

ARCTIC INSTITUTE OF NORTH AMERICA

TECHNICAL PAPER NO. 23

**UPPER PALAEOZOIC STRATIGRAPHY AND CORALS
FROM THE EAST-CENTRAL ALASKA RANGE, ALASKA**

By

CHARLES LLEWELLYN ROWETT



PUBLISHED OCTOBER 1969

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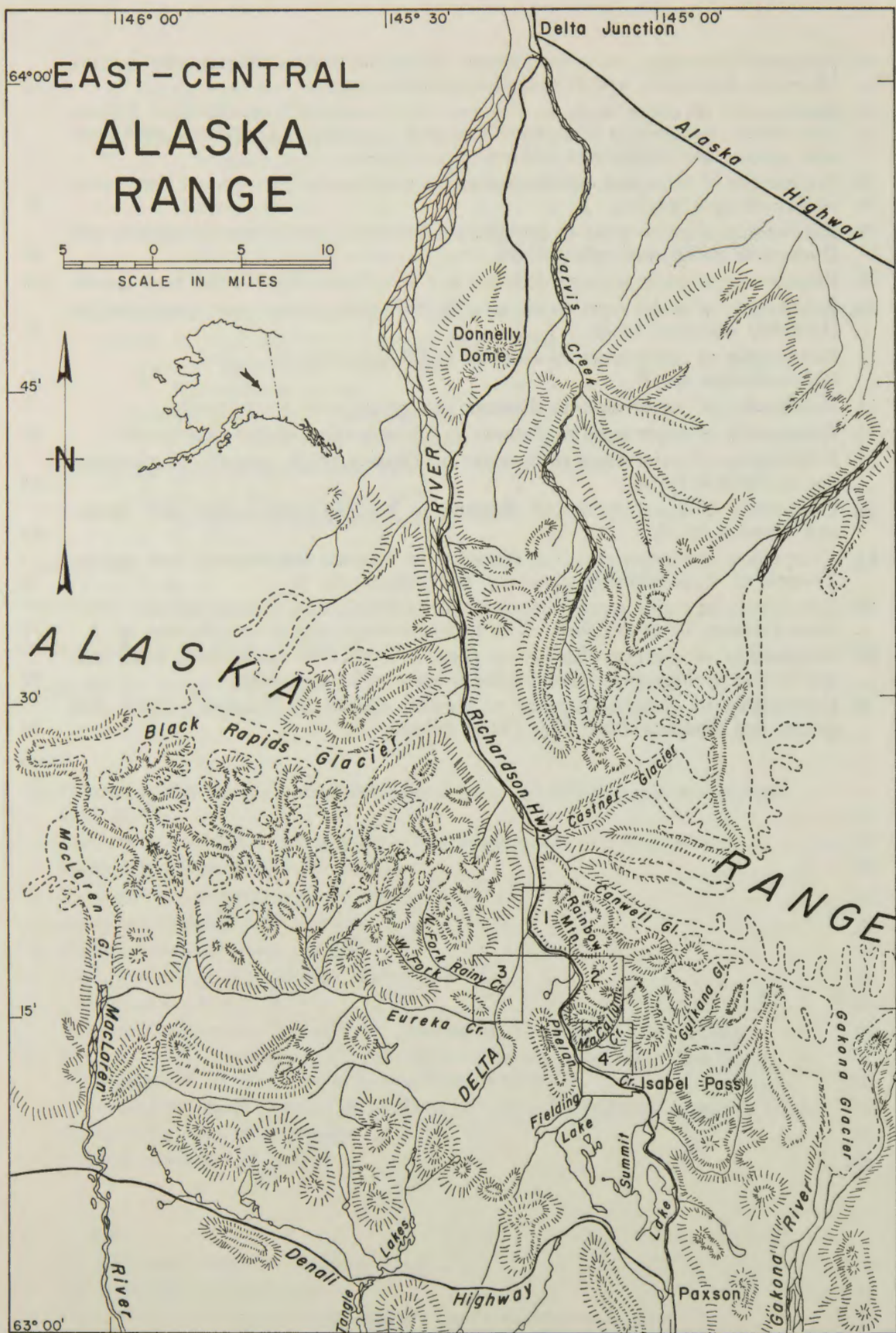
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UPPER PALAEOZOIC STRATIGRAPHY AND CORALS FROM THE EAST-CENTRAL ALASKA RANGE, ALASKA

Charles Llewellyn Rowett*

Introduction

This report is the result of reconnaissance geology and study of fossil corals from the east-central Alaska Range from 1963 to 1966. Part I summarizes the structural and stratigraphic field and laboratory studies by the writer and several graduate students in geology at the University of Alaska during the same period. Part II includes a discussion of the significance and zoogeographic affinities of the coral fauna, which includes both lower Pennsylvanian and lower Permian rugose and tabulate corals. Fossil invertebrates other than corals have been identified to the generic level only. Although the preliminary nature of the physical stratigraphic and structural relations is emphasized, it is hoped that publication of this information will stimulate further studies. In particular, the subdivision of these rocks on the basis of the zonation and sequence of rugose and tabulate corals may be useful in biostratigraphic studies of rocks of comparable age elsewhere in the Alaska Range.

The rugose and tabulate corals from this region have pronounced affinities with fossil corals of comparable age from Asia, notably those described from the Moscow Basin and Ural Mountains of Russia. Some preliminary conclusions are drawn relating to the palaeogeography, dispersal patterns, and faunal realms of upper Palaeozoic time in the arctic and subarctic regions of the present; this is, however, a fascinating but separate area of research, whose detailed discussion will depend on future studies, both geological and palaeontological.

Location and physiography. The study area lies in the east-central part of the Alaska Range between longitude 145° and 146°W and latitude 63°10 and 63°20N (Text-fig. 1). North-flowing rivers, which have their headwaters in the high glaciated parts of the Alaska Range, flow into the Tanana River in interior Alaska; waters of this river flow westward to join the Yukon River, and eventually into the Bering Sea. The regional drainage divide is located in the southern part of the study area at Isabel Pass; streams to the south and southeast flow southward into the Copper River and empty into the Gulf of Alaska. The principal streams in the study area are the north-flowing Delta River and a large tributary, Phelan Creek. The upper reaches of the Delta River area, in the southwest, are drained by Rainy and Eureka creeks.

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Elevations range from about 2,500 feet along the Delta River to almost 7,000 feet near Rainbow Mountain. Relief is greater in the eastern part of the area studied where mountain slopes typically are steep and mantled by frost-shattered talus. The southwestern part, in contrast, is characterized by comparatively low relief (2,000 feet or less) and by gentle tundra-covered slopes and terraces of alluvial and glacial origin. Abandoned glacial cirques are common between 3,500 to 5,500 feet, whereas higher elevations are characterized by perennial mountain and valley glaciers.

In this report, the study area is divided into four subsidiary areas: (1) Northern Rainbow Mountain, (2) Southern Rainbow Mountain, (3) Upper Delta River, and (4) McCallum Creek area (Text-fig. 1). The principal access to these areas is the Richardson Highway, which follows the east side of Phelan Creek and the Delta River northward through the Alaska Range to Delta Junction, where it intersects the Alaska Highway. A short spur road provides access to the lower part of the McCallum Creek drainage. Phelan Creek, Delta River, and Eureka Creek present barriers to the exposures along Rainy Creek, but these streams usually can be crossed by boat or rubberized life rafts.

