PENNSYLVANIAN CARBONATES, PALEOECOLOGY, AND RUGOSE COLONIAL CORALS, EASTERN BROOKS RANGE, ARCTIC ALASKA

Panoramic view of the western Sadlerochit Mountains viewed to the east from the traverse of section 69A-1. The crest of the Sadlerochit Mountains and upper slope is formed by the dark-colored Permian and Triassic Sadlerochit Formation which overlies the medium-gray Mississippian and Pennsylvanian Lisburne Group. The angular unconformity between the Mississippian and the lighter Devonian carbonates is readily apparent in the center of the photograph. The Shublik Mountains are in the background. Photograph taken on June 19, 1969.

Pennsylvanian Carbonates, Paleoecology, and Rugose Colonial Corals, North Flank, Eastern Brooks Range, Arctic Alaska

By AUGUSTUS K. ARMSTRONG

GEOLOGICAL SURVEY PROFESSIONAL PAPER 747

Carbonate and paleoecological studies, and description of two new species of colonial rugose corals from four described sections of the Wahoo Limestone, Lisburne Group, Arctic Alaska

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CONTENTS

ILLUSTRATIONS

[Plates follow index]

PENNSYLVANIAN CARBONATES, PALEOECOLOGY, AND RUGOSE COLONIAL CORALS, NORTH FLANK, EASTERN BROOKS RANGE, ARCTIC ALASKA

By Augustus K. Armstrong

ABSTRACT

The Pennsylvanian carbonates of four measured sections of the Late Mississippian and Pennsylvanian Wahoo Limestone consist of 310–1,250 feet of deposits 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 time generally progressed from shallow-water open-marine sedimentation to higher-energy shoaling water oolitic sedimentation.

The Atoka age rugose colonial corals, *Corwenia jagoensis* n. sp. and *Lithostrotionella wahooensis* n. sp., are described. Paleoecological and biostratigraphic analysis of the carbonate beds associated with the colonial corals indicates that they lived in clear agitated water between oolitic tidal bars.

INTRODUCTION

Pennsylvanian carbonates are well exposed in northeastern Brooks Range (see frontispiece) of eastern Arctic Alaska. The outcrops are suitable for detailed stratigraphic, facies, and paleoenvironmental studies. Also, a few other 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 foraminiferal samples were collected every 5–10 feet. Most of the corals were collected from within measured sections. Thin sections, cut from lithologic samples, were petrographically described and studied for microfossiles.

Calcite and dolomite were identified in thin sections by the Alizarin-red staining techniques of 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, Rezak, and Ginsburg (1964), Shinn, Ginsburg, and Lloyd (1965), Roehl (1967), Wilson (1967a, b, 1969), Shinn (1968a, b), Ball, Shinn, and Stockman (1967), Ball (1967), and Murray and Lucia (1967). The concepts for cyclic carbonate deposition cyclic which are used in this report are those developed by Fischer (1964), Wilson (1967a, b), Coogan (1969), Armstrong (1967), and Armstrong, MacKevett, and Silberling (1969).

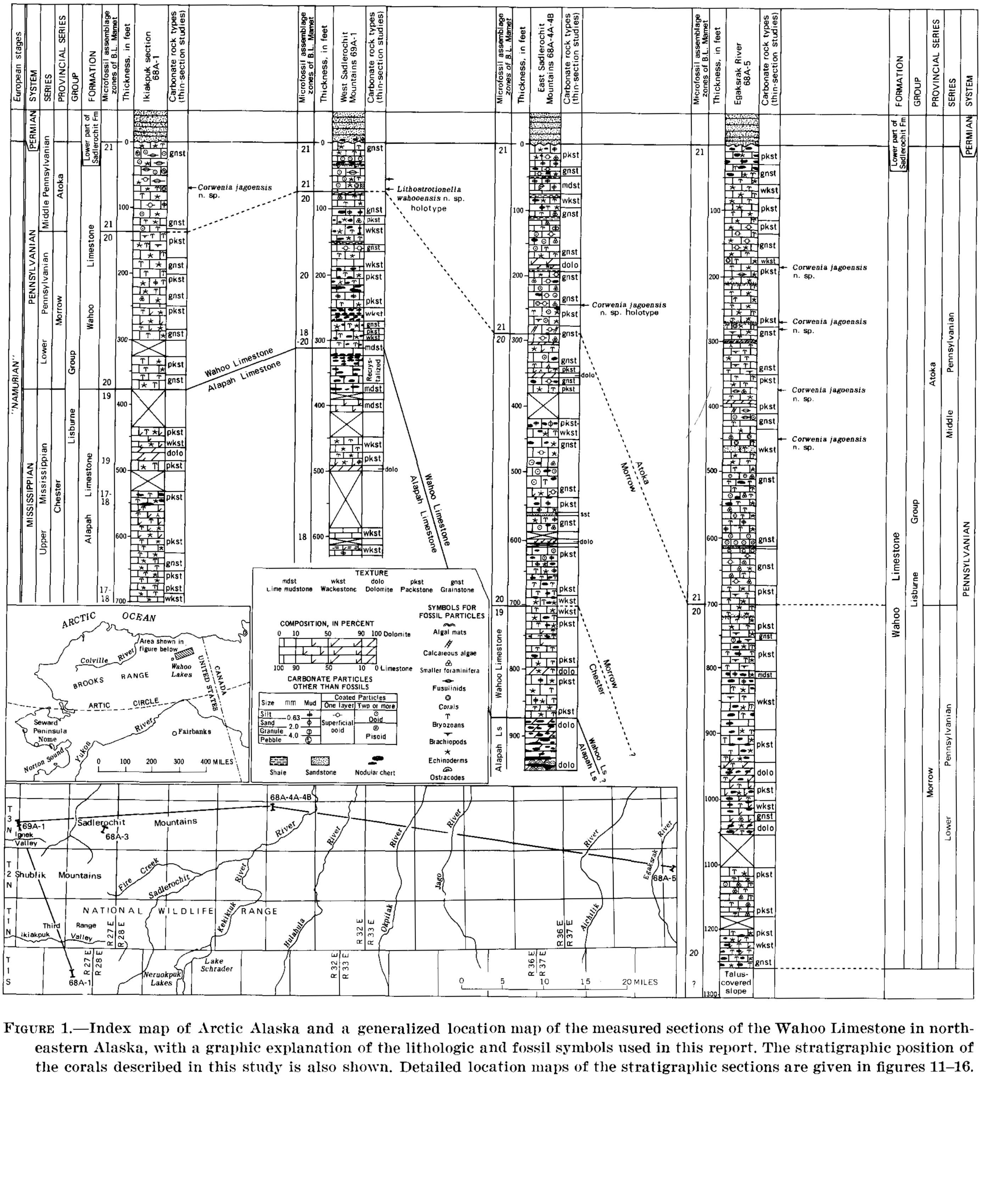


FIGURE 1.—Index map of Arctic Alaska and a generalized location map of the measured sections of the Wahoo Limestone in northeastern Alaska, with a graphic explanation of the lithologic and fossil symbols used in this report. The stratigraphic position of the corals described in this study is also shown. Detailed location maps of the stratigraphic sections are given in figures 11–16.

PREVIOUS WORK AND ACKNOWLEDGMENTS

In 1962, Brosgé, Dutro, Mangus, and Reiser extended the name Lisburne Group to carbonate rocks at Wahoo Lake and included in it the Early Mississippian Wachsmuth Limestone, the Late Mississippian Alapah Limestone, and the newly named Pennsylvania (?) and Permian Wahoo Limestone. The Wahoo Limestone, as mapped in the area of this report, contains some beds of very latest Chester (latest Mississippian) age but primarily contains beds of Morrow (Early Pennsylvanian) and Atoka (Middle Pennsylvanian) 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 in the Brooks Range. 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, Dutro, Brosgé, Armstrong, and Detterman (1970) have made geologic maps 1:63,-360 scale) of the Sadlerochit Mountains that delineate the outcrops of the Lisburne Group, including the Wahoo Limestone.

I wish to express my appreciation to Irvin Tailleur, party chief during the summer of 1968, and Hillard N. Reiser, party chief during the summers 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 fieldwork during the summers of 1968–70. Two specimens of colonial corals used in this study, collected by Shell Oil Co. 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 Co. 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; these biostratigraphic zones are 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 (Late Mississippian) age (zone 13); to the north in the Sadlerochit Mountains at the West Sadlerochit Mountain section (69A–1), the base is lower Chesteran (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). Atokan 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 substantiate the conclusion that the uppermost beds are not Des Moines in age.

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

CARBONATE STRATIGRAPHY

Brosgé, Dutro, Mangus, and Reiser (1962, p. 2191) described the type section of the Wahoo Limestone near Wahoo Lake as containing carbonates of Pennsylvanian (?) and Permian age. In the area of this report, the Wahoo Limestone as mapped by Reiser, Dutro, Brosgé, Armstrong, and Detterman (1970) contains carbonates of Mississippian (very latest Chester) and Pennsylvanian (Morrow and Atoka) age (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 Atokan beds are unconformably overlain by arenaceous limestones, sandstones, and conglomerates of the Sadlerochit Formation of Late Permian and Early Triassic age.

In the area of this paper (fig. 1), the Wahoo Limestone forms bold cliffs (figs. 2, 3) above the thin-bedded, generally talus-covered slopes of Alapah Limestone (Mississippian).

The Morrow age carbonates (fig. 1) of the Wahoo Limestone are predominantly bryozoan-crinoid wackestones and packstones (pl. 7, figs. 4, 8; pl. 8, figs. 4–6). The fossil fragments are typically large, 0.2–5 mm in length, and poorly sorted. Lesser amounts of grainstones formed of well-sorted fossil fragments and superficial ooids are present (pl. 7, figs. 6, 7). 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 150–300 feet (pl. 7, fig. 5) below the Sadlerochit Formation is composed of coarse-grained bryozoan-echinoderm packstones which form 25- to 50-foot-thick beds (fig. 2). 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,

FIGURE 2.—West Sadlerochit Mountains section (69A–1) showing line of traverse and stratigraphic footage marks. The contact between the thin-bedded dolomitic carbonates of the Alapah Limestone and the massive limestone of the Wahoo Limestone is shown at 310 feet. Locality of the type specimen of *Lithostrotionella wahooensis* n. sp. is indicated. The contact of the Permian and Triassic Sadlerochit Formation is shown in the right center of the photograph. The view is to the south; in the background are the Shublik Mountains. The well-exposed Pennsylvanian-Permian unconformity shown in figure 5 is located a few hundred yards to the right of the contact shown in this photograph.

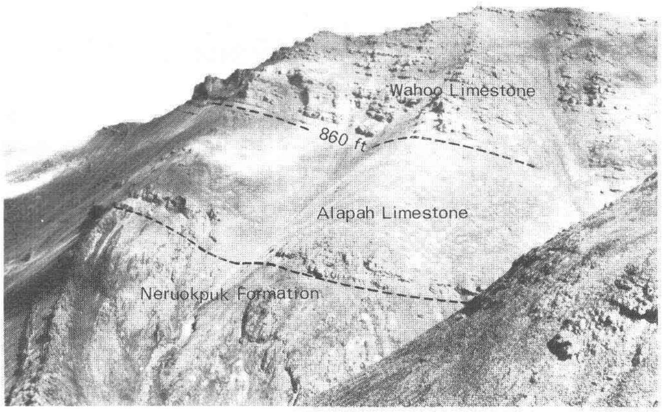


FIGURE 3.—The Lisburne Group outcrop on the hillside to the east and opposite the line of traverse of East Sadlerochit Mountains section (68A–4A–4B). Thin-bedded dolomites near the top of the Alapah Limestone form the rubble-covered slope beneath the massive cliffs of the Wahoo Limestone which begins at the 860-foot mark. The basal beds of the Wahoo Limestone are of late Chester age. The varied topographic expression of the Lisburne Group clearly reflects the several carbonate rock types formed in differing ancient depositional environments. (See fig. 6.)

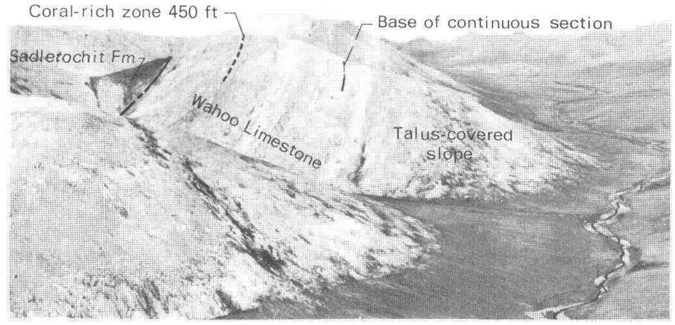


FIGURE 4.—The Egaksrak River section (68A–5), showing the contact of the Sadlerochit Formation with the underlying Wahoo Limestone and the rubble-covered slope at the base of the section. The section was measured over the crest of the ridge. The *Corwenia jagoensis* n. sp. zone, named for the prolific species, occurs on the apex of the hill. View is to the east.

grainstones, and pelletoidal-bioclastic packstones and grainstones (pl. 7, figs. 6, 7). The Morrow age carbonates to the east in the Egaksrak River section, 68A–5 (fig. 4), are again low-energy bryozoan-crinoid wackestones and packstones (pl. 8, figs. 4–6) with only minor amounts of superficial ooids and oolitic grainstones.

The Atoka age carbonates are predominantly grain-supported packstones and grainstones with minor amounts of wackestone and lime mudstones. Characteristically these beds are 5- to 15-foot thick, weakly cross-bedded, well-stratified oolitic grainstone which contains well-developed ooid grains (pl. 8, figs. 2, 7) that are from 0.5 to 1.0 mm in diameter. Some of the ooids have numerous layers and many show much evidence of algal boring. The nuclei 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 and packstones are formed by Formaminifera and broken bryozoan fragments whose interiors are generally filled with micrite (pl. 8, figs. 3, 4). A small percentage (1–2 percent) of these fossils have glauconite filling the internal spaces. The carbonates between some of the oolite beds are 6-inch to 4-foot thick, argillaceous, arenaceous, dolomitic, and hematitic. These "marker" beds persist over long distances in the Sadlerochit and Shublik Mountains and give the Wahoo Limestone its characteristic yellowish-orange weathering color. Thin sections of the carbonates which form these "marker" beds show their composition to be 50–70 percent dolomite rhombs ranging from 25 to 50 microns and the remainder fragmental subangular grains of detrital quartz ranging from 50 to 100 microns. Limonite and hematite fill the interstices between many of the dolomite rhombs. The iron oxides probably are the weathering products of pyrite. Associated with the grainstones are thicker nonlimonitic lime mudstones and wackestones which contain 5–30 percent detrital quartz whose grains range from 50- to 100-microns. Glauconitic shale partings, 1–4 inches thick, are not uncommon between the massive carbonates.

