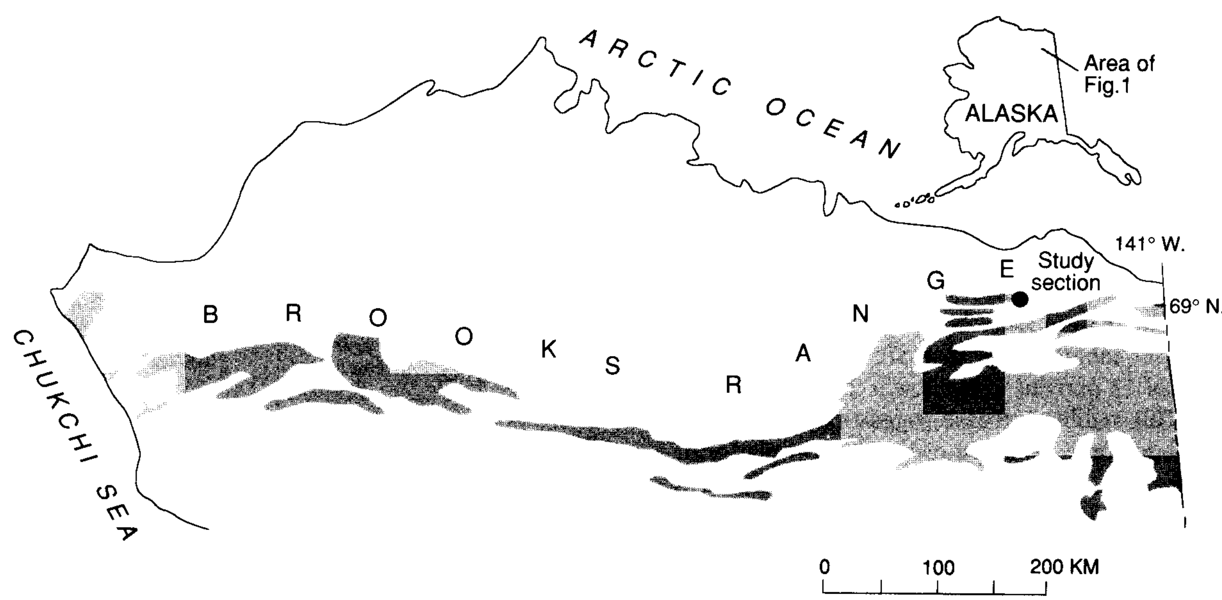


Fig.1. Map showing outcrop distribution of the Lisburne Group in northern Alaska and location of study section.

LISBURNE GROUP, NORTHEAST BROOKS RANGE

The Lisburne Group, a sequence of chiefly platform carbonate rocks more than 500 m in thickness, is exposed across the Brooks Range (Fig.1). In most of the northeast Brooks Range, the Lisburne Group gradationally overlies fluvial to marginal-marine deposits of the Endicott Group (Upper Devonian and Lower Mississippian). In the eastern Sadlerochit Mountains, however, the Endicott Group is thin or absent because older rocks formed a paleotopographic high so that the Lisburne rests with angular discordance on chiefly Proterozoic rocks (Watts et al., 1988).

In the northeast Brooks Range, the Lisburne Group consists of the Alapah Limestone and the overlying Wahoo Limestone. The Wahoo is subdivided into lower and upper members (Watts et al., 1989). The contact between the members appears to be planar, but, locally, in the eastern Sadlerochit Mountains, it may have erosional relief (Carlson, 1987).

WAHOO LIMESTONE, EASTERN SADLEROCHIT MOUNTAINS

At the study section (Fig.1), the lower member of the Wahoo Limestone is 70 m thick and consists primarily of bryozoan-pelmatozoan packstone to grainstone that formed in a chiefly open-marine environment. A peloidal-skeletal wackestone partly replaced by nodular chert occurs 55 m above the base of the lower member. The bed is <0.5-1 m thick, has sharp contacts, and appears to have been deposited on a surface of relief developed on rocks that were subaerially exposed (Carlson, 1990). The chert-bearing bed is 0.5 m above the highest Mississippian conodonts and immediately below a bed containing the lowest Pennsylvanian conodonts.