Previous investigations. Virtually all the early geological studies in the Alaska Range were made by members of the United States Geological Survey. Considering the difficulties faced by these early reconnaissance geologists, many of these reports are remarkable for their scope. One of the earliest reports was by W. C. Mendenhall (1900), who made a traverse across the Alaska Range through Isabel Pass and described tuffaceous and rhyolitic rocks in the vicinity of Rainbow Mountain. In 1905 he tentatively correlated the tuffs with the "Carboniferous" Chisna Formation to the southeast on the basis of similar lithic types and degree of deformation. Another pioneering geologist, F. H. Moffit, conducted geological studies in Alaska from about 1912 to 1942. Of the Rainbow Mountain area, Moffit (1912, pp. 27-8) stated that the slates, tuffs, quartzitic sedimentary rocks, and limestones east of Phelan Creek and west of Delta River extend eastward into the Chistochina River region where they had previously been referred to the Carboniferous Chisna Formation by Mendenhall. Although Moffit initially accepted Mendenhall's statement that these strata were older than the Permian Mankomen Formation, he subsequently (1954, pp. 103-6) concluded that these rocks are in part of Permian age and extend over a wider area east of Phelan Creek and west of the Delta River than had formerly been believed.

In his discussion of the Permian faunas of this region, Moffit (1954, p. 115) drew the following conclusions:

"The sedimentary units of the Permian rocks, including the tuffaceous beds, are notably calcareous and fossiliferous. Moreover, where fossils are found they are commonly abundant, and good collections have been made; they are diagnostic, and little doubt exists regarding the age of most of them. Most of the collections so far made were submitted to Mr. G. H. Girty for identification and determination of age. From his study it appeared that the fauna is more closely related to the Permian of Russia than to that of more southern parts of North America. One or two of the collections suggested Carboniferous time but since the Pennsylvanian . . . is probably not represented in most of Alaska, if at all, and as the associated rocks include no known Mississippian, any question concerning the age of the fossils has been provisionally decided in favor of the Permian."

The presence of rocks of Pennsylvanian age subsequently has been established in southeastern Alaska, and rocks of undoubted Pennsylvanian age (post-Morrowan, pre-Missourian) have been identified during the course of this study. These rocks are present in the Northern Rainbow Mountain area and in parts of the Southern Rainbow Mountain area (Text-fig. 2). Also, the Asiatic character of the invertebrate fossils from both the Pennsylvanian and the Permian has been confirmed and documented.

In 1962, the Department of Geology at the University of Alaska initiated a geologic mapping program in the Alaska Range in areas accessible from the Richardson Highway. The first of these, supported by the State Division of Mines and Minerals, was a study of the Rainbow Mountain area by a graduate student, L. G. Hanson. Hanson's work resulted in a published State report (1963), and was followed by unpublished studies (Master's thesis) of the glacial deposits of the Gulkana Glacier (Reger, 1963), the bedrock geology of the McCallum Creek and Gulkana Glacier area (Bond, 1965), and the geology between Rainy Creek and the Denali fault (Stout, 1965). Permian Fusulinidae discovered during the 1965 field season were studied by R. G. Petocz under the direction of the writer.

Fusulinidae have been found in close association with fossil corals at many localities on both the east and west sides of Delta River and Phelan Creek. The sequence of coral zones is reported here, and it is probable that a useful biostratigraphic zonation of the Permian rocks on the basis of both corals and Fusulinidae will be established in the near future.

Acknowledgments. This study was made possible by research grants and grants-in-aid from several sources, including the Arctic Institute of North America, the National Science Foundation, and the Society of the Sigma Xi. The University of Alaska provided facilities for much of the field and laboratory research and also financial aid for graduate assistance from the Otto Geist fund. The support of these agencies is appreciated.

Several otherwise unobtainable palaeontological studies from the U.S.S.R. were supplied by Dr. N. A. Bogdanov of the Geological Institute, Academy of Sciences, U.S.S.R. Type specimens for coral genera were loaned by the Museum of Paleontology, University of California, Berkeley, and helpful comments on various aspects of the palaeontological study were offered by Dr. E. C. Wilson, Dr. Ralph Langenheim, Dr. S. J. Nelson, Dr. M. Minato, and Dr. M. Kato.

PART I

Upper Palaeozoic Stratigraphy

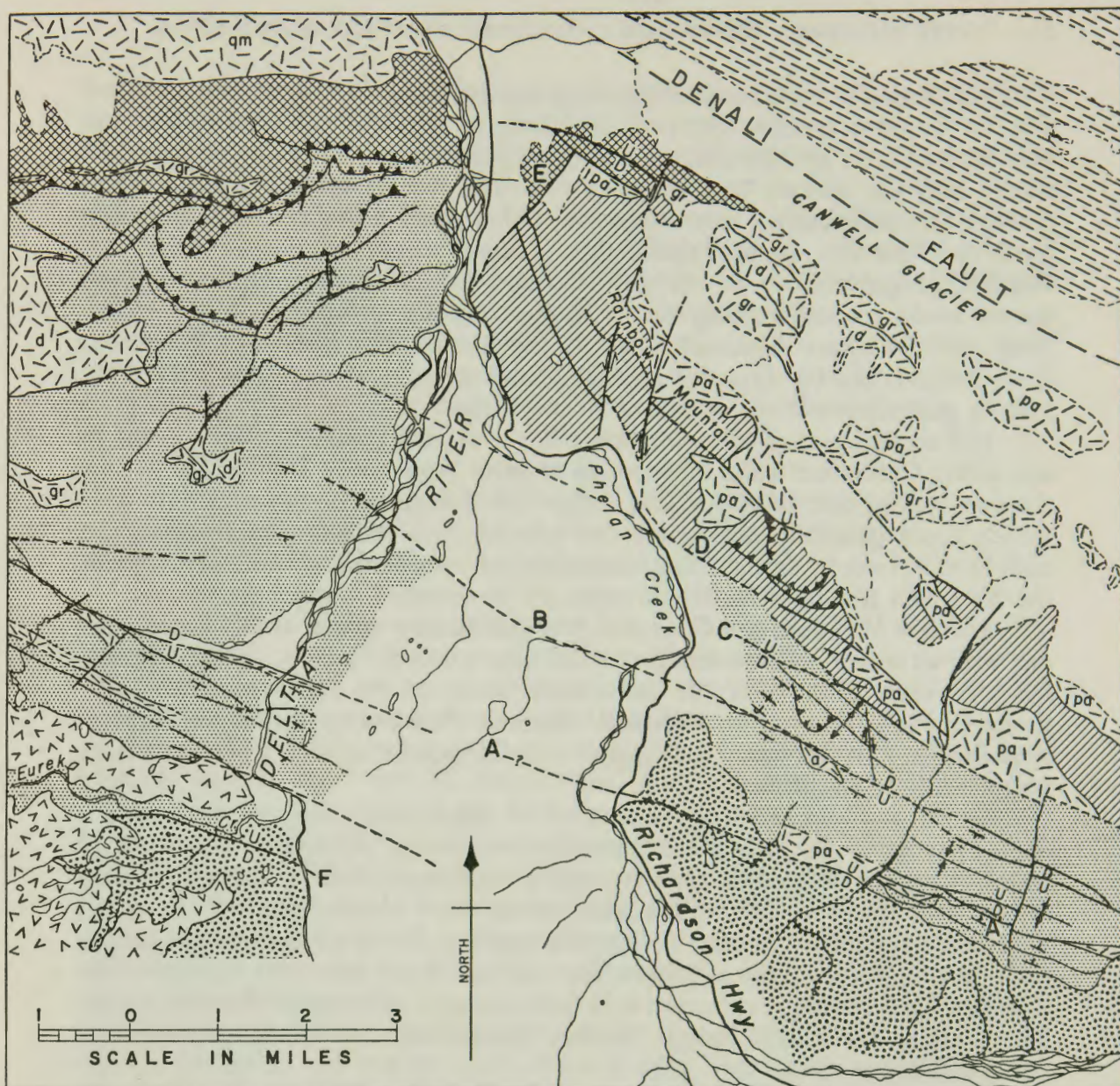
Regional geologic history. The Alaska Range, one of the most imposing mountain chains in the world, is the result of comparatively recent uplift. This region has, however, been the site of repeated geosynclinal and orogenic activity throughout most of geologic time. The coastal areas of Alaska probably are as tectonically active now as at any past time: volcanic and seismic activity in these areas is virtually continuous; the disastrous earthquake of 27 March 1964 was but one manifestation of this activity.

