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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PENNSYLVANIAN CARBONATES, PALEOECOLOGY, AND STRATIGRAPHY, NORTH FLANK, EASTERN BROOKS RANGE, ARCTIC ALASKA

By

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This report is preliminary
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Contents

Illustrations

Pennsylvanian carbonates, paleoecology, and stratigraphy, north flank, eastern Brooks Range, Arctic Alaska

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Abstract

The carbonates of four measured sections of the Pennsylvanian Wahoo Limestone comprise 310 to 1,250 feet of the Lisburne Group. Shallow-water, open-marine carbonates of Morrow age overlie, without hiatus, restricted marine to intertidal dolomitic carbonates of the Alapah Limestone of latest Mississippian age. The Morrow age carbonates are predominately echinoderm-bryozoan wackestones and packstones, with minor amounts of ooid grainstones and lime mudstones. The Atoka age carbonates are in part cross-bedded bryozoan-echinoderm and oolitic grainstones, with associated minor amounts of thin-bedded dolomites. Outcrops of the Wahoo Limestone in the Sadlerochit Mountains indicate that Pennsylvanian sedimentation from Morrow to Atoka generally progressed from shallow-water, open-marine sedimentation to higher energy shoaling water, oolitic sedimentation.

Atoka age colonial corals are *Corwenia* sp. and *Lithostrotionella* sp. Paleoecological and biostratigraphic analysis of the carbonate beds associated with the colonial corals indicates the corals lived in clear, agitated water between oolitic tidal bars.

Introduction

Pennsylvanian-age carbonates are well exposed in northeastern Brooks Range of eastern Arctic Alaska. The exposures are suitable for detailed stratigraphic, facies, and paleoenvironmental studies. Also, a few localities, at certain stratigraphic levels, contain large numbers of colonial corals. The location of the study area is shown in figure 1.

The four stratigraphic sections discussed in this report were measured with a Jacob's staff and tape. Lithologic and Foraminifera samples were collected every 5 to 10 feet. Most of the corals were collected from within measured sections. Thin sections were cut from the lithologic samples and then were petrographically described and studied for microfossils.

Identification of calcite and dolomite in thin sections was made by Alizarin-red staining techniques described by Friedman (1959). The carbonate classification is that of Dunham (1962).

The sedimentary features and structures used in this study to delineate environments of deposition and paleoecology are described in detail by Logan and others (1964), Shinn and others (1965), Roehl (1967), Wilson (1967a, 1967b, 1969), Shinn (1968a, 1968b), Ball and others (1967), Ball (1967), and Murray and Lucia (1967). The carbonate depositional cycle concepts used in this report are those developed by Fischer (1964), Wilson (1967a, 1967b), Coogan (1969), Armstrong (1967), and Armstrong, MacKevett, and Silberling (1969).

Previous work and acknowledgments

In 1962 Brosgé and others gave the name Lisburne Group to the Lisburne Formation at Wahoo Lake and divided it into the Mississippian Alapah Limestone and the Pennsylvanian and Permian Wahoo Limestone. In the area of this report the Wahoo Limestone as mapped contains some beds of very latest Mississippian age but is primarily Morrow, Atoka, Pennsylvanian in age and does not contain strata of Permian age. Armstrong, Mamet, and Dutro (1970), using microfossil zones, divided the Lisburne Group of central and eastern Brooks Range into a series of biostratigraphic units and defined the base of the Pennsylvanian system. Detailed accounts of the history of the study of the Carboniferous rocks of the Lisburne Group can be found in Bowsher and Dutro (1957) and Armstrong, Mamet, and Dutro (1970). Reiser and others (1970) have made 1:63,360-scale geologic maps of the Sadlerochit Mountains that delineate the outcrops of the Lisburne Group and the Wahoo Limestone.

I wish to express my appreciation to Irvin Tailleur, party chief, summer of 1968, and Hillard N. Reiser, party chief, summer of 1969 and 1970, for their generosity in supporting my coral collecting and stratigraphic studies. I wish to thank the Naval Arctic Research Laboratory (Barrow), Office of Naval Research, for their logistical support of my field work in the summers of 1968-1970. Two specimens of colonial corals used in this study, collected by Shell Oil Company geologists in 1960 and 1963, were given to the U.S. Geological Survey, and appreciation is expressed to R. E. McAdams and G. E. Burton, vice presidents of Shell Oil Company. The photographs and thin sections were made by Kenji Sakamoto and Robert Shely, respectively, both of the U.S. Geological Survey.