A few redeposited, latest Mississippian conodonts occur sporadically in the Pennsylvanian part of the lower member of the Wahoo Limestone and increase in abundance 1 m below the boundary between the lower and upper members. The redeposited conodonts indicate intermittent reworking of slightly older Wahoo deposits. Quartz sand increases slightly in the upper 1 m of the lower member and then abruptly increases to an average of 12 percent in the lower 20 m of the upper member. This sudden increase suggests considerable regression and some exposure of the Wahoo platform. Exposure surfaces have been reported in the lower member at the study section and in outcrops 1 km to the west (Carlson, 1990).

The upper member of the Wahoo Limestone is 192 m thick at the study section and represents a major transgressive-regressive sequence containing many parasequences recording repeated fluctuations in relative sea level. The upper member consists chiefly of packstone and grainstone deposited in a variety of open-platform to open-marine environments. A disconformity of considerable magnitude separates the Wahoo from the overlying Echooka Formation of Permian age (Crowder, 1990). The disconformity produces regional variation in thickness of the Wahoo.

CONODONT BIOSTRATIGRAPHY

The conodont zonation (Baesemann and Lane, 1985) for uppermost Mississippian and Pennsylvanian (Morrowan) rocks in North America can only be recognized in the lower 84 m of the Wahoo Limestone (Fig.2). The Upper *muricatus* Subzone (latest Mississippian) occurs from at least 82 m below to 55 m above the base of the Wahoo; the *noduliferus-primus* Zone (earliest Pennsylvanian) is present from 55 to 84 m above the base of the Wahoo. The remaining

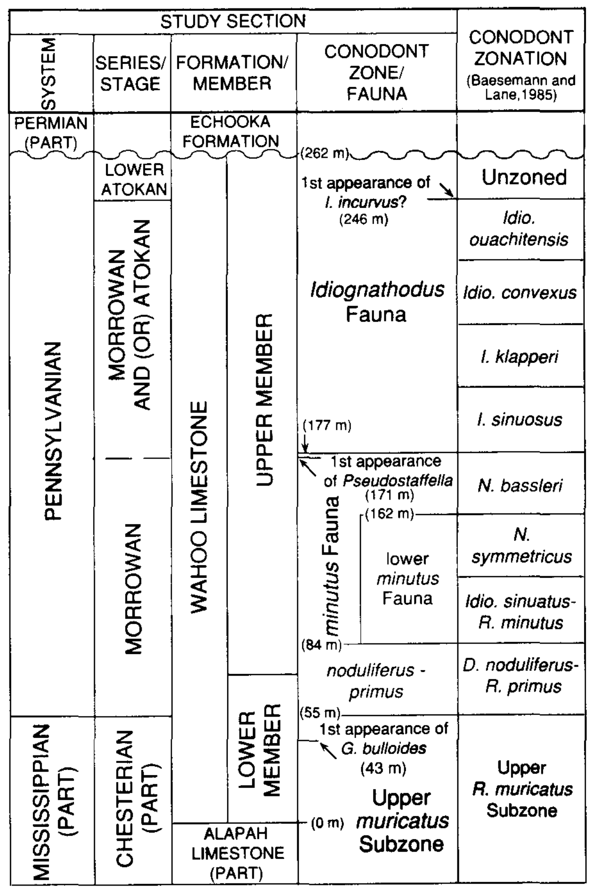


Fig.2. Conodont zones and faunas recognized in the Wahoo Limestone at the study section compared with the North American middle Carboniferous conodont zonation of Baesemann and Lane (1985). Numbers in parentheses indicate stratigraphic position above base of Wahoo Limestone in the study section. Foraminiferal data from P.L. Brenckle, Amoco Production Co. (written commun., 1991). Generic abbreviations for conodonts are *D., Declinognathodus; I., Idiognathodus; Idio., Idiognathoides; N., Neognathodus; R., Rhachistognathus.* Foraminifers are *Globivalvulina bulloides* and *Pseudostaffella.*