The details of the geologic history of the Alaska Range are as yet unknown. However, good general summaries have been presented by several authors, including Payne (1951, 1955), St. Amand (1957), and Gates and Gryc (1963). Only a brief review of this history as it relates to the area studied is given here.

The early Palaeozoic Cordilleran geosyncline of western North America can be traced northwestward across Alaska. The southern and southeastern part of Alaska was the site of eugeosynclinal deposition during pre-Devonian time, with volcanic source areas to the south, southwest, and possibly within this region. A broad belt of miogeosynclinal deposition extended across the present site of the Brooks Range in northern Alaska and was bordered on the north by a major landmass. Studies of the clastic deposits indicate that the northern limits of this positive area were well to the north of the present shores of the Arctic Ocean.

In the southern eugeosyncline a period of orogeny in early Devonian time resulted in the uplift, folding, and intense metamorphism of early Devonian and pre-Devonian deposits. Where these rocks are preserved in the Alaska Range, alteration due to this and subsequent periods of deformation has prevented their mapping except as undifferentiated metamorphic rocks. This sequence is exposed in the northern part of the study area (Text-fig. 2).

Pre-Devonian and Devonian? metamorphic rocks are overlain with marked discordance by younger marine sedimentary and volcanic deposits in the Alaska Range, chiefly of Permian age but including, in the study area at least, a considerable thickness of lower Pennsylvanian rocks. These are also dominantly eugeosynclinal deposits, and include turbidites, "greywackes", tuffs, discontinuous volcanic-rich carbonates and a few micritic limestones. Palaeontological evidence from the Northern Rainbow Mountain area suggests that eugeosynclinal deposition began, at least locally, in lower Pennsylvanian time. In the area covered by this report the combined thickness of eugeosynclinal deposits may be between 12,000 and 13,000 feet, including rocks of both Pennsylvanian and Permian age.



SEDIMENTARY ROCKS

-  Recent alluvium, Pleistocene tills and colluvium; in part unmapped
-  Tertiary Coal-bearing Formation; weakly consolidated sandstones, siltstones, conglomerates; coals thin to absent in this region
-  Permian McCallum Creek sequence; lower (Wolfcampian) greywackes, tuffs, graded siltstones, agglomerates, minor volcanic-rich limestones, extensively silicified; middle and upper (Wolfcampian-lower Leonardian?) dark slaty and concretionary shales, siltstones, fossiliferous black limestones
-  Pennsylvanian Rainbow Mountain sequence; Lower Pennsylvanian (Atokan-Desmoinesian?) greywackes, tuffs, minor silty limestones (may locally include unfaulted or infolded Permian rocks)

IGNEOUS ROCKS

-  Late Mesozoic and Tertiary? intrusive rocks; gr, granite and granodiorite; qm, quartz monzonites; d, dunite; pa, porphyritic andesite

-  Triassic? extrusive rocks; slightly altered basic flows

METAMORPHIC ROCKS

-  Devonian and pre-Devonian crystalline schists and gneisses, locally serpentinized
-  Precambrian and lower Palaeozoic? Birch Creek Schist

Text-fig 2. Geologic map of study area. Geology based on mapping by Hanson (1965), Bond (1965), Stout (1965), and the writer. Major faults designated by letters A-E.

Although the structural evidence is inconclusive, it is generally believed that no major orogenies occurred in Alaska at the close of Palaeozoic time (Gates and Gryc, 1963). Eugeosynclinal deposition and volcanic activity continued into the Triassic and Jurassic, when the trough separated into several more or less independent segments, each with a somewhat different subsequent history. Thus the end of Triassic time is regarded as marking the end of the Cordilleran geosyncline in Alaska. In most regions where Upper Triassic marine rocks are known they rest with apparent disconformity on the underlying rocks of upper Palaeozoic age. In the area studied, the upper Palaeozoic rocks are overlain by Triassic? lavas and are cut by numerous basic dikes that may in part represent the source of these volcanic rocks.

The second period of major uplift in the Alaska Range has been dated as mid-Early Cretaceous (late Neocomian or early Aptian) by Payne (1955). In the east-central part of the Alaska Range this deformation produced fold axes which trend generally northwest and locally form arcuate patterns that are convex southward. Some folds, including an anticlinal and synclinal fold in the Southern Rainbow Mountain area, are overturned toward the south.

The late Mesozoic and Cenozoic geologic history of the Alaska Range was one of alternating continental deposition, vertical uplifts, and faulting. Deposits such as the volcanic and clastic rocks of the Cretaceous (Albian) Cantwell Formation in Mt. McKinley National Park are typical of this depositional phase. In this study area deposits of Cretaceous age have not, however, been definitely established.

By the end of Cretaceous time most of Alaska was emergent, and marine deposition apparently has not occurred subsequently. Orogenic activity that began in earlier Cretaceous time reached a maximum intensity during the late Cretaceous, but renewed uplifts have taken place throughout the Tertiary. The present relief of the Alaska Range is entirely due to comparatively recent periods of uplift: in the southern part of the study area, for example, the Tertiary Coal-bearing Formation is in fault contact with marine Permian rocks. Elsewhere in the Alaska Range Tertiary deposits are commonly preserved in structural depressions.

The major structural feature is the Denali fault, which can be traced without interruption from near Breton Sound eastward into Canada—a distance of more than 1,300 miles. The surface expression of this lineament is readily identified because its position along the axis of the Alaska Range is occupied by numerous glaciers, including the Susitna, Muldrow, and Chistochina glaciers. Immediately north of the study area the lineament formed by the Denali fault is occupied by the upper part of the Black Rapids Glacier to the west of Delta River and the Canwell Glacier to the east. The Denali fault separates two major structural and geological provinces in Alaska: the undifferentiated Precambrian and lower Palaeozoic? Birch Creek Schist lies on the north side of the fault, whereas the southern flanks of the Alaska Range consist of upper Palaeozoic and (locally) Mesozoic deposits. There is as yet no conclusive evidence for either the age or the displacement along the Denali fault; estimates range from that of St. Amand (1957), who estimated right lateral movement of up to 150 miles, to that of Muller (1958), who cited evidence to show that the Denali fault may be a north-directed thrust in the Yukon Territory and eastern Alaska. Wahrhaftig (1958) believes the Denali

fault to be a reverse fault in which the northern block is upthrown, a hypothesis that is supported by the presence of much older rocks on the north side of the fault and the remarkably linear fault trace. Displacement of Mesozoic granite plutons nevertheless suggest that at some time during its history right lateral displacements of considerable magnitude may have occurred. Recurrent movement along this fault has continued into the Recent, as is indicated by many reports of displaced alluvial fans along the fault. Stout (1965, p. 59) noted one such displacement several miles north of the study area.