Atoka age 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 410–570 feet below the top. Oolitic grainstones are well developed from 590 to 600 feet below the top of the section (pl. 8, fig. 2). 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. Here 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 (pl. 8, figs. 7, 8). 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 and Triassic Sadlerochit Formation conformably 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 (fig. 5) represents a hiatus of Des Moines through Leonard, and possibly early Guadalupe, time. The westward thinning of the Atoka age carbonates in the Sadlerochit Mountains (fig. 1) suggests uneven erosion, probably caused by differential uplift previous to sedimentation of the Sadlerochit Formation. 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 rossa-like clay (fig. 5). 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.

FIGURE 5.—Contact between Atoka carbonates of the Wahoo Limestone and Permian sandstones of the Sadlerochit Formation (upper arrow). Large cobbles and smaller pebbles of Wahoo Limestone are present at the base of the Sadlerochit Formation. Cracks and solution joints (lower arrow) in the upper part of the Wahoo Limestone are filled by a terra rossa-like clay. The hiatus between the Wahoo Limestone and Sadlerochit Formation represents all of Des Moines, Missouri, Virgil, and Early Permian time. The ruler is 6 inches long.

ENVIRONMENTS OF DEPOSITION

Within the area of this study, the Wahoo Limestone is part of a two-phase carbonate depositional megacycle which began in Late Mississippian time and continued into Pennsylvanian time (fig. 6). This carbonate sedimentation is part of a regionally transgressive Lisburne Group sequence that began at the Ikiakpuk section (68A–1), Third Range, in Meramecian time (zone 13) and at the West Sadlerochit Mountain section (69A–1) in Chesteran (zone 16_1) 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 noncurrent-deposited bryozoan-echinoderm packstones and wackestones. The environment of deposition for these carbonates is interpreted as open platform, normal marine (figs. 6, 7). 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.

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, 68A–4A–4B, (fig. 1). At a level 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; these features indicate 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 (figs. 2, 3).

This regressive suite of carbonates (fig. 6) which culminates in an intertidal-restricted marine facies is overlain, as indicated by microfossil assemblages (Arm-

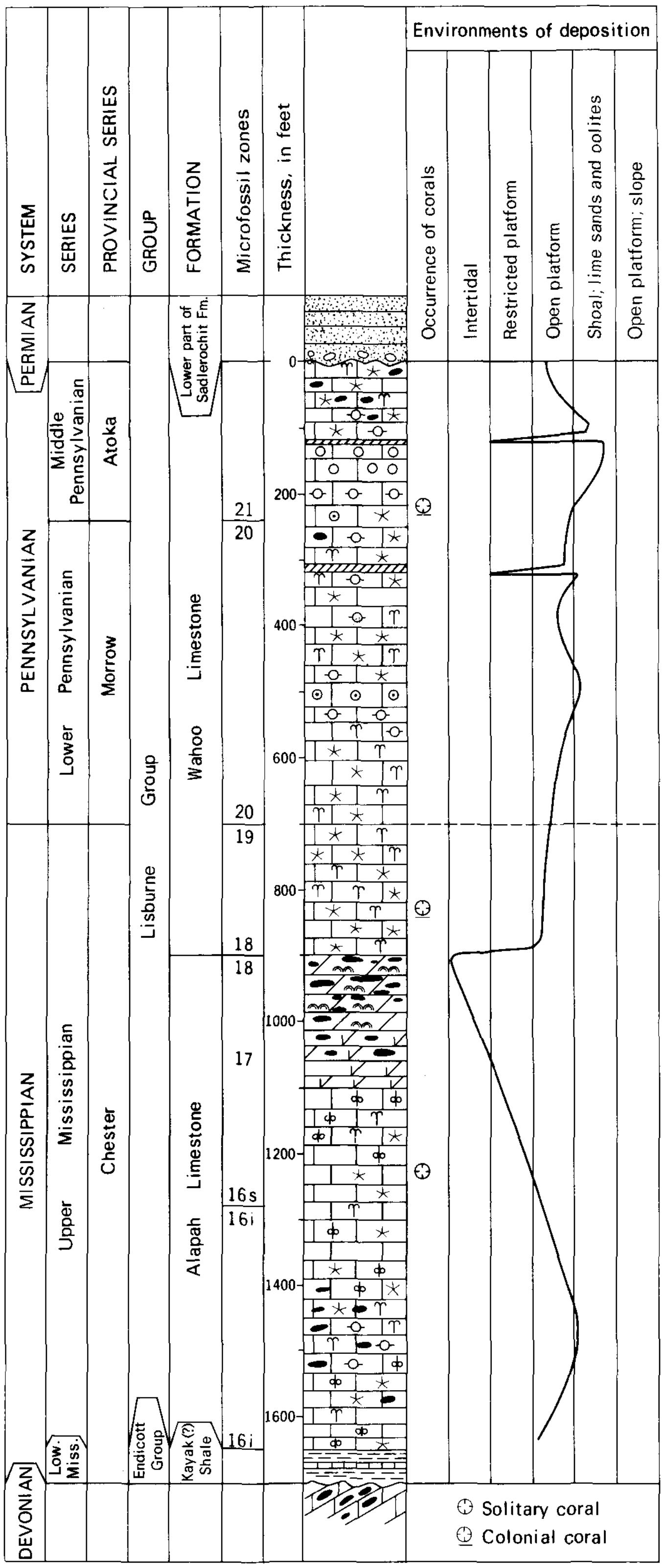
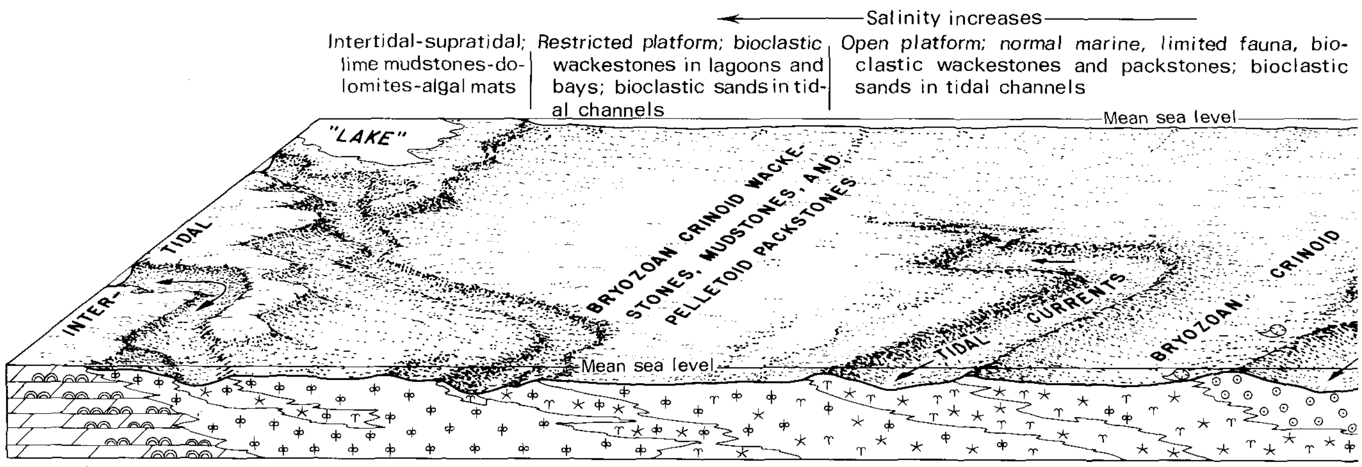


Figure 6.—Composite and idealized Lisburne Group sequence in the Sadlerochit Mountains showing the interpreted shifts of carbonate environments of deposition at various stratigraphic levels. Explanation of symbols for fossil particles given in figure 1.

strong and others, 1970), by a marine transgressive carbonate facies of bryozoan-echinoderm wackestones and 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. 6). 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 at the base of the Permian, the general trend in sedimentation is towards higher energy water, that is a shoaling water oolitic environment of deposition. This is inferred 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 6.

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 that 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 fig. 7).



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 crossbedded. In many places, the beds are capped by dolomites which are from 6 inches to 2 feet thick, argillaceous, arenaceous, and limonitic; the dolomites weather to pale yellowish orange. This rock is composed of dolomite rhombs some 30 microns in size and 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 the underlying sediments that are characteristic of an open platform normal marine environment which is probably slightly reducing and glauconite-forming. The thin-bedded 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, Madrid-Solis, and Malpica-Cruz (1967, p. 81) report a similar sequence of oolitic grainstone and unfossiliferous mudstones from Pennsylvanian 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 Limestone 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 carbonate beds are believed to be a younger Atoka age than those carbonates 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 oolitic grainstone represent the development of a slowly regressive carbonate depositional phase.

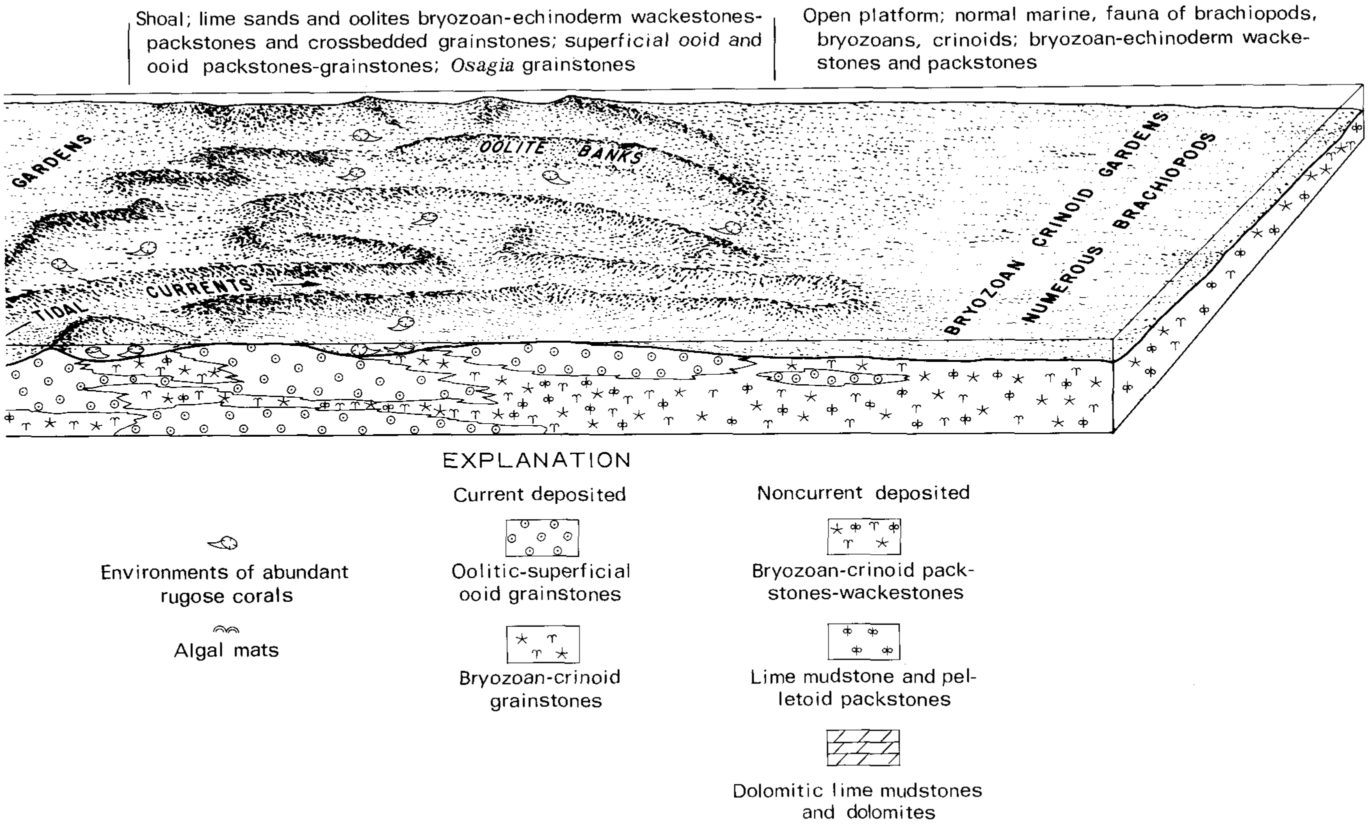


FIGURE 7.—The Pennsylvanian environments of carbonate deposition of the Wahoo Limestone on the north flank, eastern Brooks Range. Vertical distance is less than 100 feet, horizontal distance 50–100 miles.

WAHOO LIMESTONE CORAL PALEOECOLOGY

The colonial corals, *Corwenia jagoensis* n. sp., and *Lithostrotionella wahooensis* n. 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 foraminifers. This rich and diverse biota indicates 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, as much as 4 mm in size, and pore 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 interbar 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, which was 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 7, and the preferred environments for coral growth are shown as between and below the ooid sand tidal bank.

The association of colonial rugose corals with grainstones having oolites indicates that they needed a relatively high-energy clear shoaling-water environment. The general absence of corals from the packstones and grainstones which are interstratified with the ooid-bearing beds but which lack oolites provides evidence that these corals tolerated a narrow range of environments.

The Pennsylvanian rugose colonial corals of the Lisburne Group appear to be more environmentally sensitive than the Mississippian (Meramec) lithostrotionoid corals of the older parts of the Alapah Limestone of the Brooks Range. 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) reported that in the Kogruk Formation, DeLong Mountains, the lithostrotionoid corals are abundant in ooid grainstone and are common in bryozoan-crinoid packstones and wackestones.

SYSTEMATIC PALEONTOLOGY

Family Aulophyllidae Dybowski, 1873

Genus CORWENIA Smith and Ryder, 1926 emend.

Corwenia Smith and Ryder. 1926, Ann. Mag. Nat. History, v. 17, p. 149.

Corwenia Smith and Ryder. Hill, 1940, Paleontographical Soc. Mon., p. 100–101.

Corwenia Smith and Ryder. Hill, 1956, *in* Moore, R. C., ed., Treatise on invertebrate paleontology, Part F, Geol. Soc. America, p. F288.

Corwenia Smith and Ryder. Dobroljubova, 1958, Akad. Nauk. SSSR Paleont. Inst. Trudy, v. 70, p. 114–117.

Corwenia Smith and Ryder. Groot, 1963, Leidse Geol. Meded., pt. 29, p. 66.

Type species.—*Lonsdaleia rugosa* McCoy, 1849, Lower Carboniferous, upper Visean; Corwin, Wales.

Diagnosis.—Phaceloid aulophylline corals with a radially or bilaterally symmetrical axial columella; septa thin or dilated in all quadrants; dissepitheca may be present; some forms have lonsdaleoid dissepiments; tabularium with periaxial and axial series of tabellae, strongly arched distally and peripherally convex. (Modified in part from Groot, 1963, p. 66.)

Corwenia jagoensis n. sp.

Plate 1, figs. 1–6; plate 2, figs. 1–5; plate 3, figs. 1–4; plate 4, figs. 1–4; plate 5, figs. 2–4

Material.—The material and specimens available for study are shown in the following tabulation.