Pennsylvanian strata could not be precisely dated because most zonal indicators are absent. Consequently, we used an informal conodont succession based on local ranges of some rhachistognathids and the first appearance of *Idiognathodus* (Fig.2). The informal *minutus* Fauna represents the local range of *Rhachistognathus minutus* below the first appearance of *Idiognathodus* (Fig.2). A lower subdivision of the *minutus* Fauna is defined by the overlapping ranges of *R. minutus* subspp. and *R. websteri*. The lower *minutus* Fauna is considered Morrowan because the foraminiferan guides to the base of the Atokan occur in the uppermost part of the *minutus* Fauna (Fig.2). At the study section, the *minutus* Fauna occurs from 84 to 177 m above the base of the Wahoo; the basal 78 m are assigned to the lower *minutus* Fauna.

The *Idiognathodus* Fauna is characterized by the association of *Idiognathodus* spp., *Rhachistognathus minutus*, and *Adetognathus lautus*. The first appearance of *Idiognathodus* in the Wahoo Limestone marks the lower boundary of the fauna; the fauna extends to the top of the formation (Fig.2). The lower boundary of the *Idiognathodus* Fauna could be as old as middle Morrowan, or as young as early Atokan. Many of the idiognathodids in our collections are specifically indeterminate. Representatives of *Idiognathodus*, a genus that ranges from the middle Morrowan through at least the Pennsylvanian, occur in the upper 75 m of the Wahoo and 6 m above the lowest occurrence of *Pseudostaffella*, a foraminifer that is used to approximate the base of the Atokan in much of North America (Groves, 1986). If *Pseudostaffella* approximates the base of the Atokan in Alaska, then the entry of *Idiognathodus* above it occurs in the early Atokan and, thus, considerably later than its debut in the type Morrowan. One specimen of *I. incurvus*? was found 16 m below the top of the Wahoo. This species is restricted to the Atokan and lower Desmoinesian so that the upper 16 m of the *Idiognathodus* Fauna in the study section is no older than Atokan. In addition, *I. incurvus*? occurs within the range of *Rhachistognathus minutus*, further suggesting that the top of the *Idiognathodus* Fauna here is no younger than early Atokan.

MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY: FORAMINIFERS VERSUS CONODONTS

Because foraminifers have chiefly been used to correlate the Lisburne Group (Armstrong et al., 1970; Armstrong and Mamet, 1975), we were eager to tie conodont biostratigraphy to Mamet's foraminiferal zonation. Unfortunately, the foraminiferal zonation appears to have been used inconsistently in the eastern Sadlerochit Mountains. Microfossil analyses of the same thin sections taken from the Sunset Pass section (about 1 km west of our study section) were reported by B.L. Mamet at least three times with conflicting results; the Sunset Pass section was resampled by Carlson (1987) and also analyzed by Mamet. Conodonts indicate that the Mississippian-Pennsylvanian boundary (on the basis of the first occurrence of *Declinognathodus noduliferus* above forms transitional from *Gnathodus girtyi simplex*) is at about the same stratigraphic level shown in Armstrong et al. (1970) and Armstrong (1974), but about 25 m higher than in Armstrong and Mamet (1975), and about 17 m lower than in Carlson (1987) for the Sunset Pass section. If the first appearance of the foraminifer *Globivalvulina bulloides* is used as a guide to the base of the Pennsylvanian in our section (Fig.2), the systemic boundary would be 12 m lower than indicated by conodonts, but would still not coincide with any position determined by Mamet. The Subcommission on Carboniferous Stratigraphy (SCCS), however, has recommended that the first appearance of the conodont *Declinognathodus noduliferus* be used as the primary micropaleontologic guide for the base of the Pennsylvanian (Lane and Manger, 1985). We followed the biostratigraphic recommendation of the SCCS in our study.