Within the study area Hanson (1963), Bond (1965), and Stout (1965) recognized as many as three separate fault systems. These may be related to the several periods of uplift during the Mesozoic and Cenozoic history of this region. According to Stout, the oldest fault set (fault set I) may have occurred in Middle or Late Cretaceous time. Faults related to this system are vertical or near-vertical dip-slip faults that trend generally northwest. Vertical separation along faults of this type in the Rainbow Mountain area may amount to several thousand feet, although precise estimates of displacements are not yet possible. These faults are approximately parallel to the fold axes in the upper Palaeozoic rocks in this area but cannot be related to the folding with certainty. This faulting produced large fault blocks, whose correlation constitutes one of the major stratigraphic problems as the absence of laterally continuous units prevents reliable physical correlations.

The oldest faults, and locally fold axes, are offset by faults related to a younger system (fault set II) which trend north to northeast. Lateral displacement along these faults is not, however, everywhere apparent. This fault system may be related to early Tertiary (post-Eocene) deformation in the Alaska Range or to the still younger thrust faulting. The faults in the Northern Rainbow Mountain area are examples of this fault system (Text-fig. 2). On the west side of Delta River, in the northwestern part of the study area, faults with similar trends may be tear faults related to the low angle south-directed thrust plates in that area.

The youngest faults in the study area are thrust faults (fault set III) that dip northward at low angles (20 to 30 degrees). These are well exposed to the northwest, and bring Devonian(?) and pre-Devonian metamorphic rocks southward and over the upper Palaeozoic marine volcanic and sedimentary rocks in that area. Stout (1965) estimated this southward overthrusting as having a minimum displacement of about 5,000 feet and probably as much as 3 to 5 miles. Estimates of the age of thrust faulting in the Alaska Range vary: Wahrhaftig and Hickox (1955) believe thrust faults to be as old as Eocene; Stout (1965) presented evidence indicating that movement along one of the thrust faults in the northwestern part of the study area may have continued into the Recent. It seems probable that thrust faults related to this system are more numerous than are shown in the accompanying geologic map and further mapping is needed.

The geologic history of the Alaska Range is unquestionably much more complex than is suggested by this brief summary. Within the study area and in adjacent areas mapped by graduate students during recent years, for example, there is evidence that repeated movement has taken place along many of the major faults. It also appears that fault zones may have controlled the subsequent intrusion of basic dikes and sills into these rocks; this appears to have

occurred along the northwest-trending fault along Rainy Creek in the southwestern part of the study area. In addition, there is as yet no satisfactory explanation for arcuate pattern and southward overturning of folds in the southeastern part of the study area; the fold axes in upper Palaeozoic rocks, although trending generally southeast, are part of a large arcuate fold pattern that is convex toward the south and truncated by the Denali fault approximately 20 miles to the southeast. Finally, the relationship of the several fault systems in this area to the Denali fault may be of the utmost significance.

Northern Rainbow Mountain area. This area was described by Hanson (1963) as the "Northwest Fault Block". It is bounded on all sides by high-angle faults whose known or inferred position are shown on Text-fig. 2. The fault bounding this block on its southwestern side (fault D, Text-fig. 2) trends approximately $N30^{\circ}W$ and is believed to be related to the oldest recognized fault system in this area (fault set I of Hanson, 1963), along which vertical movements predominated. The northwestern bounding fault (E) and two major subparallel faults within this fault block trend from $N10^{\circ}E$ to $N30^{\circ}E$ and are related to a later system (fault set II) along which both vertical and horizontal components of movement have been recognized. The precise position and movement on several northeastern bounding faults have not been established in this area.

No major folds are present in this fault block. According to Hanson (1963, p. 59), strata

"... form a dominantly subparallel trending structure which varies only in dip in the following manner. Along the southern margins of the fault block in the mapped area the units are upright, strike 270 degrees and dip 35 degrees north. . . . Northward, the dip steepens to 90 degrees and strike swings to 315° degrees. Still further north, the units are overturned (dips 44° southwest). The only complication of this general structure occurs . . . where several small sharp crested folds are developed—an anticline and syncline."

The stratigraphic succession exposed in this fault block can be divided, for the purpose of discussion, into a lower volcanic-rich sequence and an upper clastic and limestone sequence. Such division, however, is arbitrary, and the lower rocks grade into the upper sequence both vertically and horizontally near the upper boundaries.

The lower part of this succession has an aggregate thickness of about 3,700 feet and consists of dacite crystalline lithic tuffs and volcanic breccias intercalated with grey to grey-green volcanic-rich sandstone and siltstones. Conglomerates containing significant amounts of volcanic detritus also occur locally. Bedding in these strata is highly variable in thickness and in general is discontinuous laterally. These strata produce both mapping and nomenclatorial problems; neither the volcanic-rich limestones nor the clastic rocks containing volcanic material conform to any classificatory system proposed to date. This was noted by Hanson (1963, p. 21), who therefore used the term "greywacke" to refer to detrital marine sedimentary rocks in which the volcanic fraction is apparent in field examination. This usage is followed throughout this report, as well as the term "volcanic-rich limestones".

The succession of rocks described above is unfossiliferous and of unknown age. These strata grade upward into approximately 3,300 feet of thinly bedded

to massively bedded sandstones, siltstones, pebble-conglomerates, and silty limestones. In the southern part of this fault block these beds dip to the northwest; northward, dips become steeper and near the bounding fault on the northwest strata are overturned and dip to the southwest.

Age and correlation. Fossiliferous strata in the upper part of this succession occur approximately 4,200 feet from the base of the exposed section. These beds (locality RM-8, Text-fig. 3) consist of silty and argillaceous limestones cut by several thin (1 foot to 2 feet) dacite dikes. The most accessible exposures occur on the east side of the Richardson Highway at mile 212 (measured from Valdez). Strata are overturned and dips range from 65 to 70 degrees southwest; strike is approximately N70°W.

The rugose and tabulate corals from these beds have been studied in detail and are described here; they include *Cryptophyllum striatum* n. sp. (Rugosa), *Cladochonus* sp. and *Michelinia* sp. (Tabulata).