Stratigraphic section	USNM catalog No.		Corallum fragment (cm)
68A–4A	161034	Holotype	8×10×10
68A–5	160533	Paratype	12×15×20
68A–5	160534	do	8×10×11
68A–5	160535	do	15×24×26
68A–5	160536	do	10×12×20
63B–808	160537	do	5×6×9
68A–1	160538	do	6×12×13
68A–4A	161035	do	5×9×14
68A–4A	161036	do	6×7×15
68A–5	161037	do	15×19×20
68A–5	161038	do	6×7×12
68A–5	161039	do	10×14×14
60C–201	161040	do	9×12×15

Stratigraphic section	Transverse thin sections (2″×3″)		Longitudinal thin sections (2″×3″)	
	Number of thin sections	Number of corallites	Number of thin sections	Number of corallites
68A–4A	2	20	3	5
68A–5	1	4	2	6
68A–5	1	23	2	8
68A–5	2	4	1	2
68A–5	1	4	1	1
63B–808	1	3	2	4
68A–1	2	5	1	3
68A–4A	1	1	1	1
68A–4a	1	11	1	4
68A–5	3	23	1	2
68A–5	2	21	2	5
68A–5	2	34	1	2
60C–201	3	16	1	4

Description.—The holotype, USNM 161034, is a fasciculate corallum (fig. 8). Corallites arise by offsets. A corallum is approximately 40–45 cm in diameter. In transverse section corallites range from 5 to 18 mm in diameter, and long, slightly sinuous major septa range from 20 to 32. The major septa are continuous through the dissepimentarium and are 100–125 microns thick at their junction with the corallite wall. Within the tabularium the major septa are dilated and are 250–350 microns thick at the tabularium wall, tapering gradually to their distal ends. The axial side of the tabularium wall and the dissepiments are thickened by a 150- to 300-micron-thick stereozone (pl. 1, figs. 2, 4). In transverse section the minor septa are short, penetrate only a short distance past the dissepimentarium into the tabularium, and are commonly discontinuous within the dissepimentarium. The counter septa, and in some specimens, the cardinal septa are continuous with the columella; the other major septa are generaly withdrawn from the axial region. The columella is clearly formed by the dilation of the axial end of the counter septum and ranges from 1–4 mm long and 100–200

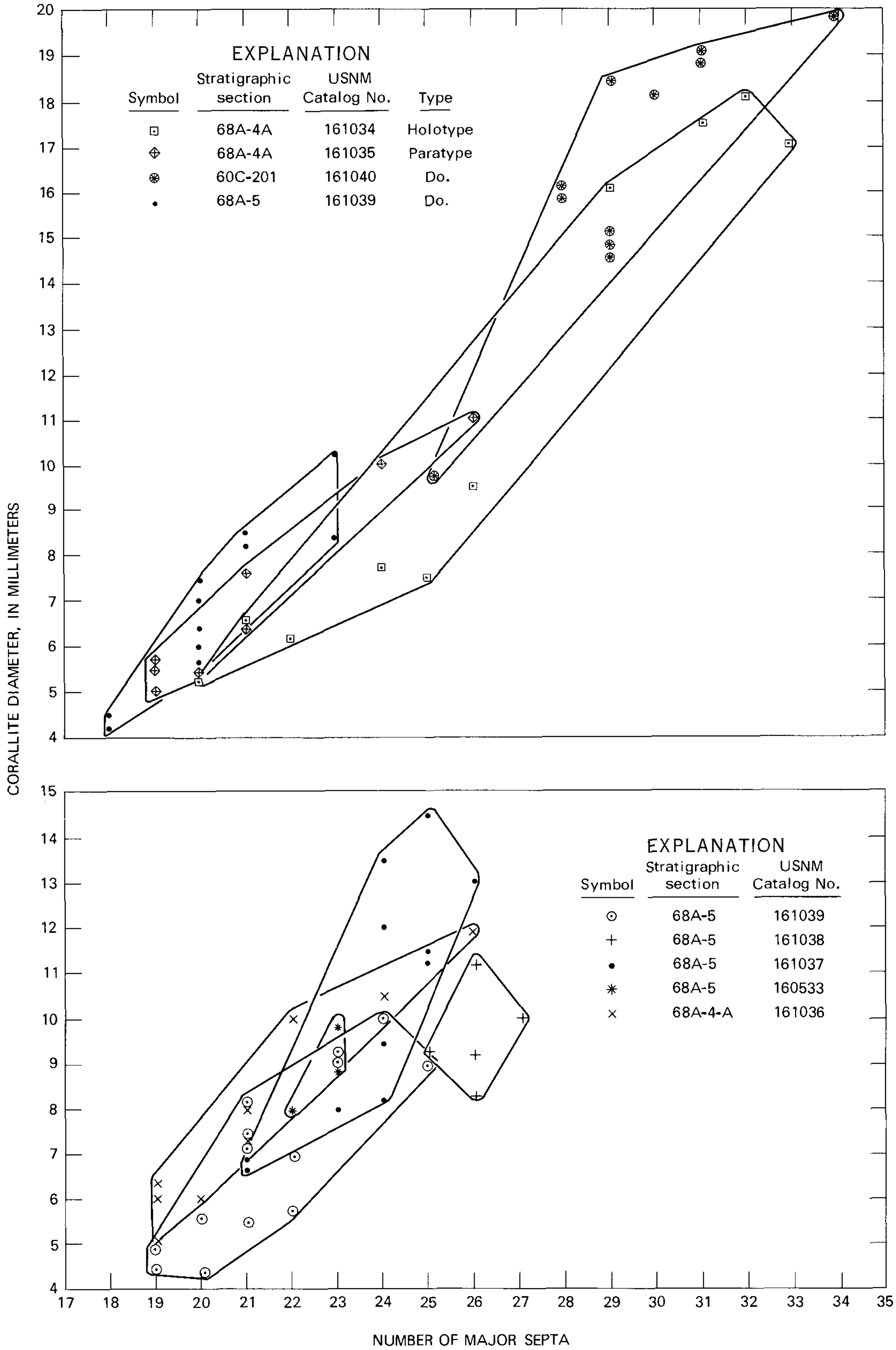


FIGURE 8.—Corallite diameter and number of major septa in *Corwenia jagoensis* n. sp.

microns thick. In transverse thin section the columella is commonly surrounded by a spiderweb pattern that is formed in the plane of the thin section which cuts the upturned axial surface of the tabulae and their septal ridges (pl. 1, fig. 3).

Within coralla the smaller corallites (diameter 8.0 mm or less, 21–24 major septa) resemble the larger corallites except for their narrower dissepimentarium that is composed of two rows of dissepiments and their minor septa that are discontinuous within the dissepimentarium.

A corallite 18 mm in diameter in transverse thin section (pl. 1, fig. 6) has a dissepimentarium 2.5–3.5 mm wire formed by 4–6 rows of globose dissepiments. The peripheral stereozone is present on the axial side of the last ring of dissepiments facing the tabularium. The tabulae, generally incomplete, show a tendency to develop an inner and outer series of tabulae (pl. 1, fig. 5). The columella is persistent and slightly sinuous. The tabulae near the dissepimentarium slope up from the horizontal 20°–30°, whereas those near the columella may slope 50°–60° from the horizontal.

The microstructure of the corallum is generally well preserved (pl. 1, figs. 1–4). The corallite wall, 100–125 microns thick, is formed by dense fibrous calcite with the fibers oriented normal to the exterior wall. The wall can be divided into two parts—an outer dark-gray band, 30–40 microns thick, and an inner lighter colored band, 70–95 microns thick. The septa appear to be composed of a slightly different textural type of calcite. The junction of the septa and the corallite wall is distinctly marked by an embayment of the septa into the corallite wall. The microstructure of the corallite wall and the septra is similar to and conforms to the type described by Kato (1963, fig. 17C) as lamellar. In transverse section, the septa in the dissepimentarium have a dark central band 10–15 microns wide, and at either side fibrous calcite is at nearly right angles to the central band (pl. 1, fig. 1). The septal stereozone in the tabularium appears to be a simple thickening of the fibrous calcite forming the outer layer of the major septa. The stereozone on the dissepiments is also fibrous calcite (D on pl. 1, fig. 4), but where it abuts against the septal stereozone, a sharp line of demarcation can be seen (pl. 1, figs. 1–2). Petrographic studies clearly show that the columella is an extension of the counter septum and that the tabulae are fused to it. In longitudinal thin sections, the dissepiments and tabulae are 20–35 microns thick and are composed of dense calcite crystals which are fiber shaped to rhomb shaped and 4 microns in size or smaller (pl. 1, fig. 4). The sequence of void filling within the corallum began with an initial deposition on all internal surfaces of rhombs of sparry calcite 10–15 microns in size followed by deposition of interlocking rhombs 0.1–3 mm in size.

Specimens USNM 161035, 161037, 161040, 160535, and 160536 typify the large corallites of this species and are very similar to the holotype in morphological details.

Specimens USNM 160533 and 160539 typify the smaller corallites of the species with fewer major septa. Thin sections of USNM 160539 show that the corallites range in diameter from slightly more than 4 mm to 10 mm and have 19–23 major septa. Morphological features in general are similar to those of the holotype and are very similar to those of the smaller corallites in the corallum of the holotype, however, the major septa are slightly longer and the axial structures are better developed than in the holotype.

Occurrence.—The holotype, USNM 161034, and the paratypes, USNM 161035 and 161036, were collected 250 feet below the top of the East Sadlerochit Mountains section, 68A–4A–4B. Paratype USNM 160537 was collected by Stanley F. Schindler, Shell Oil Co., in 1963, in a measured section about 1.25 miles west of section 68A–4A–4B at a stratigraphic level in the Wahoo Limestone 165 feet below the contact with the Sadlerochit Formation. Other paratypes were collected at the following levels below the top of Egaksrak River section 68A–5 (fig. 9): USNM 161039 at 230 feet, USNM 161037 and 161038 at 270 feet, USNM 160533 and 160534 at 285 feet, and USNM 160535 and 160536 at 450 feet. Paratype USNM 160538 was collected about 70 feet below the top of the Ikiakpuk Creek section 68A–1. Paratype USNM 161040 was collected by Stanley F. Schindler, Shell Oil Co., in 1960, in a measured section near Salisbury Mountain, long 146°19′ W., lat 69°14′ N. The specimen was collected in the Wahoo Limestone 5

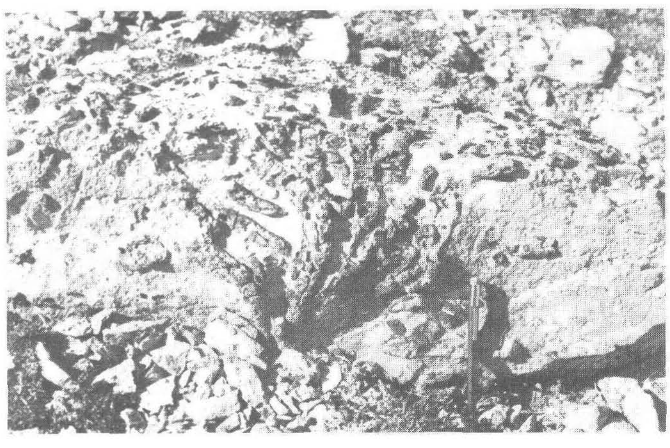


FIGURE 9.—Large corallum of *Corwenia jagoensis* n. sp. showing shape of colony and corallite growth. Scale shown by pencil in lower right. Corallum occurs in a coral-rich bed of the Wahoo Limestone about 450 feet below the top of the Egaksrak River section 68A–5; see figure 1 for stratigraphic location.

feet below the contact with the Sadlerochit Formation in limestone beds which contain a microfossil fauna of Atoka age.

Corwenia jagoensis n. sp. is found within the Wahoo Limestone in a biostratigraphic zone of Atoka age. Associated microfossils are *Millerella* spp., *Endothyra* of the group *E. mosquensis* Reitlinger, *Lipinella* sp., *Neoarchaediscus grandis* (Reitlinger), *Climacammina* cf. *C. moelleri* Reitlinger, *Drinella* sp., *Eoschubertella* sp., *Globivalvulina* sensu stricto, and *Pseudostaffella* sp.

Remarks.—The fasciculate rugose corals of the Wahoo Limestone present problems of classification at both the generic and specific levels and appear to represent a transitional form between the Mississippian genus *Corwenia* Smith and Ryder and the Permian genus *Heritschioides* Yabe.

A conservative concept is used in this study to define the genus *Corwenia*. Groot's (1963, p. 66) observations on the type species of *Corwenia rugosa* (McCoy) are: "That the septa may be dilated at the margin of the tabularium in all quadrants is shown in figure 12 of Smith, 1916, pl. 21, a section of the ephebic stage of a specimen of *Corwenia rugosa* from the type-locality. A section of an earlier stage of the same corallum * * * shows likewise a slight dilation of the septa and the presence of a dissepitheca." These two characteristics, the development of stereozones on the septa and dissepitheca, are the primary reasons why Yabe (1950) set up the genus *Heritschioides*, whose type species is *Corwenia columbica* (Smith, 1935) which is from the Pennsylvanian or Permian beds of British Columbia. Minato and Kato (1965, p. 31), in their redescription of the genus *Corwenia* as contrasted to the genera of their new family Durhaminidae which includes *Heritschioides*, state "the axial structure of *Corwenia* is quite characteristic, in which septal lamellae are firmly united with the prolongation of axial ends of major septa. Further, cardinal and counter septa are also directly united with medium plate. Accordingly, the axial structure in *Corwenia* is quite regularly constructed by radially arranged septal lamellae and a few concentrically arranged axial tabulae." The fasciculate corals from the Wahoo Limestone have well-developed columellae formed by the cardinal and counter septa and have dilated major septa in the tabularium and well-developed dissepitheca (pl. 1, figs. 1–4). The Wahoo Limestone specimens differ from the type species of *Heritschioides*, *H. columbica* (Smith), in having less well-defined inner and outer series of tabulae. Furthermore, the tabulae in the Wahoo Limestone specimens are relatively widely spaced in contrast to the closely spaced inner tabellae of *Heritschioides columbica*.

Specimens of *Corwenia jagoensis* n. sp. from the Atoka age beds of the Wahoo Limestone are believed to represent an unstable form because they show considerable structural variation in the corallites of a corallum and of different coralla. One is strongly tempted to define two species of *Corwenia* from the Wahoo Limestone material, based on corallite size and number of septa, development of the columellae, and length of major septa, but even within one colony wide gradations exist in corallite diameter, number of septa, and morphology. The contrast between corallum end members of the population is great, as can be seen by comparing specimens USNM 160534 (pl. 3, fig. 1) and USNM 161040 (pl. 4, fig. 4; pl. 5, figs. 2–4).

Specimens USNM 160534 and 161039, with their smaller corallite diameters, longer major septa, and less steeply inclined inner tabellae, resemble more closely the generic characteristics of *Corwenia*.