CONODONT BIOFACIES

All conodont morphotypes identifiable to genus were used for biofacies analysis. Samples containing <20 generically identifiable elements and genera represented by <5 elements were not used for analysis. Following Ziegler and Sandberg (1990), conodont biofacies are named for the one or two genera that make up ~70 percent of a sample. If the two most abundant genera make up <70 percent of the conodont fauna, the assemblage is, with some exceptions, considered the result of postmortem mixing. Although most of our samples indicate some mixing, samples dominated by two genera are interpreted as *in situ* assemblages or assemblages derived from laterally adjacent environments. The data set for conodont biofacies described below is given in Krumhardt (1992).

Paleoenvironments were interpreted from regional and local, and vertical and lateral stratigraphic relationships; carbonate lithology and grain types (including skeletal grains); and fossil assemblages. Some lithologies, representing environments considered unfavorable for conodonts, were rarely sampled (e.g., intertidal and restricted-marine lithofacies).

Mississippian Biofacies

Regional relationships suggest that the Mississippian part of the lower member of the Wahoo Limestone was deposited on an open-marine carbonate platform. The eastern Sadlerochit Mountains probably lay along the inner part of this platform (Krumhardt, 1992; Watts, 1992). The base of the Wahoo coincides with the beginning of a major transgressive-regressive cycle; the Mississippian part of the lower member formed during the transgressive phase of this cycle. The major environments sampled for conodonts and conodont biofacies are shown in Fig.3*A*.

Samples that yielded a cavusgnathid biofacies represent a near-restricted to open-platform environment. Conodonts are rare to common (11/kg), but only 43 percent are generically determinate, reflecting a relatively high-energy regime. *Cavusgnathus* makes up about 85 percent of the identifiable conodonts in this environment.

Samples that produced a cavusgnathid-kladognathid biofacies represent an open-platform to open-marine environment. These samples contain relatively abundant conodonts (26/kg), but ~60 percent are indeterminate fragments. Many conodonts, however, are complete, so that postmortem transport probably was local and relatively short lived.

The gnathodid-hindeodid biofacies was recorded in one sample representing a low-energy (below wave base), open-marine environment. *Gnathodus* and *Hindeodus* probably lived in and seaward of the site represented by the study section as these forms are rare in contemporaneous shoreward facies.

Pennsylvanian Biofacies

Pennsylvanian depositional patterns are less complex in the lower member of the Wahoo Limestone than in the upper member (compare Figs.3*B* and 3*C*). Ooid shoal facies make up 20 percent of the upper member. This high-energy regime caused many conodonts to be transported beyond their habitat, substantially disrupting and even obliterating original biofacies patterns.

The adetognathid biofacies was found in one sample from the Pennsylvanian part of the lower member of the Wahoo Limestone (Fig.3*B*). *Cavusgnathus*? *tytthus* (included here in the adetognathids) is virtually the only conodont present. It is characteristic of nearshore, possibly intermittently restricted environments. It is fitting that this species dominates rocks representing the initial phase of Pennsylvanian transgression. Two other samples from this part of the lower member represent an adetognathid-declinognathodid biofacies. Microlithofacies suggest a moderate-energy, open-platform to open-marine setting. Adetognathids and *Cavusgnathus*? *tytthus,* together, account for 35-58 percent of the conodonts in this biofacies. These occur with declinognathodids, a cosmopolitan group. Rhachistognathids are few in the Pennsylvanian part of the lower member because their principal habitat, the shoal-water environment, also was rare (Fig.3*B*). A fourth sample from this stratigraphic interval produced a hindeodid-adetognathid biofacies. The microlithofacies indicate a low-energy, open-marine environment. Although the sample qualifies for biofacies analysis, the species association suggests a mixed assemblage. It is likely that *Hindeodus minutus* is *in situ* as all elements of its apparatus are present. This species is long ranging and consistently appears in rocks representing the relatively deeper parts of the Wahoo Limestone (compare Figs.3*A*-*C*). This biofacies may represent the outer limit of the *Cavusgnathus*? *tytthus* and adetognathid habitats. More likely, these forms are hydraulic admixtures, so that the adetognathid part of the "biofacies" is unnatural. In addition, rhachistognathids (18%) probably were carried here from their shallow-water, high-energy habitat.