I am grateful to my colleagues, J. Thomas Dutro, Jr., William J. Sando, and William A. Oliver, Jr., who helped in preparation of the manuscript and provided critical review. James Lee Wilson helped in the development of concepts relating to the environments of deposition and paleoecology and also reviewed the stratigraphic parts of the manuscript. I wish to thank Mahlon M. Ball and Robert Ginsberg for their review of the manuscript.

Biostratigraphy

Armstrong, Mamet, and Dutro (1970, 1971) and Armstrong and Mamet (1970) have described the sequences of Mississippian and Pennsylvanian biostratigraphic zones within the Lisburne Group of Arctic Alaska based on the microfossil zones developed by B. L. Mamet.

Within the area of this study the Lisburne Group consists of the Alapah Limestone and Wahoo Limestone. The basal Alapah Limestone at the Ikiakpuk section (68A-1) in the Fourth Range is of Meramec age (zone 13); to the north in the Sadlerochit Mountains at the West Sadlerochit Mountain section (69A-1), the base is lower Chester (zone 16_1). The microfossils indicate that carbonate sedimentation continued without a significant or recognizable hiatus into Pennsylvanian time. In the Mamet zonal scheme, the base of the Pennsylvanian system is at the base of zone 20 and is defined on the first occurrence of the Morrow fossils *Endothyra* of the group *E. mosquensis* Reitlinger, *Lipinella* sp., *Millerella* sp., and *Neoarchaediscus grandis* (Reitlinger). Atoka-age (zone 21) carbonates contain the microfossils *Climacammina* cf. *C. moelleri* Reitlinger, *Eoschubertella* sp., *Pseudostaffella* sp., and *Globivalvulina* sensu stricto. The absence of *Fusulinella* spp. and *Profusulinella* spp. is a serious detriment to exact correlation with other established Pennsylvanian sections. The presence of these genera would make certain that the uppermost beds are not Des Moines in age.

Rugose corals are known only from Atoka age beds of the Wahoo Limestone; none as yet have been found in beds of Morrow age. The corals are represented by two species, *Corwenia* sp. and *Lithostrotionella* 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* sp. shows close similarity to the upper Moscovian corals *Corwenia symmetrica* (Dobroljubova) from Spain and the Moscow and Donetz Basins of U.S.S.R.

Carbonate stratigraphy

Brosgé and others (1962, p. 2191) described the type section of the Wahoo Limestone near Wahoo Lake as containing carbonates of both Pennsylvanian and Permian age. In the area of this report, the Wahoo Limestone as mapped by Reiser and others (1970) contains carbonates of Mississippian (very latest Chester) and Pennsylvanian age (Morrow and Atoka) (fig. 1). The Pennsylvanian limestones overlie Mississippian (latest Chester) carbonates without a recognizable hiatus. The boundary between the two systems and the zones within them are based on microfaunal assemblages (Armstrong and others, 1970). The Atoka beds are unconformably overlain by arenaceous limestones, sandstones, and conglomerates of the lowest part of the Sadlerochit Formation of late Permian age.

In the area of this paper (fig. 1), the Wahoo Limestone forms bold cliffs above the thin-bedded, generally talus-covered slopes of Mississippian Alapah Limestone.

The Morrow-age carbonates (fig. 1) of the Wahoo Limestone are primarily bryozoan-crinoid wackestones and packstones. The fossil fragments are typically large, 0.2-5 mm in length, and are poorly sorted. Lesser amounts of grainstones formed of well-sorted fossil fragments and superficial ooids are present. Thick-bedded lime mudstones and extensively dolomitized carbonates are absent in the Morrowan and Atokan beds.

In the West Sadlerochit Mountain section, 69A-1, the portion from 150 to 300 feet below the Sadlerochit Formation is composed of coarse-grained bryozoan-echinoderm packstones which form 25- to 50-foot-thick beds. Lenticular to nodular, brown to brownish-gray chert is abundant. Similar intervals of Morrow age in the East Sadlerochit Mountain section, 68A-4A-4B, however, contain a higher percentage of winnowed sediments in the form of ooid packstones, grainstones, and pelletoidal-bioclastic packstones and grainstones. The Morrow age carbonates to the east in the Egaksrak River section, 68A-5, are again low-energy bryozoan-crinoid wackestones-packstones with only minor amounts of superficial ooids and oolitic grainstones.