Specimen USNM 161040 appears to be the most highly evolved specimen of *Corwenia* in the collection. It has more closely spaced inner tabellae and also well-developed septal and dissepithecal stereozones. Thus, of all the specimens, it shows the closest relationship to the genus *Heritschioides* Yabe.

The holotype, USNM 161034, reveals in its larger corallites most of the characteristics of specimen USNM 161040 and in its smaller corallites most of the characteristics of specimen USNM 160534. The material now available for study indicates that all the specimens of *Corwenia* from the Wahoo Limestone probably represent one species. Further collecting of large numbers of *Corwenia* from the Wahoo Limestone may permit the differentiation of one or more species.

None of the described species of corals from the Cordilleran region of North America are closely related or similar to *Corwenia jagoensis* n. sp. *Waagenophyllum columbicum* Smith (1935, p. 38) from the Permian or Pennsylvanian of British Columbia differs in a significant number of characteristics; its corallites have a diameter of 10–17 mm, 25 major septa and long minor septa, and upward-sloping tabellae. The tabellae are more densely packed together than in *C. jagoensis* and form a well-developed and wider clisiophylloid structure.

Corwenia symmetrica (Dobroljubova) from the upper Moscovian of the Moscow and Donetz basins of the USSR (Fomichev, 1953, p. 396) and Groot's (1963, p. 69) specimens from similar age beds of Palencia, Spain, have diameters of 5–9 mm with 16–20 major septa, long minor septa, and weakly dilated major septa near the margin of the tabularium. *C. symmetrica* is close morphologically to *C. jagoensis* n. sp. The latter species differs primarily in having shorter minor septa and a colonial habit which forms coralla composed of closely spaced corallites (fig. 9). The Eurasian species, in contrast, is, from the descriptions given by Dobroljubova (1937, p. 58) and Fomichev (1953, p. 394), a solitary or weakly compound form.

Corwenia longisepta (Fomichev, 1953, p. 396) is a species from the upper Moscovian of the Donetz basin, USSR. Groot (1963, p. 69) describes her specimens, from similar age beds in Palencia, Spain, as having 24–26 major septa in a corallite diameter of 9 mm. It differs from *C. jagoensis* in having longer minor septa and major septa which generally reach the axial region.

Name.—The specific name is derived from the Jago River, which heads at a glacier in the Romanzof Mountains and flows northward into the Arctic Ocean.

Family Lonsdaleiidae Chapman, 1893

Genus LITHOSTROTIONELLA Yabe and Hayasaka, 1915

Lithostrotionella Yabe and Hayasaka, 1915, Geol. Soc. Tokyo Jour., v. 22, p. 94.

Lithostrotionella Yabe and Hayasaka. Hayasaka, 1936, Taihoku Imp. Univ., Formosa, v. 13, no. 5, p. 47–58.

Petalaxis Edwards and Haime. Fomichev (part), 1953, Vses. Nauchno-Issled. Geol. Inst. Trudy, p. 449–452.

Lithostrotionella Yabe and Hayasaka. Hill, 1956, *in* Moore, R. C., ed., Treatise on invertebrate paleontology, Part F, Geol. Soc. America, p. F306–307.

Type species.—*Lithostrotionella unicum* Yabe and Hayasaka, 1915, Permian, Chihsia Limestone, Yun-nan, South China.

Diagnosis.—Cerioid corallum, prismatic corallites, columella a persistent vertical lath frequently continuous with counter and cardinal septa. Lonsdaleoid dissepiments. All major septa intermittently reach the wall along the tops of the dissepiments. Minor septa short. Tabulae frequently complete, conical. (Summarized from Yabe and Hayasaka, 1915, p. 94).

Lithostrotionella wahooensis n. sp.

Plate 5, fig. 1; plate 6, figs. 1–5; plate 7, figs. 1–3

Material.—Fragments of eight coralla are available for study. The coralla are, by Lisburne Group coral standards, small, generally less than 25 cm in diameter. Most colonies are preserved in a pale-gray to a grayish-red-purple chalcedony; however, parts of some coralla have some corallites preserved in calcite. All the specimens were studied in 2- by 3-inch thin sections and polished slabs. The material available for study is shown in the following tabulation.

Stratigraphic section	USNM catalog No.		Corallum fragment (cm)
69A–1	160528	Holotype	12×12×18
69A–1	160525	Paratype	4× 4× 5
69A–1	160526	do	5× 7× 7
69A–1	160527	do	6× 7× 9
68A–3	160529	do	7×14×15
69A–2	160530	do	4× 6× 7
69A–2	160531		4×10×11
69A–2	160532		6× 7× 8

Stratigraphic section	Transverse thin sections (2″×3″)		Longitudinal thin sections (2″×3″)	
	Number of thin sections	Number of corallites	Number of thin sections	Number of corallites
69A–1	1	17	1	5
69A–1	1	7	2	10
69A–1	2	16	2	5
69A–1	1	8	1	7
68A–3	1	32	1	4
69A–2	1	12	1	7
69A–2	1	14	1	6
69A–2	1	15	1	5

Description.—The holotype, USNM 160528, is a cerioid corallum, about 28 cm in diameter and 16 cm in depth, that is shaped like a flattened cone.

The corallites, 5–8 mm in diameter, have 19–23 long sinuous major septa (fig. 10) that are slightly dilated in the tabularium. Most of the major septa are continuous throughout the dissepimentarium; generally no more than one or two major septa are discontinuous in any corallite. The cardinal and counter septa are commonly continuous with the elongate, thin columella. Serial sections indicate that the septa are high ridges on the upper surfaces of the tabulae. In transverse section, the upward-arched tabulae and the major septa produce a spiderweb pattern around the columella (pl. 7, fig. 1). The minor septa are short, generally less than 1 mm long. They are discontinuous in the dissepimentarium and commonly occur as a series of short ridges on the axial sides of the dissepiment walls. The major and minor septa near their junctions with the corallite wall are 80–110 microns thick. The microstructure of the holotype has been obscured by the growth of calcite crystals. The individual calcite crystals which form the corallite walls and septa are now 8–15 microns in size. Petrographic studies suggest the microstructure was fibrous. The major septa on the axial side of the tabularium wall are 80–150 microns thick and taper towards their distal ends. The columella typically is 100–150

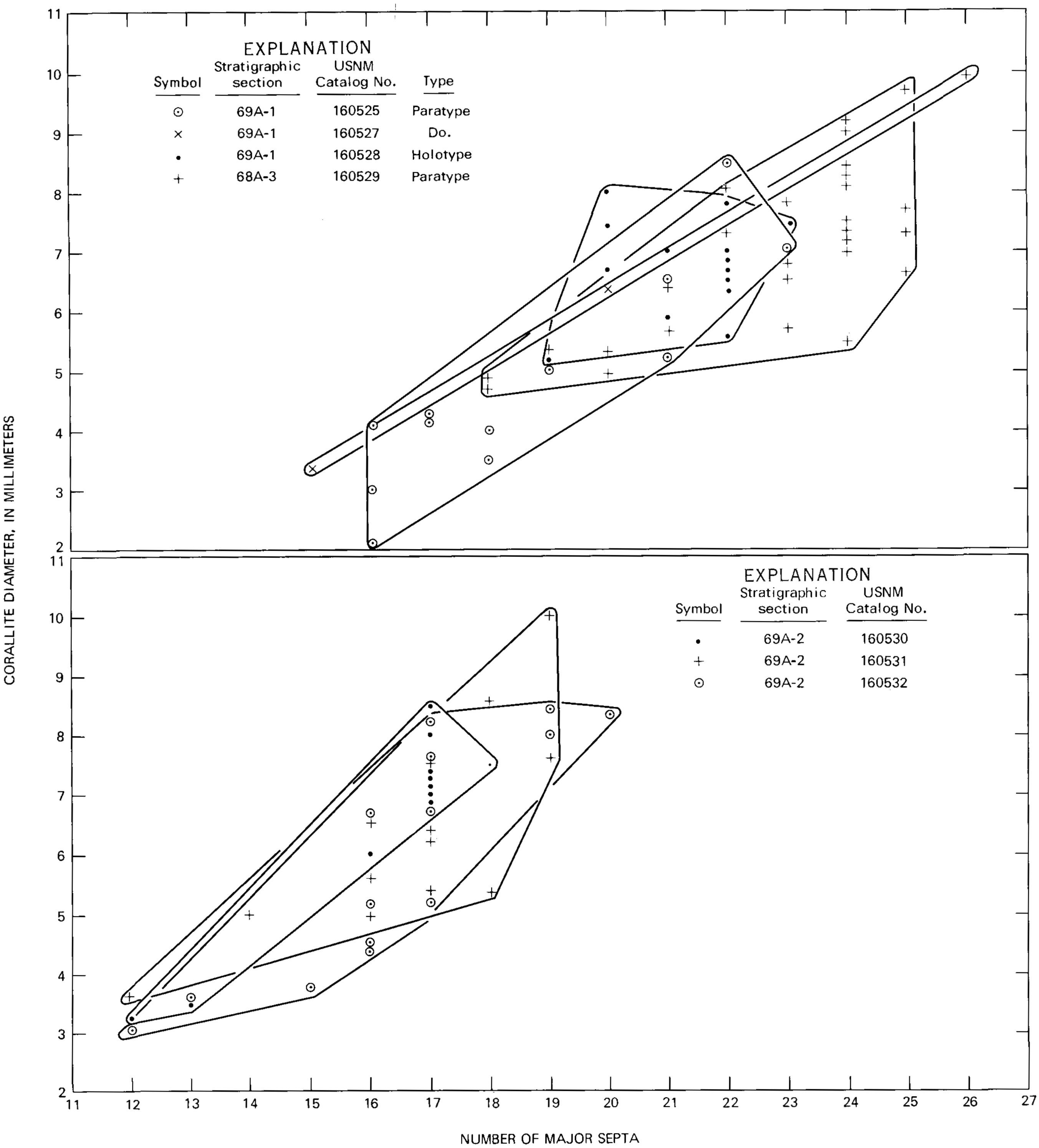


FIGURE 10.—Corallite diameter and number of major septa in *Lithostrotionella wahooensis* n. sp.

microns thick, has a central band 10 microns thick, and is composed of dense fibrous calcite. The wall between two corallites, 150–200 microns thick, has a dark, dense central band 10–20 microns thick and appears to be formed of fibrous calcite (pl. 7, figs. 1, 2). The internal voids of the corallum are filled by two phases of crystal growth. The first phase lined all interior surfaces with 25- to 50-micron-size crystals of sparry calcite; the second phase filled the voids with chalcedony.

Longitudinal sections show the dissepimentarium to be formed by three to four rows of globose dissepiments 0.5 mm wide to 1.5 mm long. The tabulae are commonly incomplete; the outer series slope upwards at angles of 30°–40° from the horizontal, the inner series slope upwards at angles of 45°–60° from the horizontal. Petrographic studies of the columella indicate that it is formed by the axial ends of the major septa. The tabulae and dissepiments in section are 15–20 microns thick and are composed of dark, dense, 8- to 10-micron-size crystals of calcite.

Paratypes USNM 160525 and 160527 were collected 3 feet stratigraphically above the holotype and are very similar in morphological details and preservation to the holotype (fig. 10).

The three specimens from the Wahoo Limestone of the Shublik Mountains, USNM 161030, 161031, and 161032, are preserved in chert nodules. In general these coralla display a thicker somewhat more massive columellae, longer septa, and three to five more major septa per corallite (fig. 10) than the holotype.

Paratype USNM 160529 (pl. 6, fig. 5) is similar to the holotype except that the columellae are less well developed and the tabulae display a tendency towards being complete and not as strongly arched upwards to meet the columellae. The specimen is preserved in a chert nodule.

Occurrence.—The holotype USNM 160528 and paratypes USNM 160525, 160526, and 160527 are from the upper part of the West Sadlerochit Mountains section 69A–1, Wahoo Limestone (figs. 1, 2). Paratype USNM 160529 is from measured section 68A–3 near the middle of the Sadlerochit Mountains (fig. 15), and USNM 161030–161032 are from within an undescribed section (69A–2) at the west end of the Shublik Mountains (fig. 16).

Lithostrotionella wahooensis n. sp. has been found only in the upper part of the Wahoo Limestone, in grain-supported high-energy packstones and grainstone that are associated with bedded oolites. Microfossils found with *Lithostrotionella wahooensis* n. sp. are *Endothyra* of the group *E. mosquensis* Reitlinger, *Millerella* spp., *Neoarchaediscus grandis* (Reitlinger), *Climacammina* cf. *C. moelleri* Reitlinger, *Eoschubertella* sp., *Pseudostaffella* sp., and *Globivalvulina* sp. These fossils are characteristic of microfaunal assemblage zone 21, Atoka age, Middle Pennsylvanian.

Remarks.—*Lithostrotionella wahooensis* is differentiated from the various species of Meramec and early Chester (Late Mississippian) age *Lithostrotionella* found in the underlying Meramec age Alapah Limestone and Kayak(?) Shale by the development of a more complex tabularium with a tendency toward inner and outer zones of tabulae.

Groot (1963, p. 85–86, pl. 18, fig. 2) describes *Lithostrotionella orboensis* Groot from the upper Moscovian Orbo Limestone of Palencia, Spain. *L. orboensis* has some characteristics in common with *L. wahooensis* but differs in having two to three fewer major septa per corallite, better developed and larger lonsdaleoid dissepiments and, in the tabularium, longer minor septa. Also in transverse section the tabularium is not as well differentiated into zones of inner and outer tabulae as in the Alaskan species.

Petalaxis mohikana Fomichev (1953, p. 459–462) from the upper Moscovian of the Donetz Basin, USSR, is similar in transverse section to *L. wahooensis* but differs primarily in having somewhat smaller corallites with only 13 or 14 major septa and complete tabulae.

Name.—The specific name is derived from the Wahoo Limestone.

GRAPHIC REGISTRY OF STRATIGRAPHIC SECTIONS AND FOSSIL LOCALITIES

This report is primarily concerned with the Pennsylvanian carbonates and corals of the Lisburne Group. The Lisburne Group also includes in this area the Late Mississippian Alapah Limestone, which is not discussed in this report. Sections 68A–1, 69A–1, and 68A–4A–4B from the Wahoo Limestone, which are described and graphically illustrated (fig. 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). Section 68A–3 in the central Sadlerochit Mountains is structurally complex and is not described in this report. (See Armstrong and others, 1970, fig. 4.) The West Shublik Mountains section, 69A–2, which has yielded a number of specimens of *Lithostrotionella wahooensis* n. sp., is badly faulted and has not previously been described; detailed stratigraphic description or stratigraphic illustrations of it are not given in this report.

Reiser, Dutro, Brosgé, Armstrong, and Detterman's (1970) geologic maps of the Sadlerochit Mountains give detailed (1:63,360 scale) geologic settings for sections 69A–1, 68A–4A–4B, and 68A–3. Figures 11 through 16 are detailed graphic locations of the measured stratigraphic sections of this report.