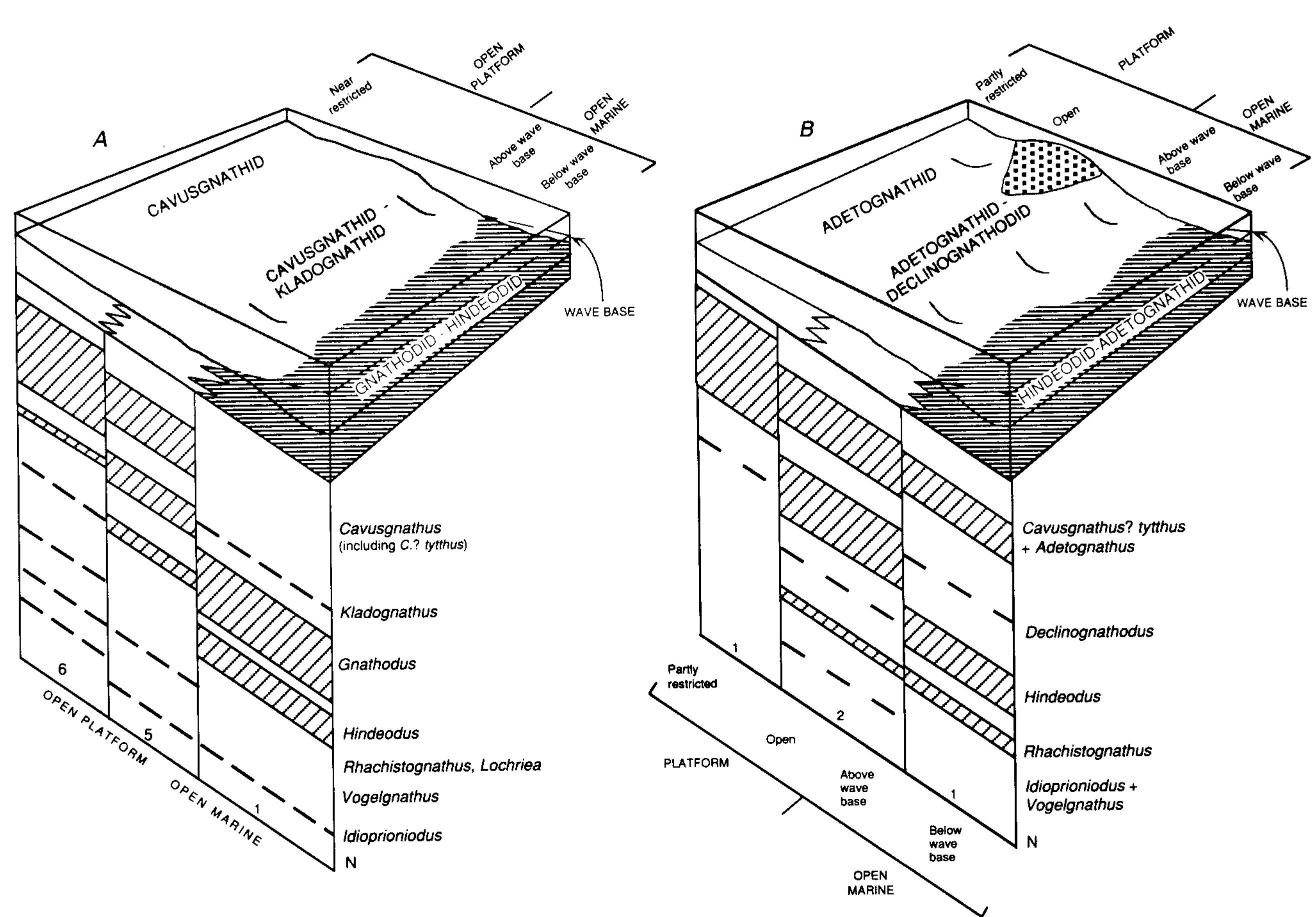
Two samples from the upper member of the Wahoo Limestone representing the restricted-platform environment qualified for biofacies analysis (Fig.3*C*). These samples yielded nearly equal numbers of adetognathids and rhachistognathids. The collections represent either the outer limit of the adetognathid-rhachistognathid biofacies or, more likely, storm-tossed skeletons or stranded voyagers.