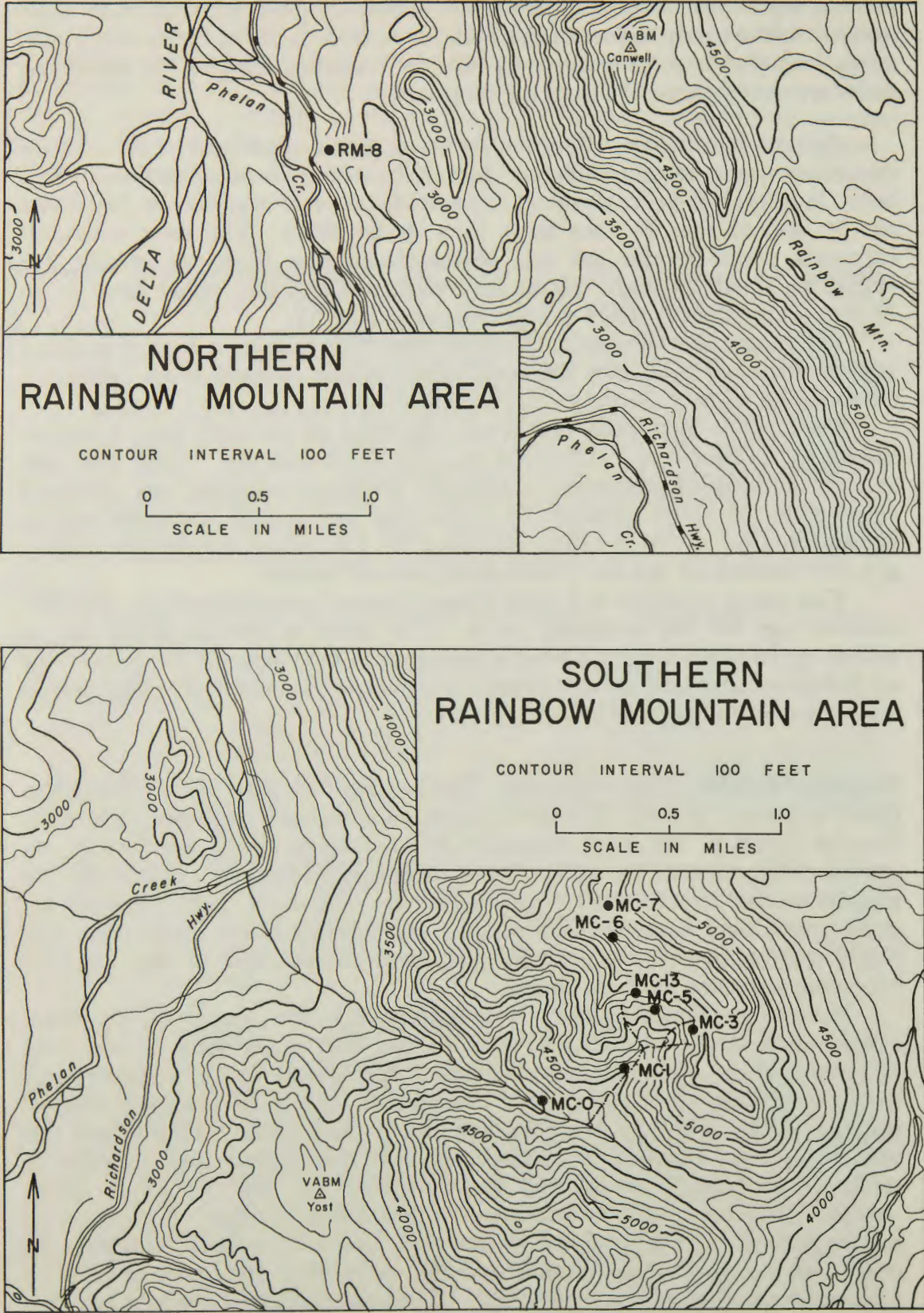
Brachiopods have been tentatively identified as *Juresania* spp., *Linoproductus* sp., ?*Institina* sp., ?*Chaoiella* sp., and *Stenocisma* sp. These beds also contain unidentified fragments of bryozoa, phillipsid trilobites, and pectinoid pelecypods. A single example of a goniatite cephalopod was collected by Hanson in 1962 which has been identified by Unklesbay and Pauken (1966) as a new ammonoid species, *Pseudoparalegoceras hansonii*.

This fauna indicates a Lower Pennsylvanian (post-Morrowan, pre-Missourian) age for the enclosing rocks. The strata at locality RM-8 are of similar age to south-dipping Lower Pennsylvanian beds exposed along the ridge of Rainbow Mountain in the Southern Rainbow Mountain area but precise correlation is not possible as yet.

Southern Rainbow Mountain area. This area includes parts of the "McCallum Creek sequence" and the "Rainbow Mountain sequence" originally defined by Hanson (1963, p. 19), who assigned a Pennsylvanian age to the former and provisionally referred the latter to the Mississippian system. This study has established that strata formerly assigned to the McCallum Creek sequence are entirely of Lower Permian (Wolfcampian and possibly lower Leonardian) age, but no contradictory evidence for the Pennsylvanian age of the Rainbow Mountain sequence has been found.

Following Hanson's study, his terminology was employed by Bond (1965) in a restricted sense to refer to the two major fault blocks only (Hanson's south and south-central blocks) in this area and in adjacent areas to the southeast. It now appears desirable to return to Hanson's original usage, as rocks of widely divergent age clearly are present. Throughout this report the term Rainbow Mountain sequence therefore is used to refer to strata of established or inferred Pennsylvanian age and McCallum Creek sequence to denote rocks of known or inferred Permian age. Formal names for formations are not proposed at this time, however, as both sequences are grossly similar in field appearance and can be reliably distinguished only by palaeontological criteria in most areas. Moreover, unfaulted contacts between the Pennsylvanian and Permian sections have not been observed.

Comparatively few fossils have been recovered from the Rainbow Mountain sequence in the study area. In contrast, the Permian McCallum Creek



Text-fig. 3. Fossil localities, Northern and Southern Rainbow Mountain areas.

sequence is locally fossiliferous and it has been possible to establish the existence and sequence of a number of zones of rugose and tabulate corals in these rocks. One or more of these zones have been recognized in three of the four subsidiary study areas: the Southern Rainbow Mountain, the McCallum Creek, and the Upper Delta River. Permian Fusulinidae, commonly in close association with the corals, have also been found in all three areas and are now under study in the section exposed in the Upper Delta River area (Rainy Creek section). Tentative identifications of these protozoans have been made and are recorded here where available.

Age and correlation. At this time it appears probable that the section exposed in the Upper Delta River area and in the McCallum Creek area is of younger Permian age than the Permian rocks exposed in the Southern Rainbow Mountain area. If this interpretation is correct, the Lower Permian McCallum Creek sequence throughout the entire study area consists of (1) a lower succession of marine volcanics, agglomerates, graded detrital volcanic-rich limestones, volcanic-rich clastic siltstones and sandstones ("greywackes"), also commonly graded, and a few comparatively pure but discontinuous micritic limestones; and (2) an upper succession of thin-to-medium-bedded fossiliferous limestones, dark carbonaceous shales and mudstones, locally concretionary, and light-coloured siltstones (locally dolomitic), shales and medium-to-thick-bedded limestones. The upper sequence is best exposed in the Upper Delta River area, where it forms the upper slopes of Rainy Mountain, whereas the intermediate part of the section is exposed in both the Upper Delta River area and (in part) in the McCallum Creek area. The lower marine volcanic and graded clastic rocks are exposed primarily in the Southern Rainbow Mountain area.

As a result of a recent reconnaissance of Permian strata north of Slana, approximately 90 miles southeast of the Rainbow Mountain area, regional correlations now appear possible. Several stratigraphic sections were measured and collected in the vicinity of Indian Pass Lake that revealed the presence of a number of rugose and tabulate corals (*Timania*, *Durhamina*, *Sinopora*) in the upper limestones in that area. Although this material has not yet been studied in detail, the presence of these genera provides good evidence for the biostratigraphic, and possibly temporal, equivalence of limestones described by Richter (1966, p. 10) as "?Mankomen" with the upper part of the McCallum Creek sequence as described here.

In the Slana area, these fossiliferous limestones are conformably (and gradationally) underlain by several thousand feet of predominantly subaerial andesitic to basaltic volcanics that Richter (1966, p. 7) refers to the Tetelna Formation of Mendenhall (1905, p. 36). As discussed elsewhere in this study, the turbidites and marine volcano-clastics of the lower part of the McCallum Creek sequence also underlie the upper non-volcanic limestones and shales with apparent conformity. Although no fossils were found in the Tetelna sections, these relationships suggest that the lower McCallum Creek sequence is a marine equivalent of the subaerial Tetelna Formation.

Recent study of the abundant fusulinids that occur in the upper part of the McCallum Creek sequence in the Upper Delta River area by Petocz indicates (Personal communication, July 1968) that the boundary between the

lower Permian Wolfcamp and Leonard Series (Sakmarian-Artinskian) lies within this interval. It now appears that biostratigraphic and geologic studies of the Permo-Carboniferous strata in the east-central Alaska Range could most profitably be furthered by (1) detailed study of the coral and fusulinids that occur in the Slana area and (2) a similar study of the Mankomen Formation at its type locality near Mankomen Lake.