The Atoka age carbonates are primarily grain-supported packstones and grainstones and with minor amounts of wackestone and lime mudstones. The most characteristic lithology of these beds is 5- to 15-foot-thick, weakly cross-bedded, well-stratified oolite grainstone which contains well-developed ooid grains that are from 0.5 to 1.0 mm in diameter. Some of the ooids have numerous coats and many show extensive evidence of algal boring. The nucleii of many of the ooids are rounded fossil fragments. Associated with the ooids are superficial ooids and rounded and coated lithoclasts from 1 to 4 mm in length. Commonly occurring with these grainstones are abundant Foraminifera and calcareous algae. The bryozoan-crinoid-grainstones-packstones are formed by Foraminifera and broken bryozoan fragments whose interiors are generally filled with micrite. A small percentage (1-2 percent) of these fossils have glauconite filling the internal spaces. Between some of the oolite beds are 6-inch- to 4-foot-thick, argillaceous, arenaceous, dolomitic, hematitic, pale yellowish orange-weathering carbonates. These "marker" beds are highly persistent over long distances in the Sadlerochit and Shublik Mountains and give the Wahoo Limestone its highly characteristic yellowish-orange weathering color. Thin sections of the carbonates which form these "marker" beds show that they are composed of 50-70 percent dolomite rhombs in the 25-50 micron size range with the remainder of the rock formed by 50- to 100-micron-size fragmental subangular grains of detrital quartz. Areas of limonite and hematite are present between many of the dolomite rhombs. The iron oxides probably are the weathering products of pyrite. Associated with the grainstones are thicker non-limonitic lime mudstones and wackestones which contain 5-30 percent detrital quartz in the 50- to 100-micron size range. Glauconitic shale partings 1-4 inches thick are not uncommon between the massive carbonates.

Atoka carbonates are about 700 feet thick at the Egaksrak River section. Bryozoan-echinoderm wackestones and packstones are the dominant rock types from 0 to 400 feet below the top of the section. Within this interval true oolites are rare, but oolites are sporadically present from 410 to 570 feet below the top. Oolitic grainstones are well developed from 590 to 600 feet below the top of the section. Within the Egaksrak section the spherical algal-foraminiferal colonies of _Osagia_ sp. are locally common at 160, 560, and 615 feet below the top of the section. _Osagia_ sp. has also been found in the East Sadlerochit Mountain section 68A-4A-4B at 40-50 and 120-130 feet below the top.

The Ikiakpuk section, 68A-1, in the Third Range, is south of the above sections (fig. 1). The section was measured on a series of exposures in stream-cut banks. The Pennsylvanian Wahoo Limestone is some 375 feet thick. The Atoka beds are about 135 feet thick and are formed by tectonically stressed ooid, foraminiferal grainstones. The underlying Morrow beds also show grain growth due to tectonic stress and are bryozoan-echinoderm-packstones and grainstones.

In the area of this study the Permian Sadlerochit Formation unconformably overlies limestones of Atoka age. Detterman (1970) reports that the basal Echooka Member of the Sadlerochit Formation contains a brachiopod fauna of early Kazanian, earliest late Permian age. The unconformity represents a hiatus of Des Moines through Leonard, and possibly lower Guadalupe time. The westward thinning of the Atoka-age carbonates in the Sadlerochit Mountains (fig. 1) suggests uneven erosion, probably due to differential uplift previous to Sadlerochit Formation sedimentation. At many localities the highest few feet of Atoka age carbonates beneath the Sadlerochit Formation show evidence of vadose weathering in the form of enlarged vertical joints and vugs filled with a terra rosa-like clay. The basal beds of the Echooka Member are conglomerates or conglomeratic sandstone formed in part of rounded chert and limestone pebbles and cobbles derived from the underlying Wahoo Limestone.

Environments of deposition

Within the area of this study the Pennsylvanian Wahoo Limestone is part of a two-phase carbonate depositional megacycle which began in Late Mississippian time with the basal Alapah Limestone and continued into Pennsylvanian time (fig. 2). This carbonate sedimentation is part

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Figure 2 near here.