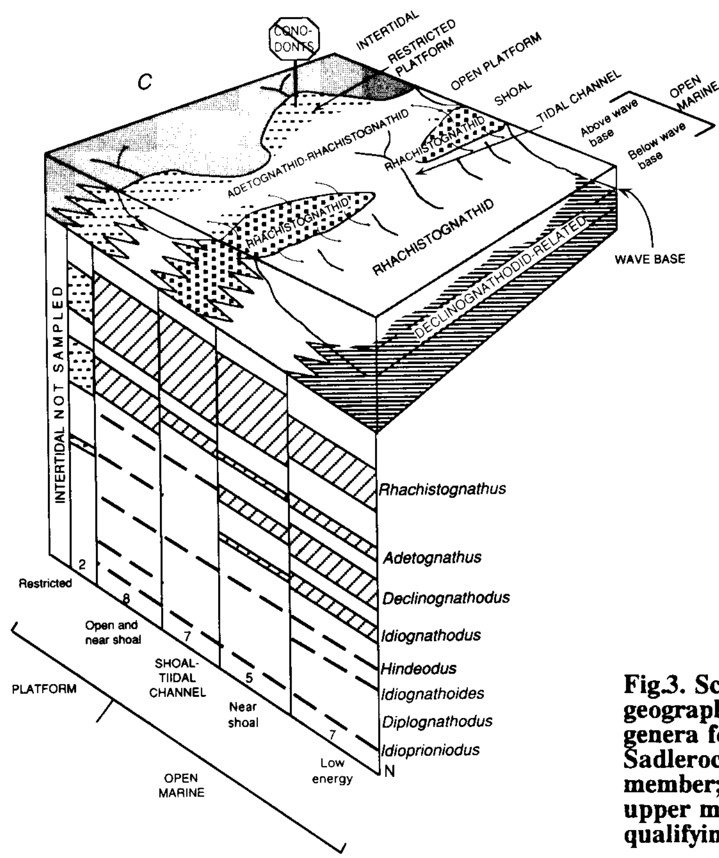
The most prevalent and sampled environment in the upper member of the Wahoo Limestone is the open-platform to near-shoal environment; eight qualified for biofacies analysis. Although conodonts are relatively rare (8/kg), 60 percent are generically determinate. Many conodonts were undoubtedly transported from the adjacent, higher energy, shoal environment. Rhachistognathids make up 67 percent and adetognathids 33 percent of collections from this environment.

The rhachistognathid biofacies was identified in five of seven samples from massive-bedded, well-sorted oolitic to bioclastic grainstone inferred to represent shoal and (or) tidal-channel environments (Fig.3*C*). Conodonts are common (20/kg) and well preserved; 57 percent are generically determinate, suggesting the conodonts lived in and (or) adjacent to these environments. Rhachistognathids make up 79 percent of the collections. Adetognathids, the only other group common in this depositional setting, represent 17 percent of the collections and probably are migrants or postmortem additions from the open platform.