Stratigraphic relationships in the Southern Rainbow Mountain area are complicated by both folding and faulting. Structural dislocations include faults related to both fault sets I and II. Folds are cut by the earlier set and are locally overturned southward. Major fault blocks are referred to as (1) the south fault block, (2) the south-central fault block, and (3) the southwest fault block. They are separated by faults D and B respectively (Text-fig. 2).

South fault block. Rocks of known Pennsylvanian age are exposed in this fault block. It is bounded on the north and northwestern sides by faults and intrusive igneous contacts with granites. The south-bounding fault (D) is a high angle fault (fault set I) whose trend is northwest and which in part parallels the northwest-trending ridge at the southern end of Rainbow Mountain. Although difficult to locate precisely in the field, this fault is of stratigraphic importance as it brings rocks of Pennsylvanian age into fault contact with the Lower Permian McCallum Creek sequence on its south side. These relations suggest that this fault (D) is upthrown on the north.

The stratigraphic succession exposed in the south fault block was not studied in detail by the writer. Hanson (1963) estimated a possible total thickness of 4,000 to 5,000 feet, based on structure sections. The uniform south dip (60 to 70 degrees) of the upper part of this section, adjacent to fault D, indicates a minimum thickness of 1,750 feet. These rocks are exposed along a narrow arête ridge and are described by Hanson (1963, pl. 3) as follows: "Thinly bedded (5'-20') sandstone, pebble conglomerates and siltstones, alternating with 5'-30' beds of fossiliferous clastic limestone and minor thin tuffs."

Fossils collected by Hanson and the writer in 1963 from the upper part of this section (Hanson's localities F-3 and F-9) included Pennsylvanian Fusulinidae identified by H. E. Wheeler (University of Washington) as assignable to *Wedekindellina* and some possibly to *Fusulinella*. Wheeler is quoted by Hanson (1963, p. 52) as follows: "The abundance of these [genera] in pre-Missourian Pennsylvanian, together with the absence of more advanced forms strongly suggests that the strata are either Des Moines or earlier Pennsylvanian." A single goniatite cephalopod was collected by Hanson from talus at his locality F-9 which also indicates a Lower Pennsylvanian age (Unklesbay and Pauken, 1966) for these strata. However, fossils collected by Hanson at his localities F-6, F-7, and F-8 and referred to the Pennsylvanian Rainbow Mountain sequence have been restudied and are identified herein as species of *Bothrophylum* and *Heritschioides* (Order Rugosa). Elsewhere on Rainbow Mountain these genera have been found in close association with fusulinids of Lower Permian age. These localities, which correspond to localities MC-6 and MC-7 (Text-fig. 3) of this study, must thus lie on the south side of fault D and within the Permian McCallum Creek sequence.

South-central fault block. This fault block has been studied in detail. It is bounded on the north by fault D and on the south by fault B (Text-fig. 2). The entire exposed section is believed to represent the lower part of the McCallum Creek sequence. Strata are folded to form an anticline and syncline and are cut by several small thrust faults. Folds are open to the southeast but toward the northwest the south limb of the anticline and north limb of the syncline are overturned toward the south. The trend of the axes of these folds is slightly more northerly than the trace of fault C, with the result that the north limb of the syncline is progressively faulted out toward the northwest. Few individual beds can be traced more than a short distance and some parts of the section are repeated up to three times due to repetition by folding. Based on structure sections and correlation of several fossiliferous zones it appears that at least 4,000 feet of section are exposed; however, topography and structure are such that the lowest (i.e., oldest) strata occur at an elevation of about 6,000 feet (locality MC-7, Text-fig. 3) whereas the youngest exposed beds occur at an elevation of only 4,000 feet (locality MC-0, Text-fig. 3). It is emphasized, therefore, that the following description is stratigraphic rather than topographic.

The oldest known Permian rocks in the study area are exposed in this fault block, adjacent to fault D. These strata occur along the narrow north-trending arête ridge in the Southern Rainbow Mountain area (Text-fig. 3) and constitute part of the north limb of the synclinal fold discussed above. Beds strike N60°W and dip 59 degrees toward the southwest. Rock types consist predominantly of alternating fossiliferous silty limestones and red-brown fossiliferous mudstones. The general absence of volcanic material in this part of the section is in sharp contrast to rocks of younger Permian age exposed elsewhere on Rainbow Mountain. Bedding is thin to medium but for the most part obscured by frost shattering or covered by snow cornices which are perennial at this elevation. For these reasons, the location of fault D on this ridge can only be established within an interval of several hundred feet.

The lowest fossiliferous horizon (MC-7, Text-fig. 3) occurs an estimated 300 feet stratigraphically above this contact. Fossil rugose corals identified from this zone include only *Bothrophyllum* cf. *B. pseudoconicum* Dobrolyubova, but this species is abundant. Associated corals too poorly preserved for description include ?*Caninia* sp. and *Michelinia* sp. No fusulinids have been found in these beds.

Approximately 70 feet higher stratigraphically (100 feet southward along the ridge) a second fossiliferous zone is present (locality MC-6) which contains abundant representatives of a colonial rugose coral here described as *Heritschioides summitensis* n. sp. The holotype specimen (UA 1025) contains a single poorly preserved schwagerinid fusulinid in the surrounding matrix that establishes a Permian age for the enclosing rocks. Fossil invertebrates other than rugose and tabulate corals are uncommon in these beds, although poorly preserved brachiopods and marine algae locally are present.

Southward along this ridge dips increase in steepness: near the point where the trend of the ridge becomes southeasterly strata are vertical to overturned toward the south, with dips ranging from 90 to 80 degrees northeast. The total thickness of this part of the section is approximately 650 feet. The nature

of the contact between the lower non-volcanic rocks and the overlying marine volcanics and volcanic-rich sedimentary rocks is obscured by talus at the crest of Rainbow Mountain. There is no significant change in strike, however, and the contact probably is gradational.

The succeeding 300 feet of section are dominantly limestone and include a high percentage of silicified silts and volcanic material. Bedding is medium to massive. These strata are exposed in the vertical to near-vertical north limb of the syncline at elevations ranging from 5,300 to 5,600 feet on south-facing slopes of Rainbow Mountain. A zone of solitary rugose corals occurs about 200 feet above the base of this interval (850 feet above the base of the section) in thick-bedded jointed limestones (locality MC-13, Text-fig. 3). These corals are described herein as *Timania rainbowensis* n. sp. Associated fossil invertebrates include only coiled gastropods (?*Omphalotrochus*) and brachiopods. Eight examples of ?*Pseudofusulinella* have been identified from matrix surrounding the corals.

A zone of tabulate corals occurs less than 100 feet stratigraphically above the *Timania* zone (approximately 950 feet above the base of the entire section), these are described as *Syringopora katoi* n. sp. The specimens are closely associated with a zone of productid and strophomenid brachiopods (*Plicatifera* sp. and *Derbyia* sp.). This locality is identified as MC-5 (Text-fig. 3), and also occurs in the steeply dipping north limb of the syncline.

A short distance to the southeast, across the synclinal axis, silicified silty volcanic-rich limestones are exposed in the north limb of the anticlinal fold at an elevation of approximately 5,300 feet. Strata dip 35 degrees northeast and strike northwest (locality MC-3, Text-fig. 3). *Bothrophyllum* cf. *B. pseudoconicum* also occurs at this horizon, as well as a rich but poorly preserved brachiopod fauna including spiriferid, productid, strophomenid, and rhynchonellid brachiopods. Brachiopods have been tentatively identified as *Neospirifer* sp., *Choristites* sp., ?*Unispirifer* sp., *Yakovlevia* sp., *Linoproductus* sp., ?*Calliprotonia* sp., ?*Kochiproductus* sp., *Rugosochonetes* sp., and *Denticulophora* sp. This zone is approximately 50 feet stratigraphically above strata exposed at locality MC-5 (1,000 feet above the base of the section). Fusulinids tentatively identified as *Pseudofusulinella* and ?*Eoparafusulina* occur with the corals, but are uncommon.