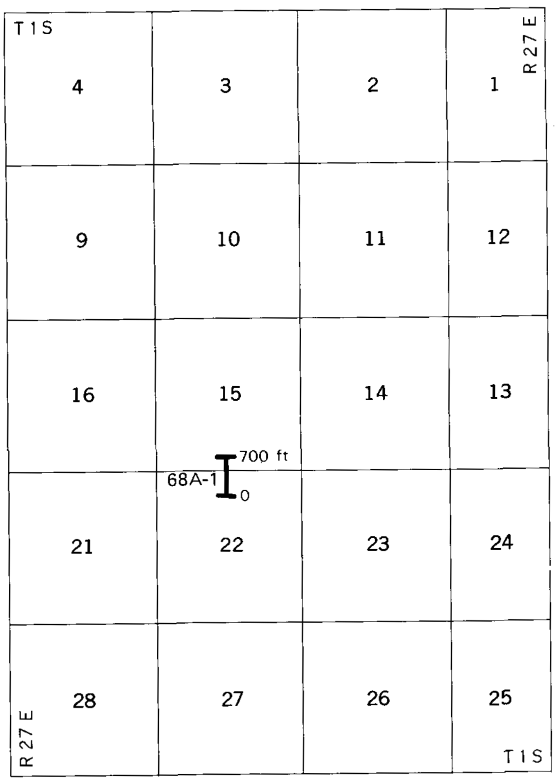


FIGURE 11.—Ikiakpuk River section 68A–1.

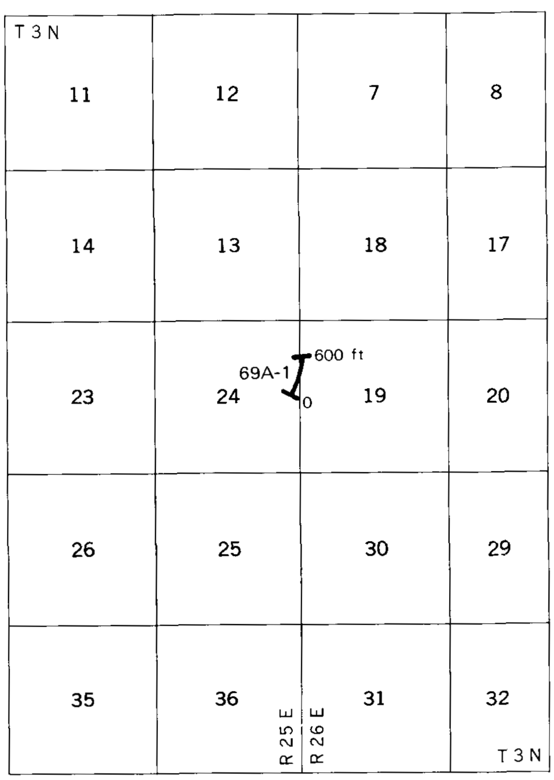


FIGURE 12.—West Sadlerochit Mountains section, 69A–1. See figure 2 for a photograph of the outcrop and fossil locality.

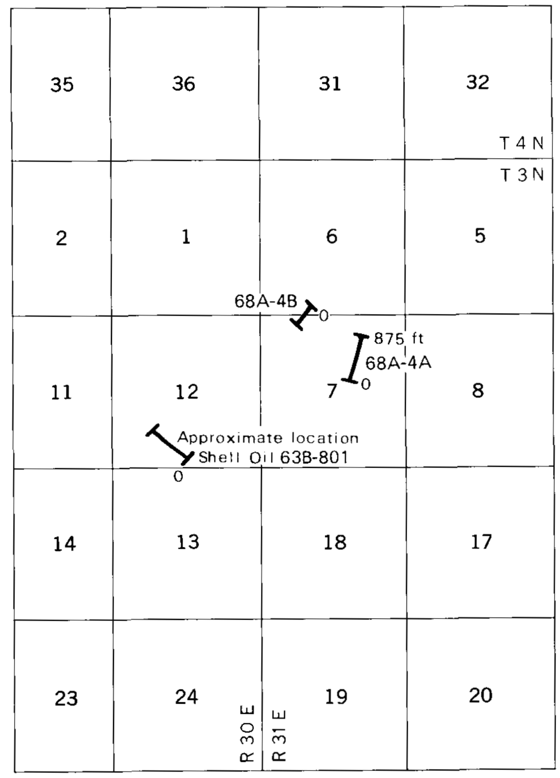


FIGURE 13.—East Sadlerochit Mountains sections, 68A–4A–4B, and approximate location of Shell Oil Co. section 63B–801 from which paratype, USNM 160537, *Corwenia jagoensis*, was collected.

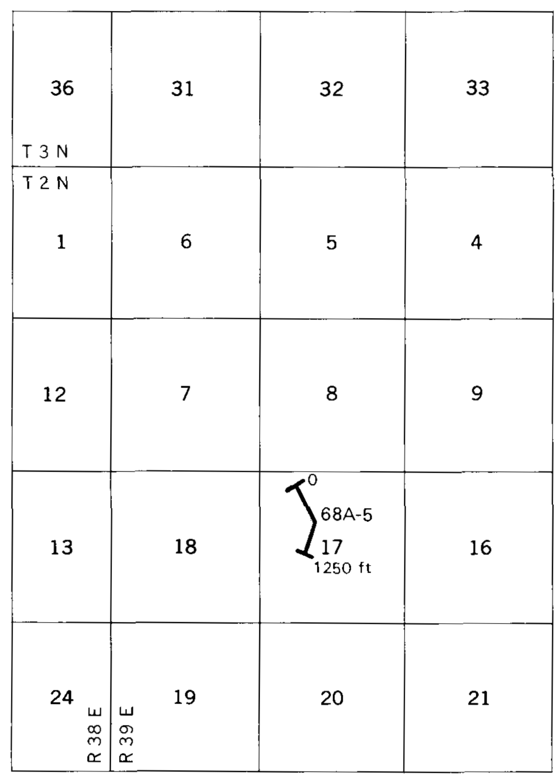


FIGURE 14.—Egaksrak River section 68A–5. See figure 4 for an outcrop photograph.

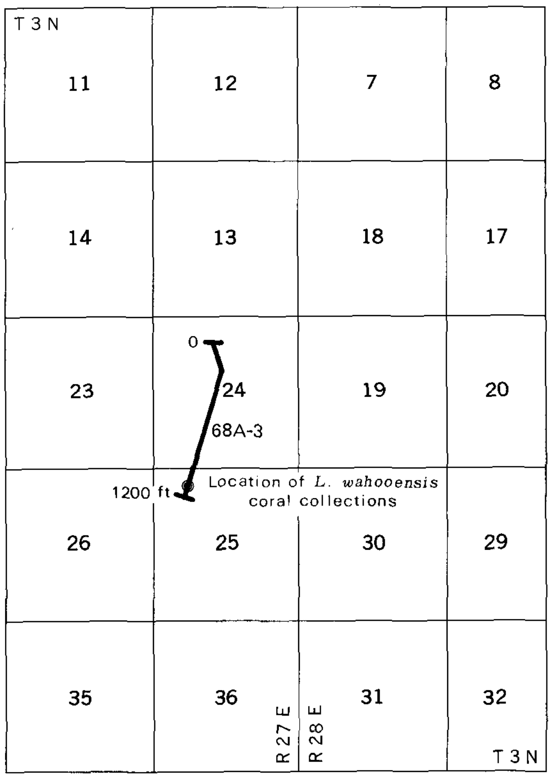


FIGURE 15.—Central Sadlerochit Mountains section 68A-3. This section is not discussed in detail in this report.

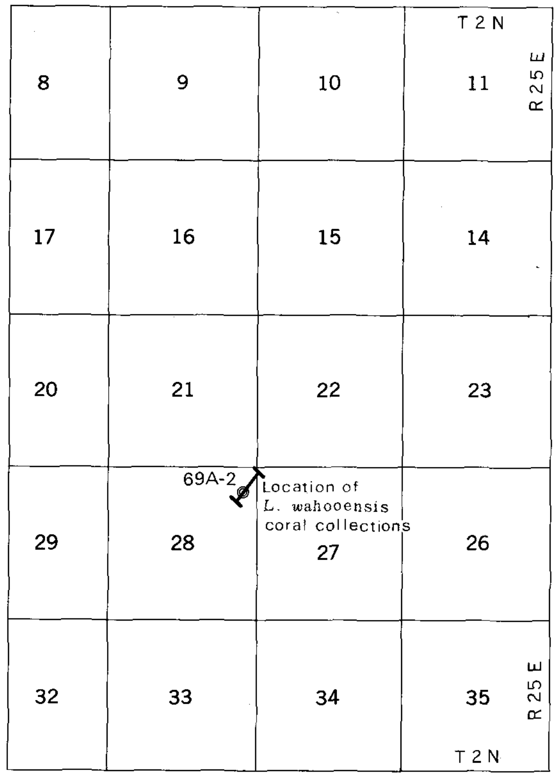


FIGURE 16.—West Shublik Mountains section 69A-2. This section is not discussed in detail in this report.

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INDEX

[Italic page numbers indicate major references]

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PLATES 1–8

[Contact photographs of the plates in this report are available, at cost, from the U.S. Geological Survey Library, Federal Center, Denver, Colo. 80225]

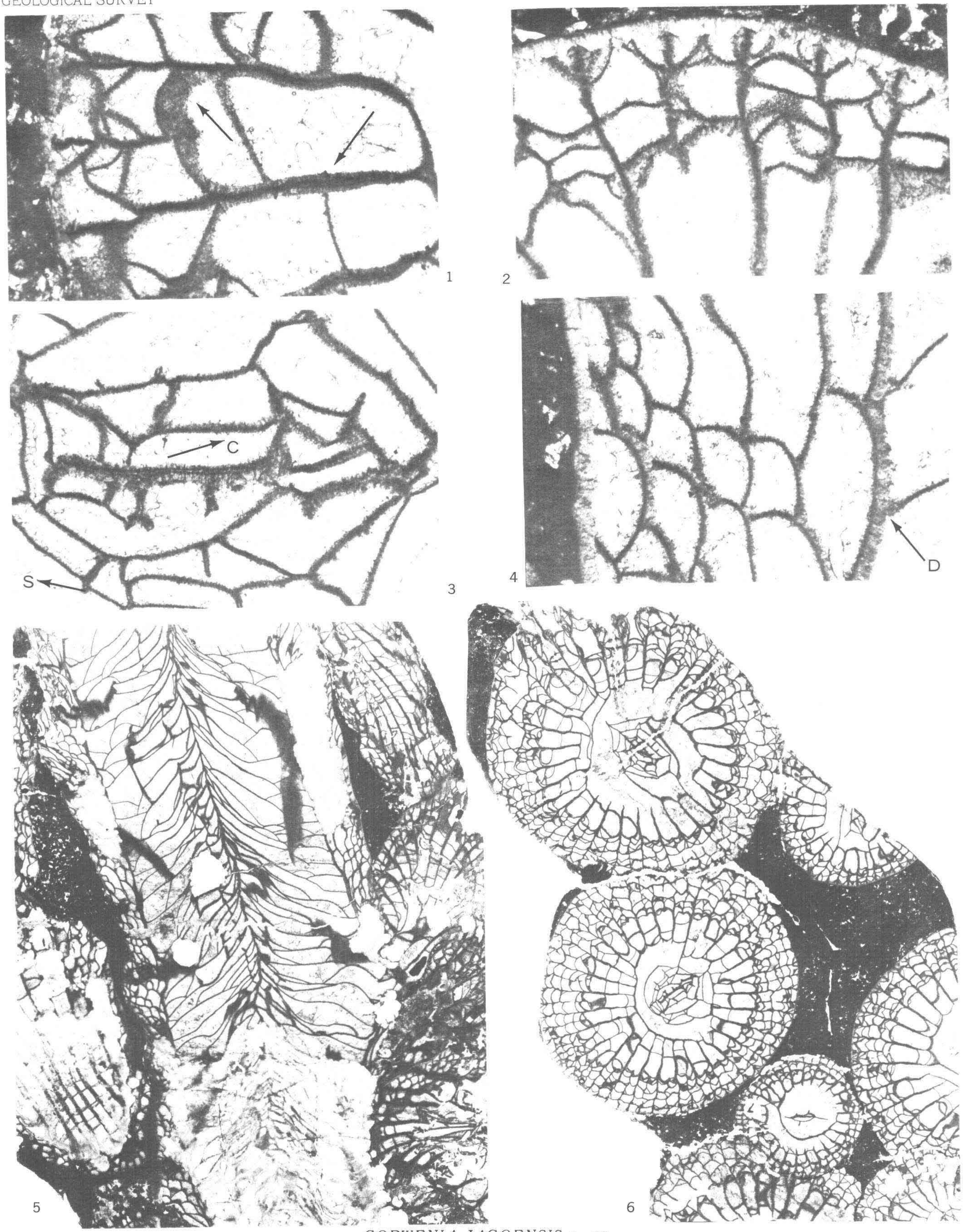
PLATE 1

FIGURES 1–6. *Corwenia jagoensis* n. sp. USNM 161034, holotype. 250 feet below the top of East Sadlerochit Mountains section 68A–4A–4B, Wahoo Limestone, Atoka age.

1–3. Transverse thin sections, × 25. 1, Arrows point to the well-developed dissepitheca and dilated septa. 2, Illustrates the differing microstructure of the septa and corallite wall, the dilated septa, and dissepitheca. 3, View of the axial region showing lath shape and microstructure of the columella (C) which is continuous with cardinal and counter septa, septal ridges (S) on upper surfaces of tabulae, and aulophylloid axial structure.

4. Longitudinal thin section, × 25. View of corallite wall microstructure, dissepimentarium, and (D) junction of dissepitheca and tabellae.

5–6. 5, Longitudinal thin section, × 3; replacement by chalcedony obscured lower part of corallite and some of the dissepimentarium. 6, Transverse thin section, × 3.



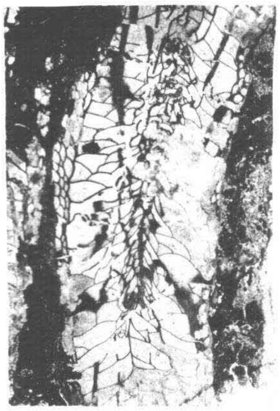
CORWENIA JAGOENSIS n. sp.

PLATE 2

FIGURES 1–5. *Corwenia jagoensis* n. sp.

1–3, 5. 1–3, Longitudinal thin sections, × 3. 5, Transverse thin section, × 3, holotype, USNM 161034; 250 feet below the top of the East Sadlerochit Mountain section 68A–4A–4B, Wahoo Limestone.

4. Longitudinal thin section, × 3, paratype, USNM 161038; 270 feet below the top of the Egaksrak River section 68A–5, Wahoo Limestone.