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of a regionally transgressive Lisburne Group sequence that began at the Ikiakpuk section (68A-1), Third Range, in Meramecan time (zone 13), and at the West Sadlerochit Mountain section (69A-1) in Chesteran (zone 16_i) time (Armstrong and others, 1970). Above the Kayak(?) Shale the basal Late Mississippian Alapah limestones are typically well-sorted, pelletoidal-bioclastic-grainstones and packstones and lesser amounts of ooid grainstones. Overlying these are beds of poorly sorted, non-current deposited bryozoan-echinoderm packstones and wackestones. The environment of deposition for these carbonates is interpreted as open platform, normal marine (figs. 2, 3). The lithology and sedimentary structures

of the higher beds of the Alapah Limestone clearly indicate a progressively more restricted marine environment of deposition and the development of a regressive sequence of carbonates.

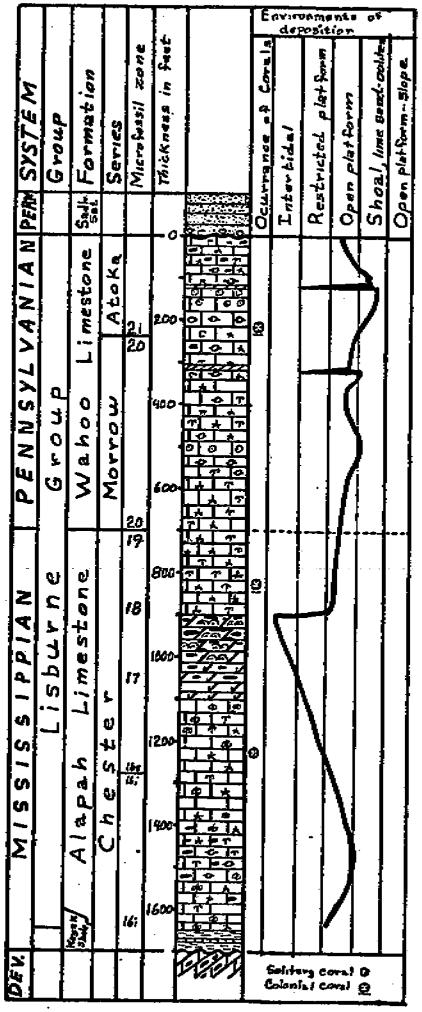

Figure 2- Composite and idealized Lisburne Group section, Sadlerochit Mountains showing shifts of carbonate environments of deposition at various stratigraphic levels. For an explanation of the lithologic symbols, see figure 1.

These younger beds show a progressive decrease in biotic diversity, an increase in the amounts of pelletoidal packstones and lime mudstones, and an increase in the percentage of dolomite. This regressive sequence is very well developed in the East Sadlerochit Mountain section (fig. 1). At a level of 950 feet below the top of the section, the Alapah Limestone is a fine-grained, light brown-gray, cherty dolomite, with well-developed algal mat and birdseye structure indicating deposition in very shallow marine to intertidal environments. A similar sequence of rock types can be seen in the Alapah Limestone at Ikiakpuk Creek and in the West Sadlerochit Mountains sections. The latter exposure has, at the same general stratigraphic level, restricted marine sediments of somewhat dolomitized, thin-bedded pelletoidal packstones but is devoid of algal mats. The restricted marine shallow water to intertidal carbonates in the upper beds of the Alapah Limestone are generally thin bedded and platy, and they form talus slopes beneath the massive limestones of the Wahoo Limestones.

This regressive suite of carbonates which culminates in an intertidal-restricted marine facies is overlain, as indicated by microfossil assemblages (Armstrong and others, 1970), by a marine transgressive carbonate facies of echinoderm-bryozoan-wackestones-packstones containing microfossils of latest Chester age (zone 19). In the area of this report this second carbonate transgressive cycle of the Lisburne Group began in latest Chester time and continued across the Mississippian-Pennsylvanian boundary without a hiatus (fig. 2). The earliest Morrow age carbonates are lithologically similar to those of very latest Chester age and are bryozoan-echinoderm wackestones and packstones that were probably deposited on an open marine platform. The outcrops of the Wahoo Limestone in the Sadlerochit Mountains indicate that, from the base of the Pennsylvanian to the unconformity beneath the Permian, the general trend in sedimentation is towards higher energy water, that is, a shoaling water, oolitic environment of deposition. This is indicated from the stratigraphically higher beds which contain less micrite, a more diversified biota, better sorted fossil fragments, and many beds with well-developed ooids. For the Sadlerochit Mountains, the interpretation of this shift in environments of deposition from the early Chester to Atoka time is graphically illustrated in figure 2.