Five samples from the near-shoal, open-marine environment (Fig.3*C*) were eligible for biofacies analysis and represent the rhachistognathid biofacies. Conodonts are slightly more abundant (22/kg) than in other environments identified in the upper member of the Wahoo Limestone. Nearly 55 percent are generically determinate and include 69 percent rhachistognathids, 16 percent declinognathodids, and 7 percent each of adetognathids and idiognathodids (Fig.3*C*). The relative abundance of adetognathids and declinognathodids is inversely related in different samples suggesting separate sources of postmortem admixture and (or) migrants. The adetognathids probably were derived from the shallower waters of the inner platform, and the declinognathodids probably came from other nearby open-marine environments or lived in small numbers within this environment.

Seven samples collected from the low-energy, open-marine environment produced a mix of biofacies, but all contain predominant to substantial numbers of declinognathodids, thus the declinognathodid-related biofacies. Conodonts are common to rare, but only 40 percent are generically determinate. The conodonts are a mix of platform, shoal, and open-marine forms (29% adetognathids, 40% rhachistognathids, and 27% declinognathodids). On the basis of microlithofacies, we assume the adetognathids and rhachistognathids are





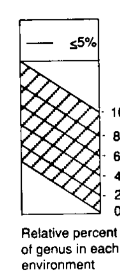


Fig.3. Schematic diagrams showing generalized paleogeography, biofacies, and distribution of conodont genera for the Wahoo Limestone in the eastern Sadlerochit Mountains: *A*, Mississippian part of lower member; *B*, Pennsylvanian part of lower member; *C*, upper member (Pennsylvanian). N, number of samples qualifying for biofacies analysis in each environment.

postmortem additions to a low-population declinognathodid biofacies.

The Wahoo Limestone formed in a range of chiefly open-platform, near-shoal, and open-marine environments on the shallow, inner part of a high-energy carbonate ramp. In the uppermost Mississippian and lowermost Pennsylvanian part of the Wahoo, shoal facies were uncommon so that open-platform and open-marine microlithofacies and conodont biofacies were not clearly separated. Grain types and, to a lesser extent, conodonts were hydraulically spread beyond their natural environments, making some environmental interpretations equivocal. The use of conodont biofacies and microlithofacies in concert clarifies some of these environmental ambiguities. In the Pennsylvanian part of the Wahoo, extensive ooid- and skeletal-shoal tracts separated open-marine and open-platform environments, producing more distinct biofacies and diagnostic microlithofacies. Rhachistognathids thrived in and adjacent to the barrier facies. After death, many of their skeletal elements remained *in situ*; however, a substantial number were washed into surrounding environments, masking natural species associations. Similarly, mixing of carbonate grains obscures microlithofacies interpretations.

CONCLUSIONS

Foraminifers have been the primary biostratigraphic indices for the Lisburne Group in ANWR. Some studies, however, indicate inconsistent assignment of foraminiferal zones and lithologic boundaries within our study area. Conodonts seem to provide better biostratigraphic resolution than foraminifers for the Lower Pennsylvanian part of the Lisburne Group. Neither group, however, adequately constrains the Morrowan-Atokan boundary.

It is apparent that taxonomic interpretations, biostratigraphic models, and paleobiogeography, in addition to spacing and selection of foraminiferal and conodont samples, control time-rock boundary placement. As taxonomic interpretations stabilize and global biostratigraphic data increase for both foraminifers and conodonts, correlations should improve. Data from other fossil groups may be needed to distinguish evolutionary from migratory patterns in foraminifers and conodonts.

Although conodont biofacies analysis of Carboniferous rocks in northern Alaska is just beginning, the use of conodonts to augment environmental interpretations based on microlithofacies is promising, particularly for rocks in which primary carbonate textures have been obscured by diagenesis and metamorphism.

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