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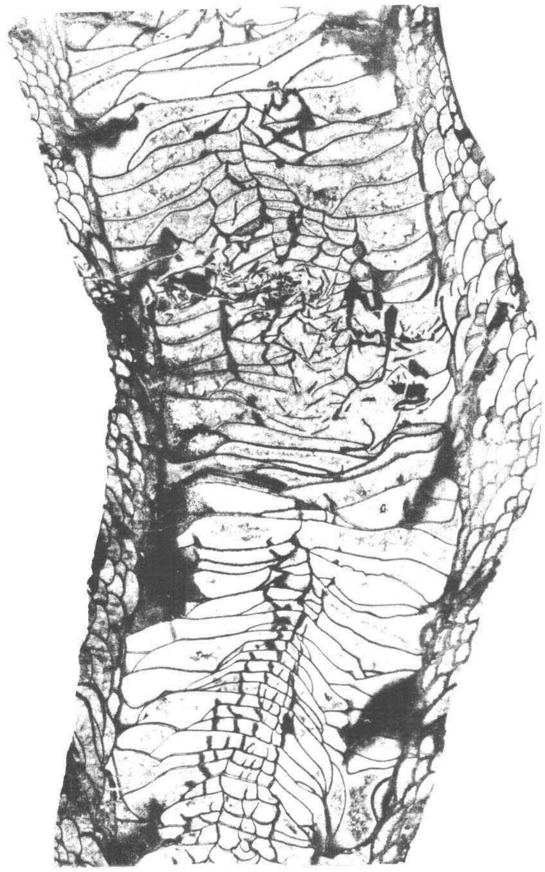

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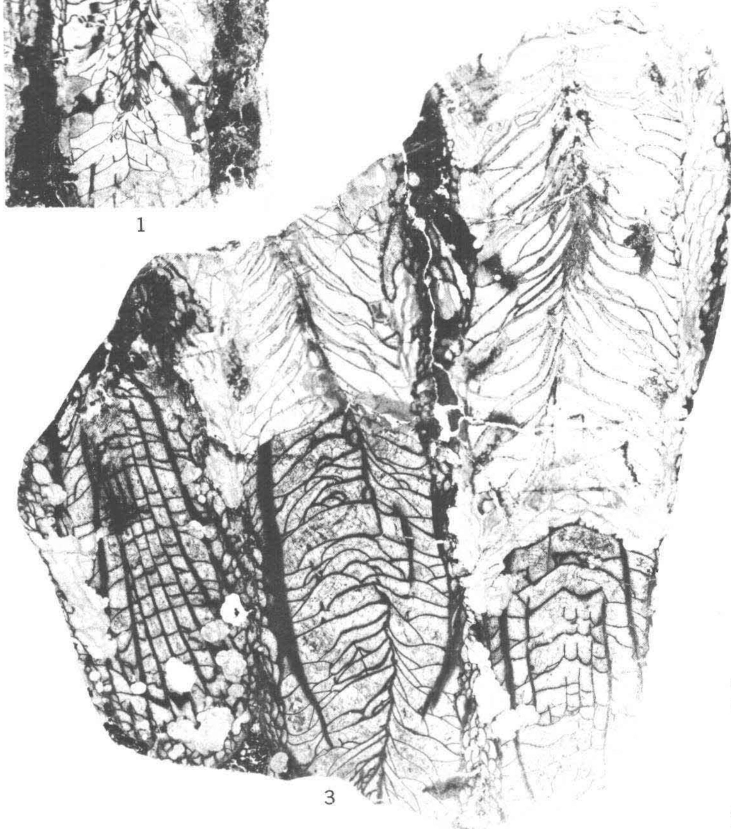

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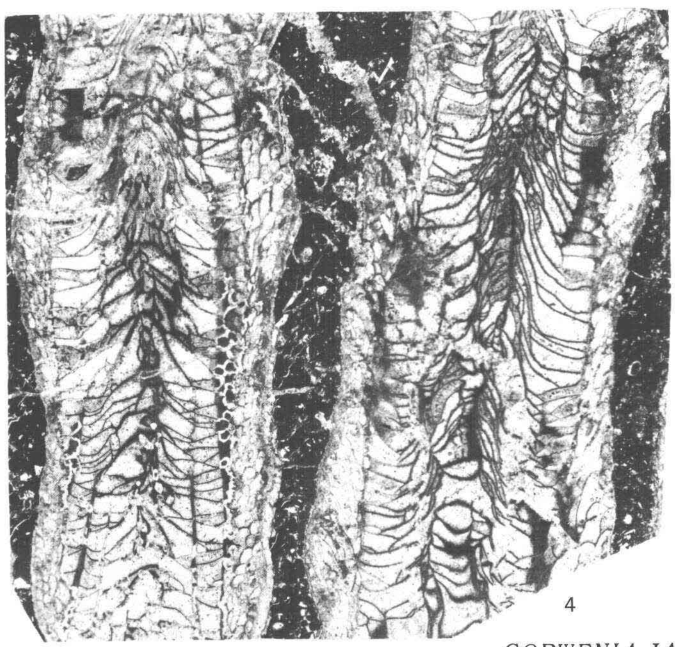

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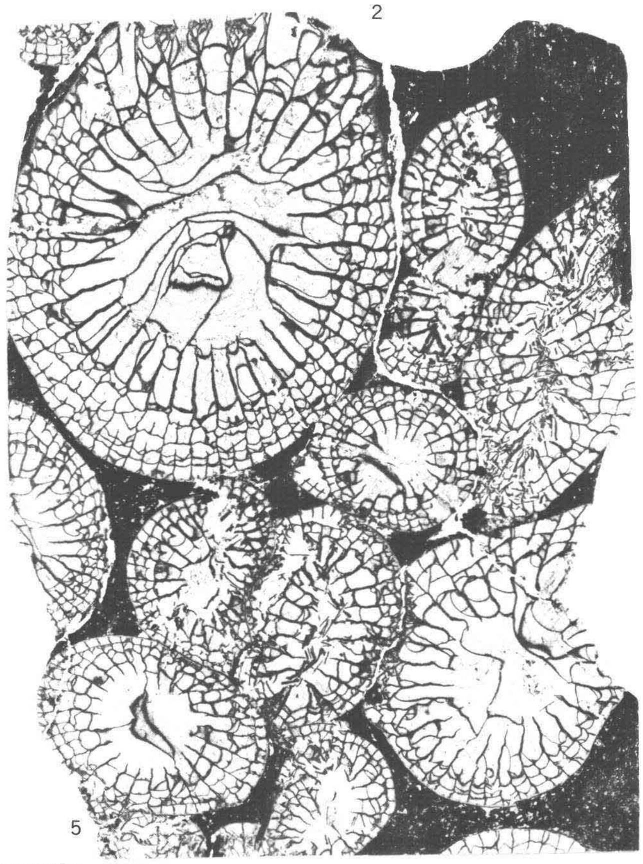

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CORWENIA JAGOENSIS n. sp.

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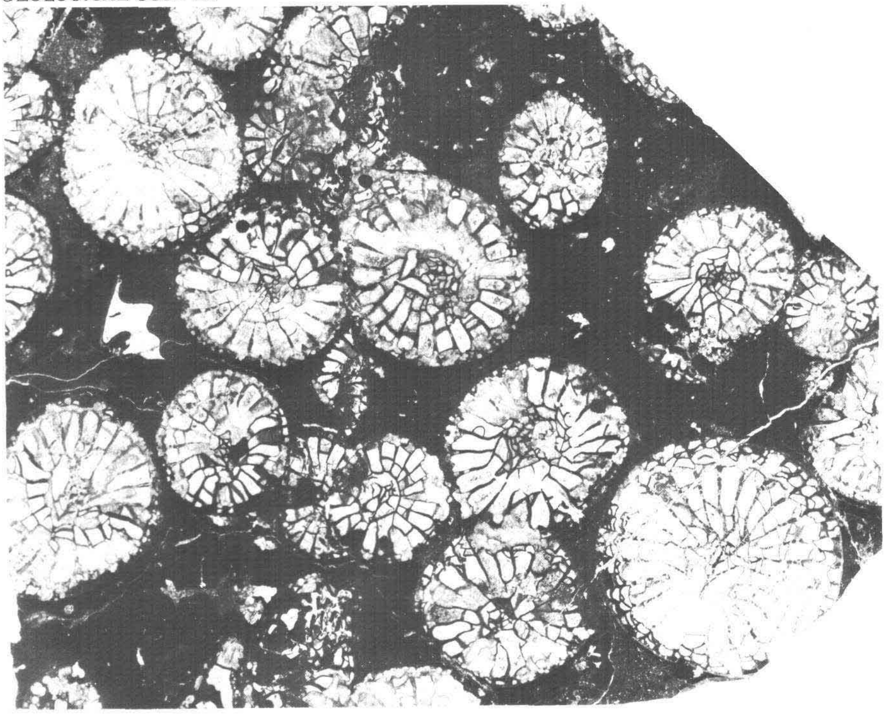
PLATE 3

FIGURES 1–4. *Corwenia jagoensis* n. sp.

1. Transverse thin section, × 3, holotype, USNM 161034; 250 feet below the top of the East Sadlerochit Mountain section 68A-4A, Wahoo Limestone.

2–4. 2, Longitudinal thin section, × 3. 3, 4, Transverse thin sections, × 3, paratype, USNM 161038; 270 feet below the top of the Egaksrak River section 68A–5, Wahoo Limestone.



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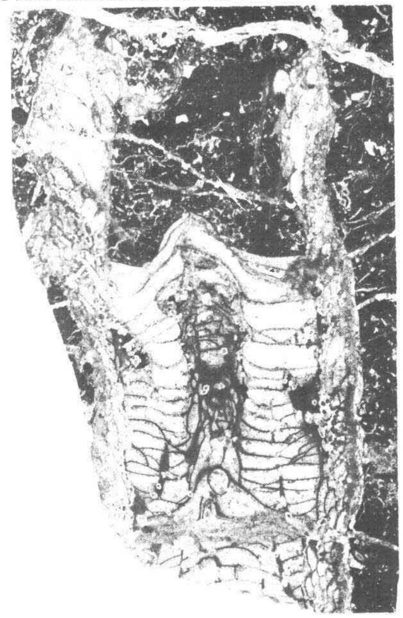

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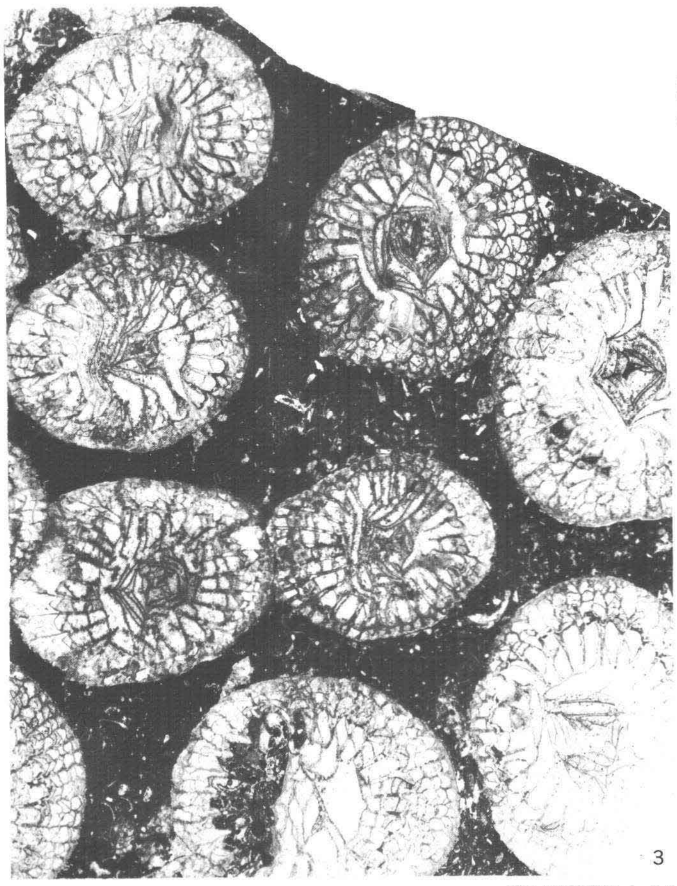

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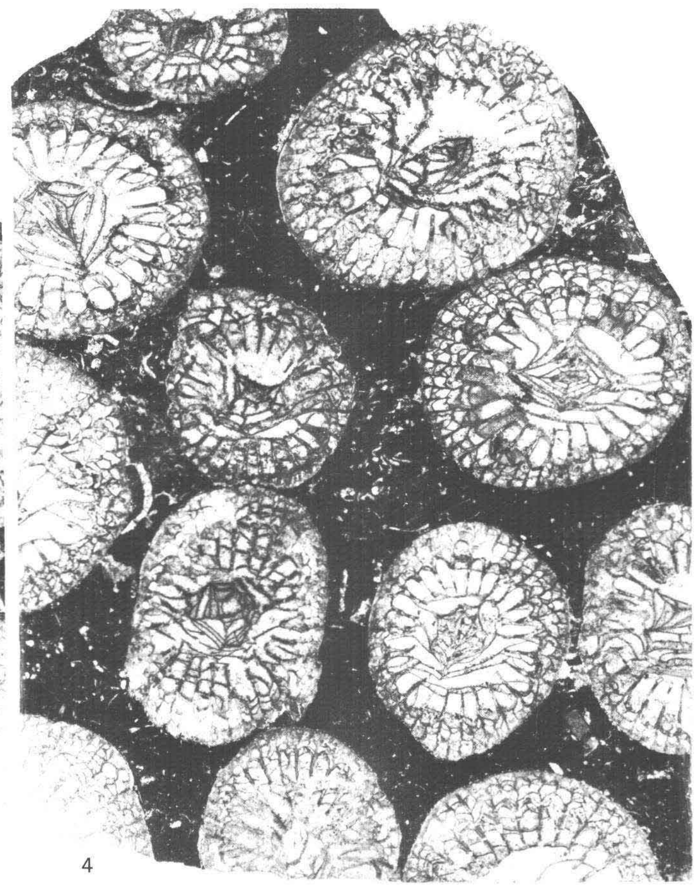

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CORWENIA JAGOENSIS n. sp.