The Wahoo Limestone echinoderm-bryozoan packstones and grainstones have 0.5-2 percent bright-green glauconite grains, most of it occurring as internal fillings in Foraminifera and bryozoan fragments and occasionally as free grains. Cloud (1955) and Lochman-Balk (1957) give detailed accounts on the environments of deposition and physical limits of glauconite formation. In general these are: normal salinity, slightly reducing conditions at sites of origin, bottom sediments rich in organic material, a water depth greater than 25 feet, and low terrigenous sediment influx. The presence of glauconite in the bryozoan-echinoderm grain-supported carbonates suggests the glauconite formed in a reducing environment in close juxtaposition to oxygenated waters in which bryozoans and crinoids thrived. The materials from these two environments were brought together by the activities of churning and burrowing organisms and by the channeling, reworking, and sorting activities of tidal channels (diagrammatically shown in figure 3).

James Lee Wilson (written commun., March, 1971) states:

"The presence of glauconite in grainstones is common in carbonate rocks all over the world despite the fact that it is a mineral of reducing environment. Stratigraphic observation and studies indicate that glauconites are associated with zones of slow deposition, often forming in strata which are overlain later by an unconformity. It seems reasonable that under a situation of very slow deposition, conditions exist for the organic reworking of sediment as well as mechanical reworking. Grains are carried down into the substrate in a reducing environment in which iron is concentrated (probably also by slow intermittent deposition during which time no clastic material is introduced to mask it). Later such grains are brought up and exposed to current and wave action by marine channeling and further burrowing; during the interim of burial glauconite has formed from the mud and organic slime caught within the grains while they have remained buried. The Wahoo Limestone glauconitic grainstones tell us that not only slow deposition prevailed but that sufficient mud occurred in between oolite bars to create impermeability and a reducing iron-rich environment. Most pore-filling glauconite is basically a product of organic feces in the mud. These ideas derive in part from discussions with H. B. Stenzel."

The oolitic grainstones which are found in association with the glauconitic grainstones are well stratified, generally 5-10 feet thick, and poorly cross bedded. In many places, the beds are capped by 6-inch-to 2-foot-thick argillaceous, arenaceous, limonitic, pale yellowish orange-weathering dolomites. This rock is formed of dolomite rhombs 30 microns in length with more than 30 percent silt-size detrital quartz. Ball's (1967) description of modern carbonate sand bodies indicate that the Wahoo oolite grainstones were probably formed in a tidal bar belt environment transgressive over sediments of the underlying, open platform, normal marine, probably slight reducing, glauconite-forming environment. The pale yellowish orange-weathering, arenaceous dolomites and the thick-bedded oolitic grainstones are interpreted as representing the interstratified record of very shallow lime mud tidal flats developed directly over oolitic tidal bars. This close physical relationship of oolitic grainstones and thin-bedded lime mudstones and dolomites is not unique to the Wahoo Limestone. Wilson and others (1967, p. 81) report a similar sequence of oolitic grainstone and unfossiliferous mudstones from Pennsylvanian-age carbonates of southwestern New Mexico. J. L. Wilson (written commun., 1971) states that similar "dolomitic marker beds are also common in Devonian and Mississippian sections of Montana where they are almost certainly tidal flat and sebkha deposits with the former sulfate minerals leached out. In places such beds are de-dolomitized. In Montana in the Mission Canyon Formation such beds are also associated with oolitic grainstones but are commonly separated from these by a transitional zone of birdseye pelletoidal mudstone and grainstone."

The Egaksrak River section has 400 feet of ooid to echinoderm bryozoan packstones-wackestones and grainstones above the highest, well-developed oolite grainstones (fig. 1). These beds are believed to be younger Atoka age carbonates than those preserved beneath the Permian unconformity in the Sadlerochit Mountains.

Osagia sp. colonies occur at 160, 560, and 600 feet below the top of the Egaksrak River section and possibly indicate a very shallow water environment of deposition. These beds also contain increasing amounts of micrite and significant amounts (5-20 percent) of silt- to fine-sand-size detrital quartz. These factors possibly indicate that the beds above the last oolite grainstone represent the development of a slowly regressive carbonate depositional phase.