The overlying 600 feet of section is best exposed adjacent to the anticlinal axis in the drainage southwest of locality MC-13. The axis of this fold is well exposed in this steep drainage at an elevation of approximately 4,300 feet. Measured sections through both the north and south limbs of this fold are generalized in the description that follows:

Collectively, thin-to-medium-bedded silicified clastic marine rocks containing moderate to abundant amounts of volcanic detritus (greywackes) constitute approximately 37% of this interval. Medium-to-coarse-grained silicified greywackes and pebble-conglomerates form an additional 24%. Bedding in the coarser rocks ranges from 1 foot to 5 feet, but is laterally discontinuous. Thin-bedded silicified dark-coloured siltstones are intermittently present and constitute about 24%, whereas andesite and dacite flows (?) and breccias ("agglomerates") form a minor part (8%). Limestones are also minor (4%) and are thin- to medium-bedded, silicified, and discontinuous laterally. A single fossiliferous limestone sequence approximately 20 feet thick occurs near

the top of this interval (about 1,600 feet above the base of the section) at an elevation of 4,600 feet (locality MC-1, Text-fig. 3). Strata at this locality strike N62°W and dip 72°SW: they are in the south limb of the anticlinal fold, which becomes progressively steeper southward and ultimately is overturned toward the south.

The brachiopod fauna at locality MC-1 is similar to that at locality MC-3. However, the coral fauna is dissimilar and contains representatives of the Hapsiphyllidae and Polycoeliidae as well as cyathopsid corals. Corals from this locality have been described in this study as ?*Pseudobradiphyllum* sp. A, ?*Bradyphyllum* sp. A, and *Bothrophyllum* sp. A. Material is insufficient for formal species designation. Identified brachiopods include *Spiriferella* sp., *Choristites* sp., *Reticulatia* sp., *Linoproductus* sp., *Yakovlevia* sp., and ?*Kochiproductus* sp. One accidentally intersected oblique section of a fusulinid has been identified as ?*Pseudofusulinella*.

These strata grade upward into approximately 2,300 feet of section exposed in the vertical to overturned south limb of the anticline. Fully 86% of this interval consists of fine-, medium- and coarse-grained graded volcanic-rich greywackes, tuffs, agglomerates, pebble-conglomerates, and breccias. Cementing materials are variously calcareous, tuffaceous, and siliceous, with the siliceous predominating. Andesite and dacite breccias and flows (?) constitute approximately 13% of this interval, whereas siltstones and limestones form less than 1%. Limestones are typically rich in volcanic detritus and discontinuous, but several medium-to-thick-bedded micritic limestones occur near the upper part of the section (here, the base of the exposures). Clastic volcanic-rich sedimentary rocks throughout this interval commonly are graded.

Micritic limestones within 100 feet of the stratigraphically highest strata exposed, which dip northeast at approximately 45 degrees (overturned) at an elevation of 4,000 feet, contained scattered solitary rugose corals and tabulate corals. The former are described here as *Timania* sp. A. Tabulate corals are fragmentary and tentatively referred to *Sinopora*. Fusulinidae have not been found in these beds (locality MC-0, Text-fig. 3).

Age and correlation. The fossil corals and brachiopods that are distributed throughout the rocks described above collectively indicate a Lower Permian (Wolfcampian) age. Although *Bothrophyllum pseudoconicum* was described by Dobrolyubova from strata believed to be of Moscovian age (approximate equivalent of Desmoinesian of North America) in the U.S.S.R., other species occur in rocks of Lower Permian age in the Ural Mountains of Russia. Furthermore, this genus occurs in the Southern Rainbow Mountain area in close association with *Timania* and *Heritschioides*, which are characteristic Permian genera. Associated fusulinids, although not yet studied in detail, provide confirmatory evidence for the assignment of these rocks to the Lower Permian.

Field structural and stratigraphic relations throughout the study area indicate that the entire section exposed in this fault block underlies strata exposed in the McCallum Creek and Upper Delta River areas.

Southwest fault block. No details are available concerning the structure and stratigraphy of this fault block. Hanson (1963, pl. 2) estimated a total thickness of at least 2,000 feet of section exposed, and his structure sections indicate that these strata are upthrown with respect to the adjacent (south-central)

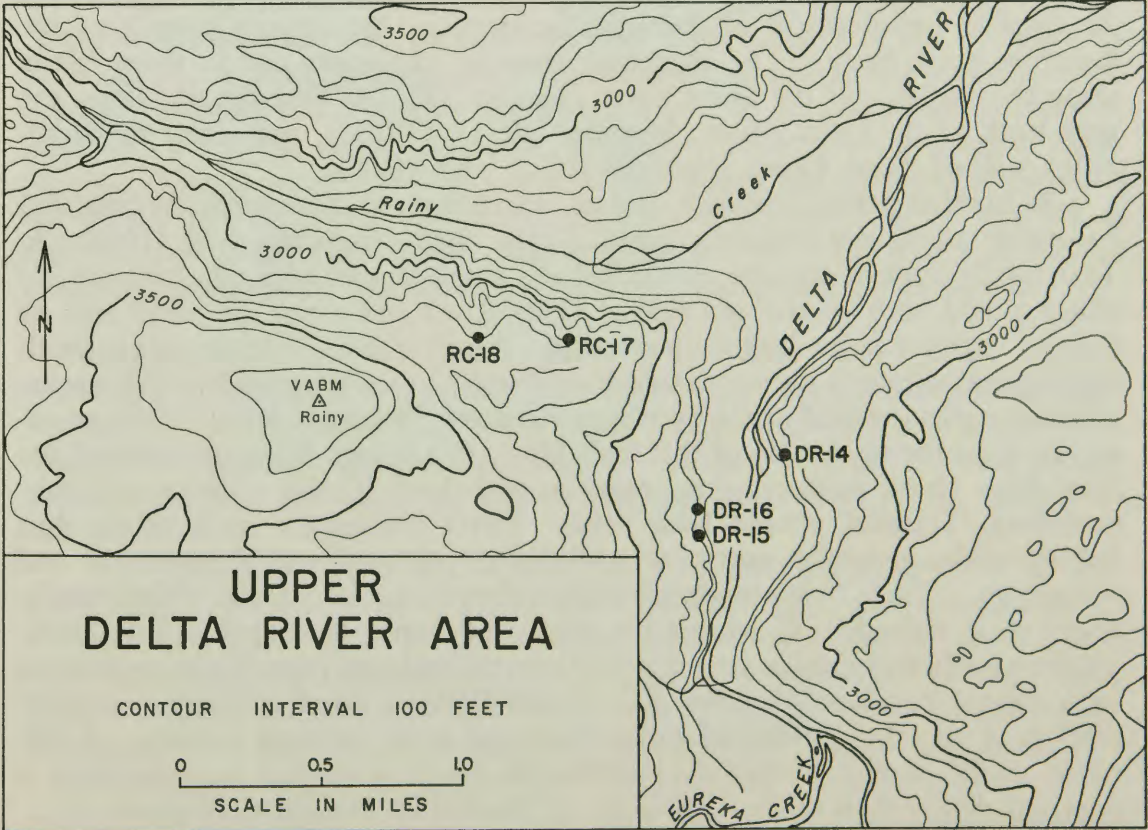
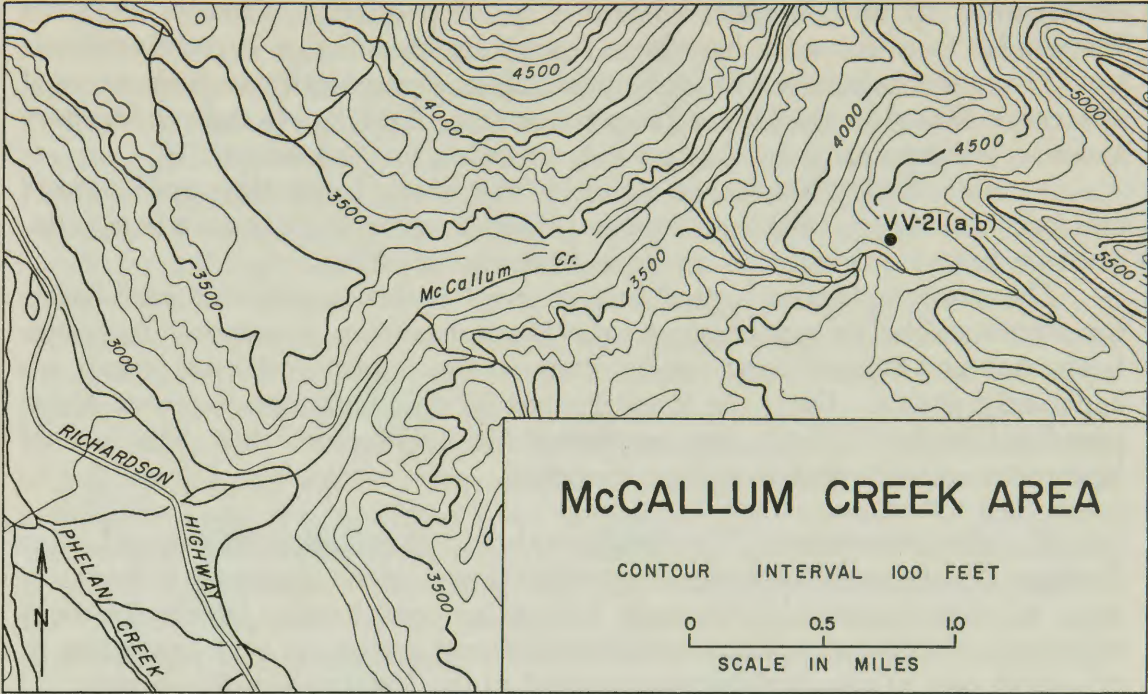
fault block. However, this estimate may be conservative, and the displacement on the north-bounding fault (fault B, Text-fig. 2) is not known. The general character of rocks in this fault block suggests at least partial equivalence to the marine volcanic rocks and greywackes exposed in the south-central fault block, but fossil collections have not yet been made.