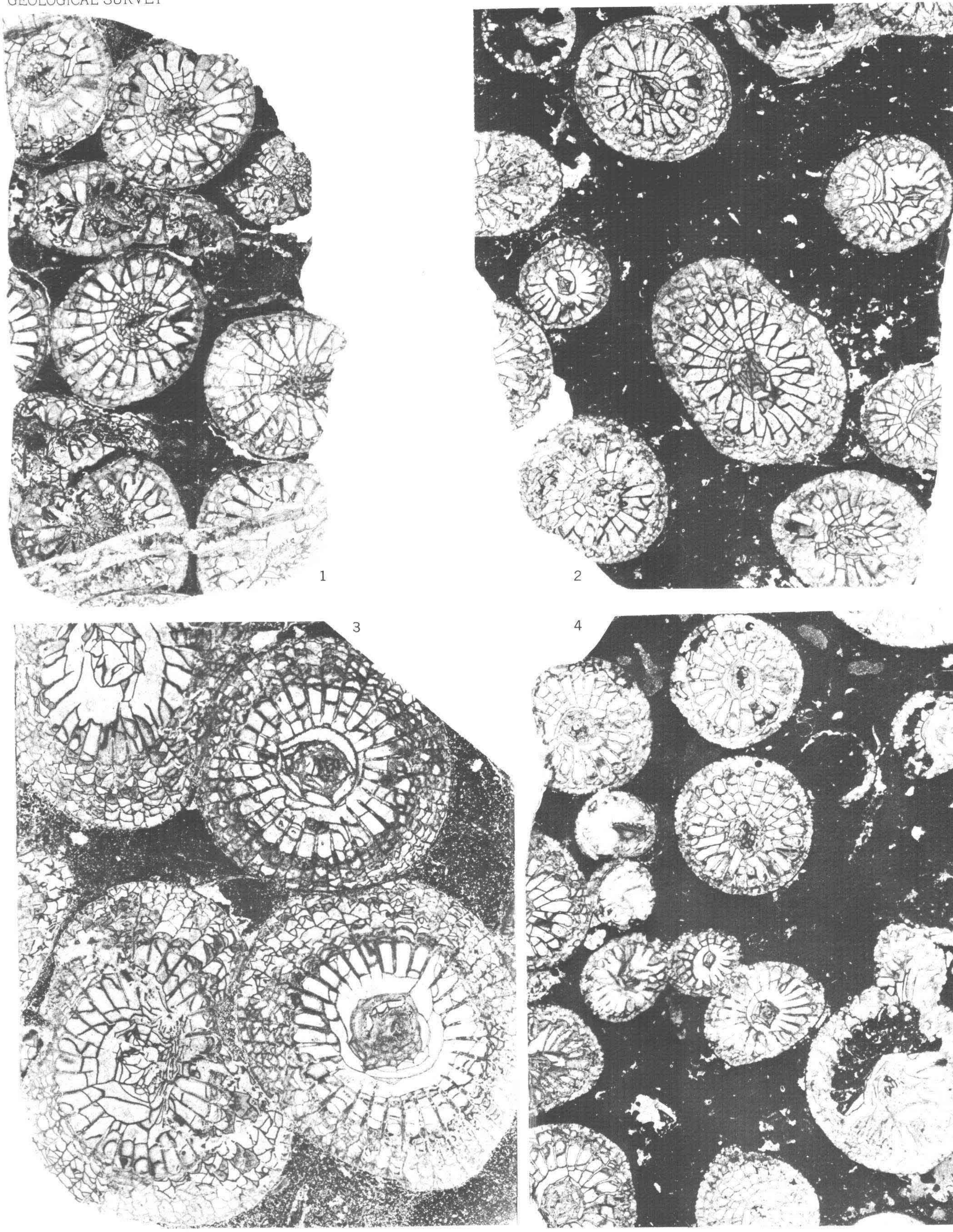
PLATE 4

FIGURES 1–4. *Corwenia jagoensis* n. sp.

1. Transverse thin section, × 3, paratype, USNM 160537; 150 feet below the contact of the Wahoo Limestone and Sadlerochit Formation. One and one-fourth mile west of section 68A–4A.

2, 3. Transverse thin sections, × 3, paratype, USNM 161039; 230 feet below the top of the Egaksrak River section 68A–5. Wahoo Limestone.

4. Transverse thin section, × 3, paratype, USNM 161040, near Salisbury Mountain, Wahoo Limestone.



CORWENIA JAGOENSIS n. sp.

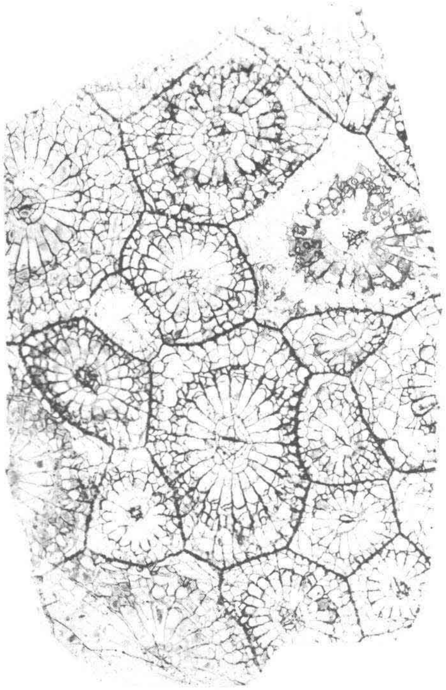
PLATE 5

FIGURE 1. *Lithostrotionella wahooensis* n. sp.

1. Transverse thin section, × 3, paratype, USNM 160527; 50 feet from the top of the West Sadlerochit Mountains section 69A–1, Wahoo Limestone.

2–4. *Corwenia jagoensis* n. sp.

2. Longitudinal thin section, × 3; 3, 4, Transverse thin sections, × 3, paratype, USNM 161040; near Salisbury Mountain, Wahoo Limestone.



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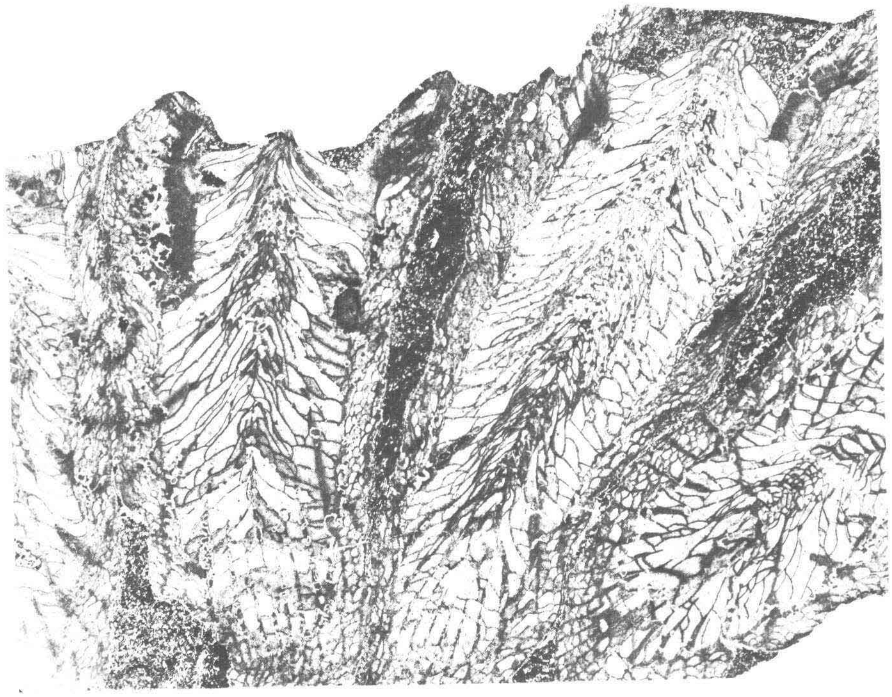

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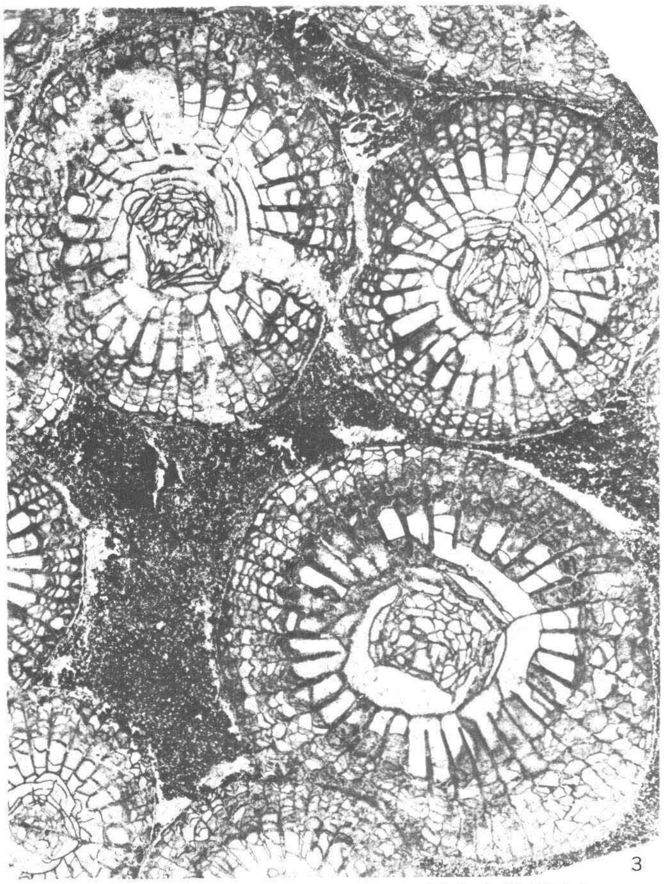

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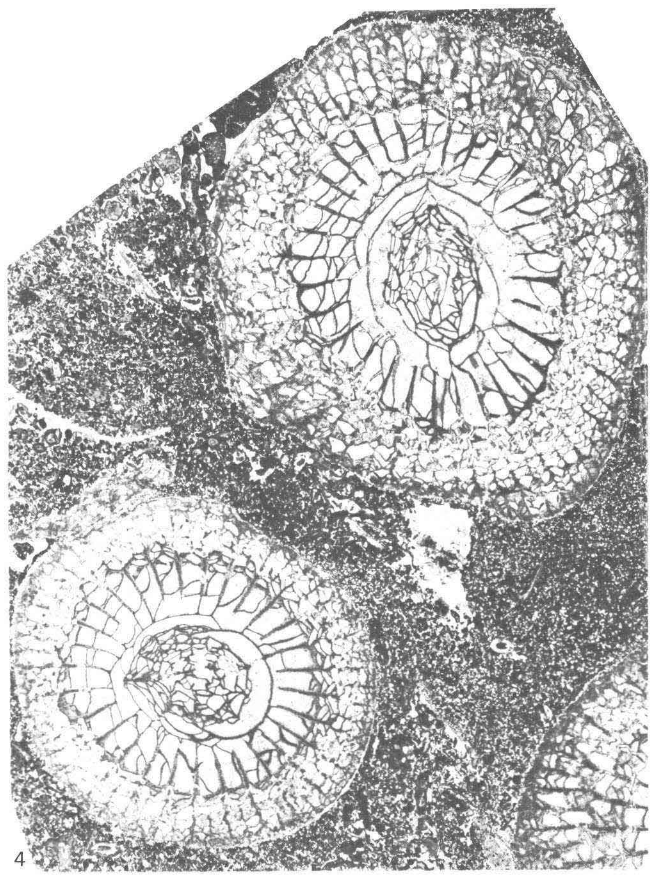


4

LITHOSTROTIONELLA WAHOOENSIS n. sp. and *CORWENIA JAGOENSIS* n. sp.

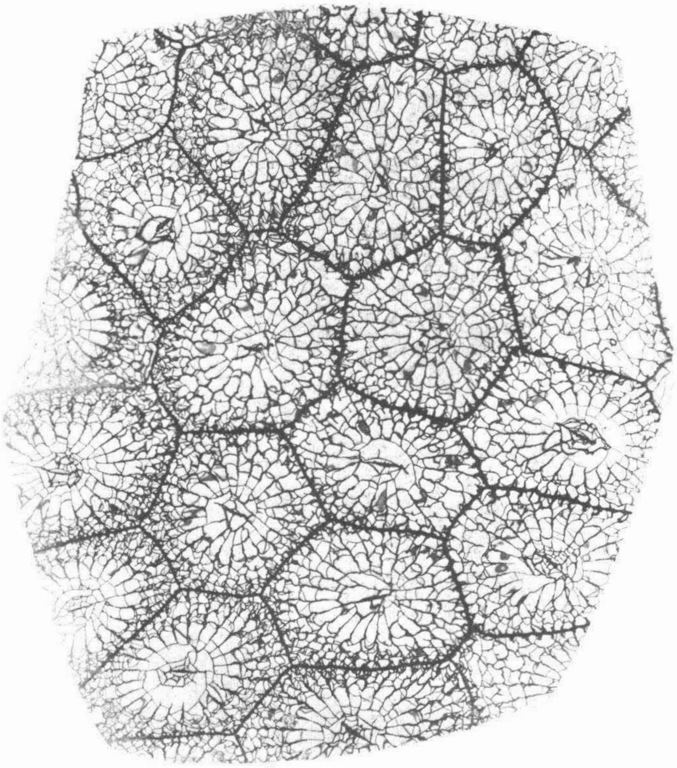
PLATE 6

FIGURES 1–5. *Lithostrotionella wahooensis* n. sp.

1–3. 1, Transverse thin section, × 3; 2,3, Longitudinal thin sections, × 3, holotype, USNM 160528; 48 feet below the top of the West Sadlerochit Mountains section 69A–1, Wahoo Limestone.

4. Transverse thin section, × 3, paratype, USNM 160530; Wahoo Limestone, West Shublik Mountain section 69A–2.

5. Transverse thin section, × 3, paratype, USNM 160529; upper 75 feet of the Wahoo Limestone, Sadlerochit Mountains section 68A–3.