Wahoo Limestone coral paleoecology

The colonial corals, *Corwenia* sp. and *Lithostrotionella* sp., occur in large numbers in certain horizons of the Wahoo Limestone. Their growth habit and spatial relationship within these beds indicates that individual colonies lived separated from each other and did not form biostromal or biohermal masses.

The colonial corals in the Wahoo Limestone are found in close association with oolitic grainstones and packstones. The specimens are not found generally in carbonates made entirely of ooids but in ooid admixtures that have varying amounts of micrite, pellets, small lithoclasts, and abundant fragments of brachiopods, bryozoans, echinoderms, calcareous algae, fusulinids, and smaller Foraminifera. These rocks contain a rich and diverse biota indicating a shallow-water environment. The abundant fragments of calcareous algae and well-developed ooid grains, 0.4-0.8 mm in size, indicate deposition in or adjacent to shoaling water. The presence of micritic lithoclasts, up to 4 mm in size, and poor filling by lime mud indicate a somewhat lower energy environment than simple ooid tidal banks. In the Bahamas lithoclasts are most common in the tidal channels and inter-bar swales. The environments of coral growth are probably below and to the side or between the oolite banks, but above the reducing environments in which the glauconite was formed. Many of the coralla appear to have been buried in a growth position, but others appear to have been turned over and broken before burial. These latter factors, plus the lithoclasts found associated with the corals, suggest periodic high-energy wave motion, probably associated with storm activity (Ball and others, 1967). The origins of these micritic-pelletoidal bioclastic-oolitic packstones are somewhat analogous to similar calcareous sand bodies of the Bahama Banks described by Ball (1967, fig. 9, particularly fig. 19). A hypothetical reconstruction of the Wahoo Limestone environments of deposition is shown in figure 3, and the preferred environments for coral growth are shown as between and below the ooid sand tidal bank.

The association of the corals with oolitic grainstones indicates that they needed a relatively high-energy, clear, shoaling-water environment. The non-oolitic echinoderm-bryozoan-algae-wackestones-packstones and grainstones which are associated stratigraphically with the ooid-bearing beds are in general devoid of colonial rugose corals, and this further suggests the narrow range of environments these corals could tolerate.

The Pennsylvanian colonial corals of the Lisburne Group appear to be more environmentally sensitive than the Mississippian (Meramec) lithostrotionoid corals of the underlying Alapah Limestone. These older rugose corals, as indicated by the rock record, could tolerate slower moving water with apparently higher amounts of suspended lime mud particles. Armstrong (1970) reports that in the Kogruk Formation, DeLong Mountains, the lithostrotionoid corals are abundant in ooid grainstone and are common in bryozoan-crinoid-packstones and wackestones.

Graphic registry of stratigraphic sections

This report is primarily concerned with the Pennsylvanian age carbonates and corals. The Wahoo Limestone sections of this study are part of the Lisburne Group, which includes also the Late Mississippian Alapah Limestone. The Wahoo Limestone parts, sections 68A-1, 69A-1, and 68A-4A-4B, which are described and geographically illustrated in this report in figure 1, are underlain by considerable thicknesses of Mississippian carbonates. The microfossil zonation and lithologies of these older carbonates are described by Armstrong, Mamet, and Dutro (1970).

Reiser and others' (1970) 1:63,360-scale geologic maps of the Sadlerochit Mountains give detailed geologic settings for sections 69A-1, 68A-4A-4B, and 68A-3. Figures 4 through 7 are detailed graphic

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Figures 4 through 7 near here.

Locations of the measured stratigraphic sections of this report.

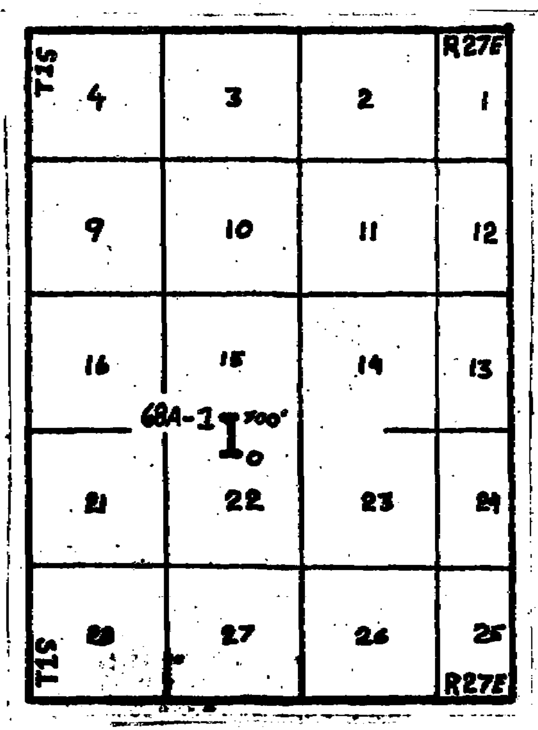

Figure 4. Location map, Ikiakpuk River section 68A-1.