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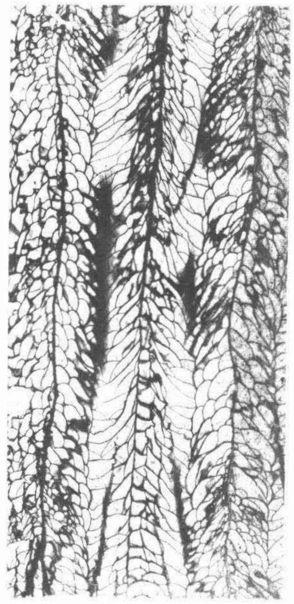

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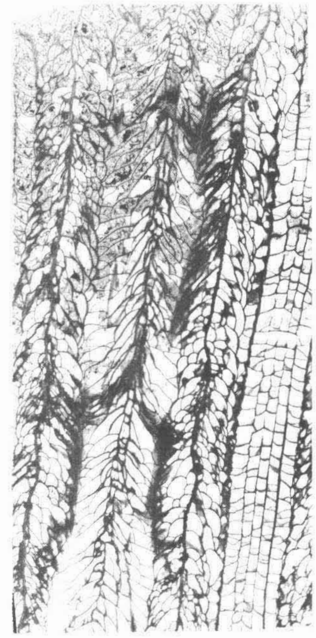

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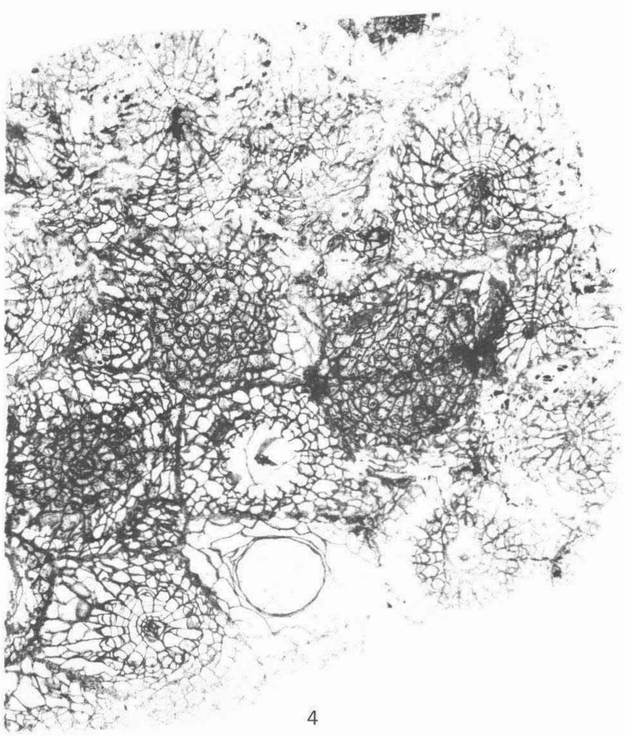

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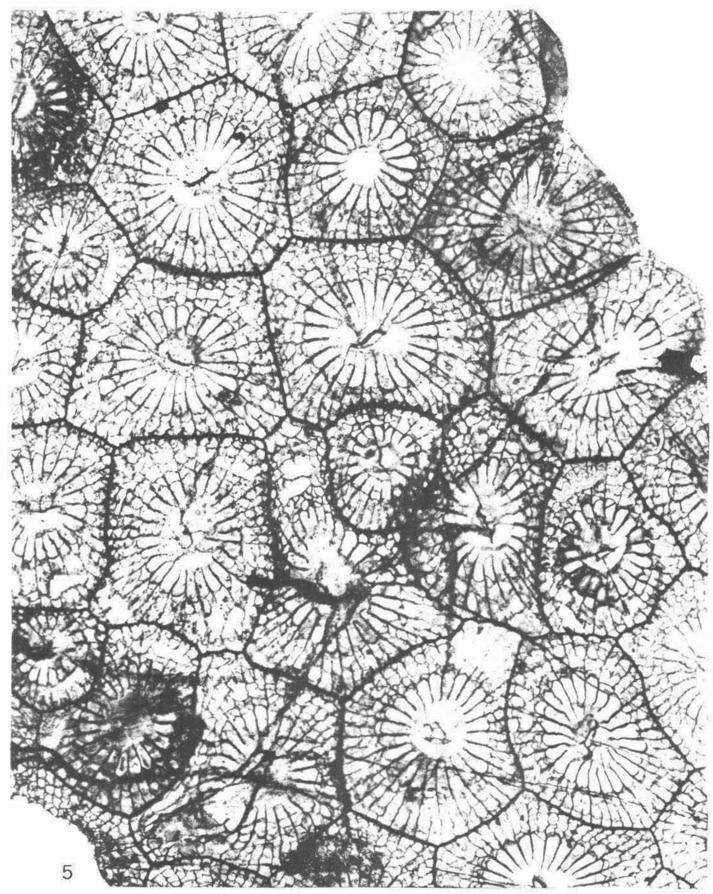


5

LITHOSTROTIONELLA WAHOOENSIS n. sp..

PLATE 7

FIGURES 1–3. *Lithostrotionella wahooensis* n. sp.

1–2. Transverse thin sections, × 25. 1, Axial region illustrating microstructure of columella which is continuous with the sinuous cardinal and counter septa. 2, Microstructure of the corallite wall, with its dark central band, and of the sinuous major septa and discontinuous minor septa. The structures of the corallum are preserved as calcite, the internal voids of the corallum are filled by clear, colorless, transparent chalcedony. Holotype, USNM 160528; 48 feet below the top of the West Sadlerochit Mountain section 69A–1.

3. Transverse thin section, × 25; corallum is preserved within a chert nodule. The microstructure of the corallites is preserved by a red jasper chalcedony, whereas the internal voids are filled with a clear chalcedony. Paratype, USNM 160529; upper 75 feet of the Wahoo Limestone, Sadlerochit Mountain section 68A–3.

4–5. Section 69A–1, West Sadlerochit Mountains, Wahoo Limestone.

4. Pelletoid to rounded micritic lithoclasts, bryozoan grainstone. Note the fine abraded bioclastic inclusion within the micritic lithoclasts. × 25; 65 feet from top of section.

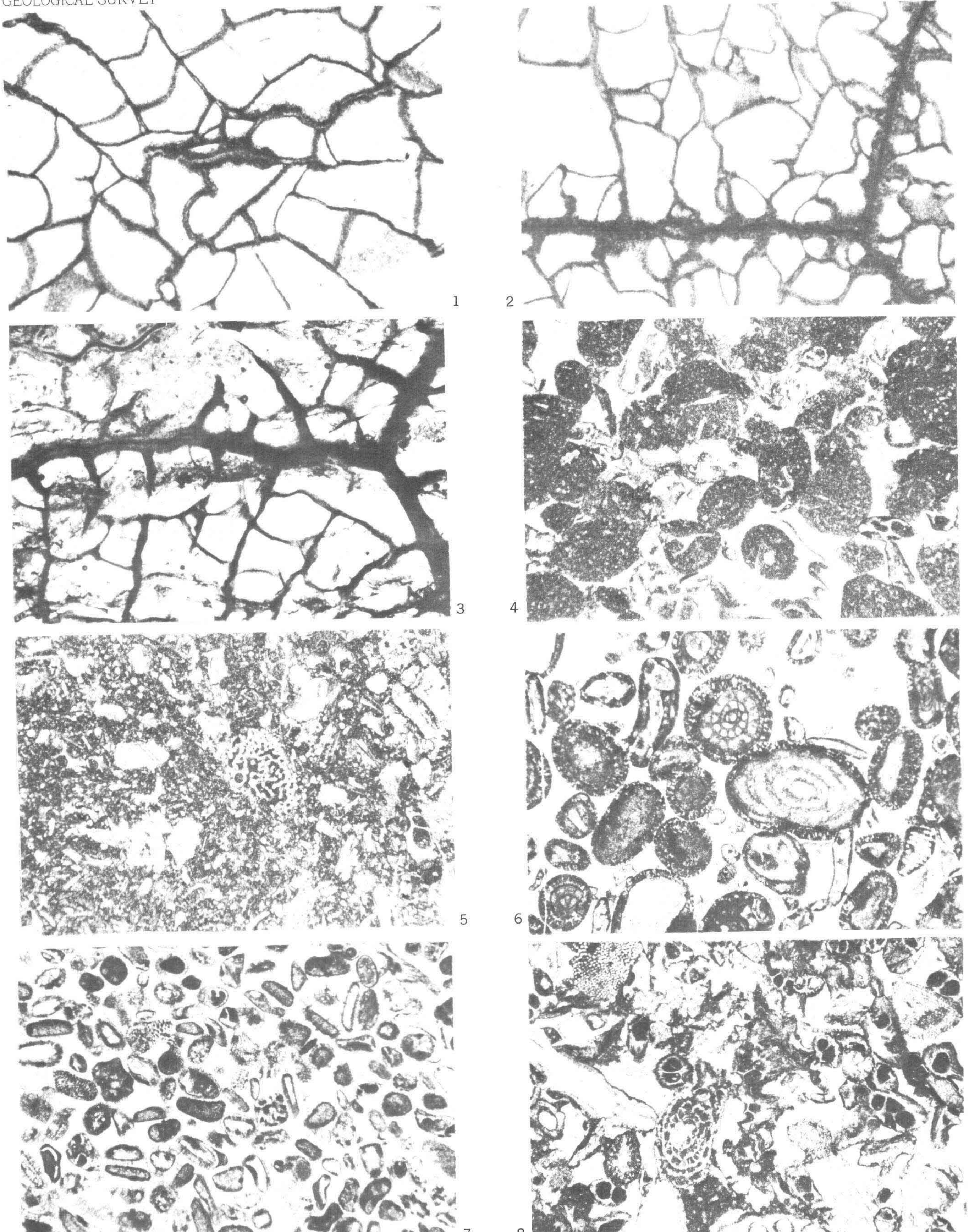
5. Crinoidal-bryozoan-algal wackestone and packstone. Bioclastic fragments are finely abraded and broken; texture of rock suggests extensive burrowing. × 25; 150 feet from top of section.

6–8. Section 68A–4A–4B, East Sadlerochit Mountains, Wahoo Limestone.

6. Ooid foraminiferal grainstone. The centers of the ooids are Foraminifera, broken and rounded fragments of echinoderms, bryozoans, and small micritic lithoclasts. × 25; 290 feet from top of section.

7. Ooid-micropelletoid grainstone. Rounded and winnowed fragments of bryozoans, echinoderms, ostracodes, and micritic pellets with, typically, a single oolitic coating; × 25; 490 feet from top of section.

8. Bryozoan-echinoderm-algal packstone. Poorly sorted fossil fragments with micrite filling the voids between the bioclasts. × 25; 570 feet from top of section.



LITHOSTROTIONELLA WAHOOENSIS n. sp. and photomicrographs of carbonate rock types in sections 69 A-1, 68A-4A-4B.

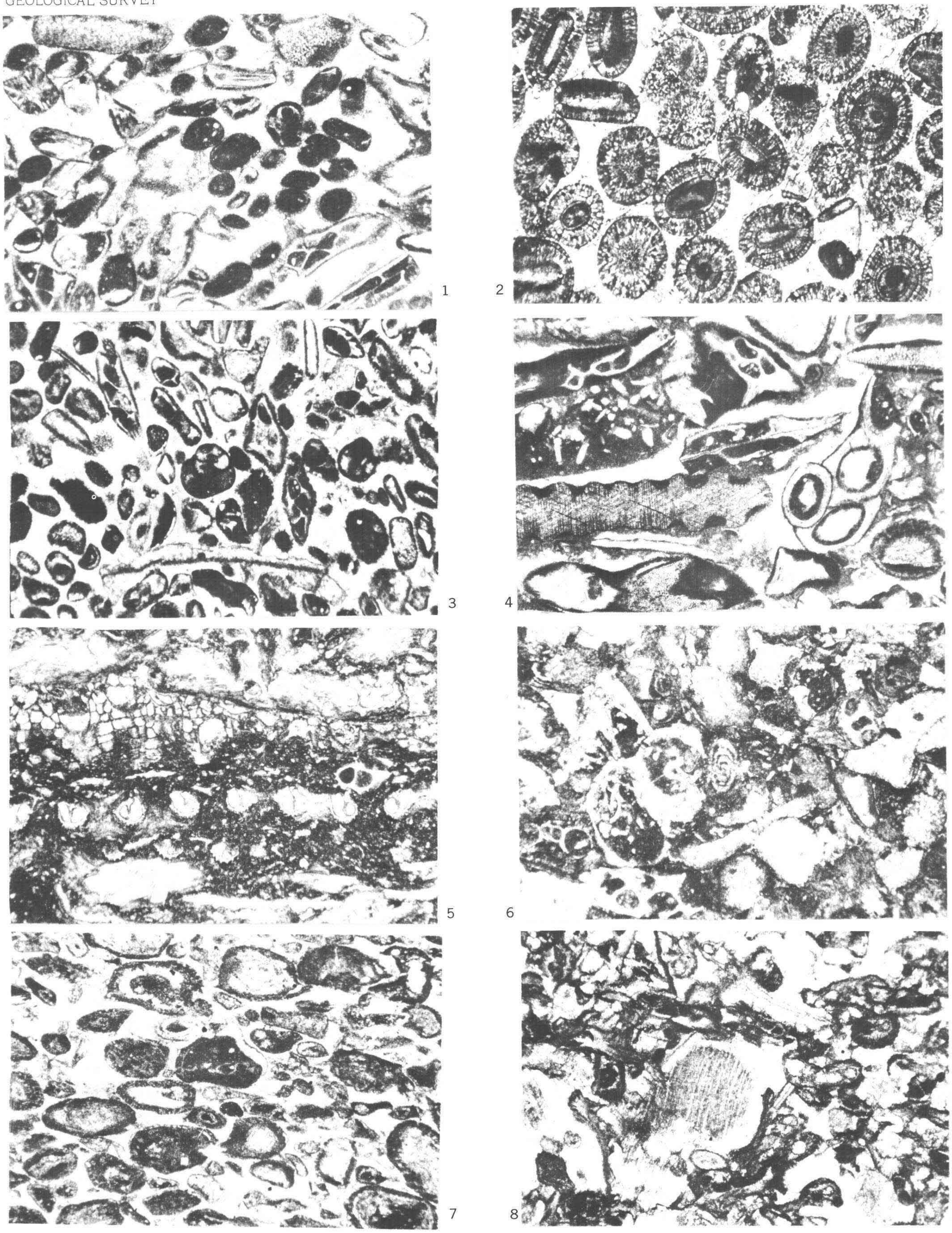
PLATE 8

FIGURES 1–6. Section 68A–5, Egaksrak River, Wahoo Limestone.

1. Pelletoid-bryozoan-echinoderm grainstone. Fossil fragments and pellets are rounded and winnowed; one layer of oolitic coating on pellets and on some rounded bioclasts. × 25, 150 feet from top of section.
2. Oolitic grainstone. Large ooids, 0.6–0.7 mm in diameter, have numerous and thick oolitic layers. Ooids generally have fossil fragments for their centers and show evidence of algal borings. Associated with the ooids are abundant *Osagia* sp. × 25, 600 feet from top of section.
3. Pelletoid-bryozoan-echinoderm grainstone. Rounded and winnowed bioclasts, with small Foraminifera, *Globivalvulina* sp. × 25, 430 feet from top of section.
4. Bryozoan-echinoderm-foraminiferal lithoclast packstone and grainstone. Large rounded fossil fragment, micrite lithoclasts, and varying amounts of micrite pore and void filling. × 25, 750 feet from top of section.
5. Bryozoan packstone. Large bryozoan fragments in micrite. Large fossil fragments parallel to bedding suggest deposition in a noncurrent environment. × 25, 830 feet from top of section.
6. Echinoderm-gastropod-foraminiferal-bryozoan packstone and grainstone. Rich, diversified fauna; broken and rounded, but poorly sorted, bioclasts and lime mud, suggesting extensive burrow and weak currents. × 25, 1,130 feet from top.

7–8. Section 68A–1, Ikiakpuk section, Wahoo Limestone.

7. Tectonically stressed oolitic grainstone. Fossil fragments and oolites have been elongated by tectonic stress and solution; Ooids are ellipsoids. × 25, 20 feet from top of section.
8. Tectonically stressed bryozoan-echinoderm packstone. Note the elongation and grain growth of the crinoid ossicles. Echinoderm ossicles are particularly prone to alteration and elongation due to tectonic stress. × 25, 95 feet from top of section.



Photomicrographs of carbonate rock types in sections 68A-5, 68A-1.