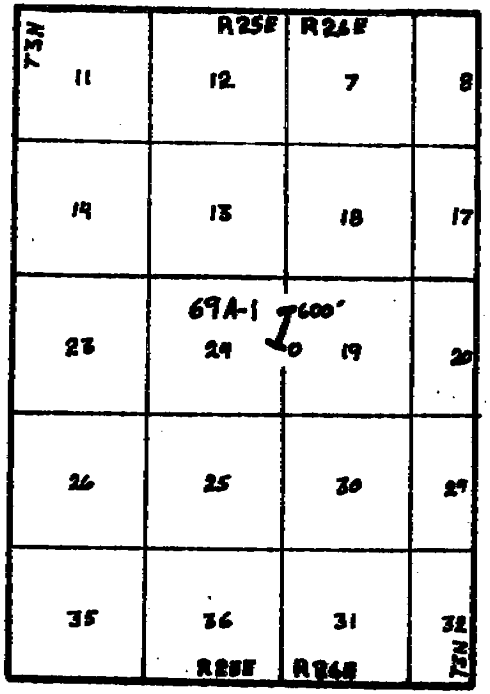

Figure 5. Location map, West Sadlerochit Mountain section 69A-1.

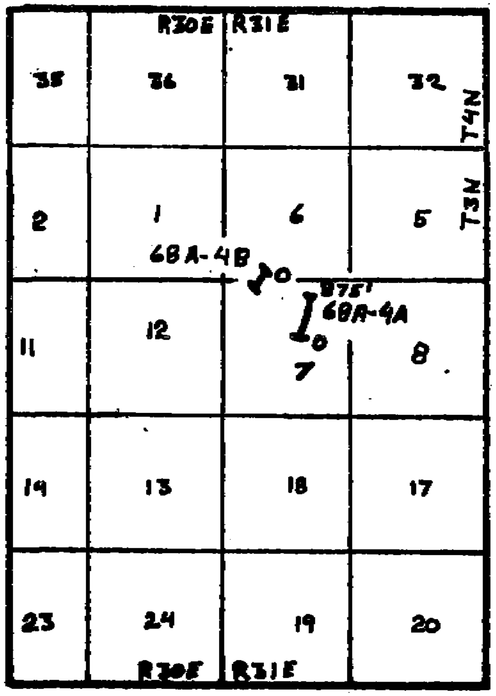

Figure 6. Location map, East Sadlerochit Mountain section 68A-4A-4B.

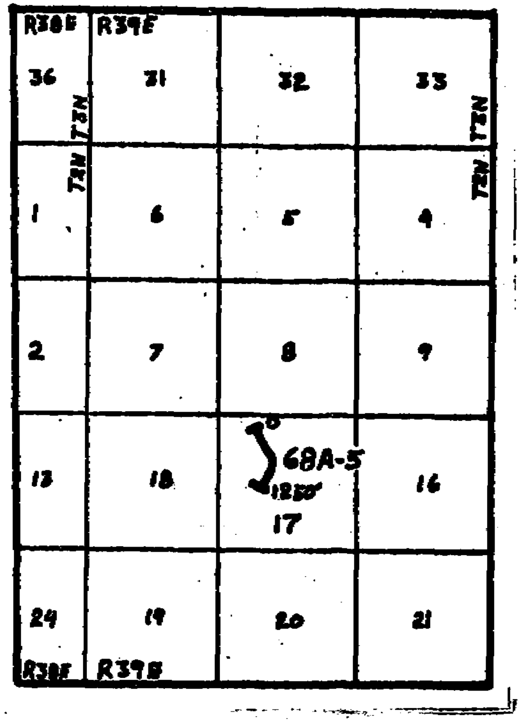

Figure 7. Location map, Egaksrak River section 68A-5.

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