McCallum Creek area. The McCallum Creek drainage was mapped on a reconnaissance basis by Bond (1965). He found that strata exposed in the Southern Rainbow Mountain area continue toward the southeast, but his study was primarily petrological rather than biostratigraphic. Fossiliferous strata in a small east-flowing tributary of McCallum Creek ("Volcanic Valley") which are markedly dissimilar to other rocks in this area were examined during the present study (locality VV-21a and VV-21b, Text-fig. 4). Approximately 880 feet of strata, which apparently constitute the middle part of the Lower Permian McCallum Creek sequence as well as the basal parts of the upper limestones, is exposed in the north and south walls of this narrow valley. These strata form a part of the south limb of a broad synclorium that is cut by several northwest-trending faults (faults A', A and B, Text-fig. 2). Subsidiary small anticlinal and synclinal folds are present whose axes are separated by only a few hundred yards. These minor structures produce local reversals in dips adjacent to locality VV-21. A prominent andesitic dike exposed in the north wall of this valley appears to follow the trace of fault A.

The oldest exposed stratigraphic unit in this area is a thick andesitic tuff. These strata are exposed both in the valley immediately north of fault A and are grey-green and extensively silicified in their lower part. Platy aggregates of chlorite occur throughout the lower part of this unit and both ash and lapilli tuff beds are present. The total thickness of this tuff, based in part on sections measured by Bond elsewhere in the McCallum Creek area, is about 740 feet. The upper 50 to 100 feet of this unit, best exposed in "Volcanic Valley", consists of a tuffaceous calcareous siltstone. These beds are in fault contact with stratigraphically higher medium-to-thick-bedded limestones, calcareous siltstones and black concretionary shales and claystones with an aggregate thickness of 320 feet at this locality. Based on the probable equivalence of a zone of rugose corals in these limestones (described below) to a zone in the Upper Delta River area, as much as 800 feet of section may be faulted out at this contact.

The lowest exposed limestones at this locality have a thickness of about 80 feet. Strike is N70°W and beds dip 74°NE. These strata consist of regularly bedded, finely crystalline limestones with minor amounts of silt. In the last part of the field season of 1966, fusulinids were found to occur in several zones in these limestones and probably are present throughout most of the section. These have not yet been collected or studied. Solitary rugose corals occur in a zone (VV-21a) between 20 and 30 feet above the base of these limestones and are described in this study as *Timania* cf. *T. schmidtii* Stuckenberg (1895).

The lower limestones are overlain by approximately 120 feet of alternating shales, calcareous siltstones, and thin, silty limestones. A finely crystalline black limestone (VV-21b) near the upper part of this interval contains colonial rugose corals and associated tabulate corals described here as *Durhamina*



Text-fig. 4. Fossil localities, McCallum Creek and Upper Delta River areas.

alaskaensis n. sp. and *Sinopora minatoi* n. sp., respectively. Closely associated Fusulinidae from this zone have been tentatively identified as *Pseudofusulinella* sp. This zone is believed to correspond biostratigraphically to beds exposed at locality DR-15 in the Upper Delta River area (Text-fig. 4), where *Sinopora* and a second species of *Durhamina* (*D. sutherlandi* n. sp.) occur.

A concretionary black shale about 40 feet thick forms the upper part of this interval. Large coiled gastropods (?*Omphalotrochus*) occur in some concretions, but are inadequately preserved for identification.

The stratigraphically highest beds exposed at this locality are fossiliferous limestones similar in appearance to the lower limestone sequence. Although bryozoans and crinoid parts are common in the upper limestones, corals are apparently absent. Only the lower 20 feet of this limestone sequence is exposed at locality VV-21, but on Rainy Mountain more than 850 feet of limestones and siltstones have been measured.

Age and correlation. The fossil corals and Fusulinidae indicate a Lower Permian (Wolfcampian — lower Leonardian?) age for the limestones at this locality. All strata exposed in "Volcanic Valley" are considered to overlie the rocks exposed in the Southern Rainbow Mountain area and are in part equivalent to the lower part of the thick section exposed in the Upper Delta River area.

Upper Delta River area. A reconnaissance of this area at the end of the 1965 field season resulted in the discovery of excellent exposures of the middle and upper parts of the McCallum Creek sequence. Limitations of time prevented the detailed measurement of stratigraphic sections, and figures given here are therefore approximate. The principal areas of exposures are in steep bluffs along the east side of the Delta River (locality DR-14, Text-fig. 4), along the west bank of the Delta River (localities DR-15, DR-16), and along the south valley wall of Rainy Creek (localities RC-17 and RC-18).

As in other parts of the area studied, strata exposed in this area are bounded by major northwest-trending faults. The north-bounding fault (fault A, Text-fig. 2) appears to have controlled the emplacement of a tabular andesitic dike exposed both on the east side of Delta River and along the south side of Rainy Creek for some distance westward. North of this fault, strata are south dipping and although poorly exposed, are similar to the greywackes and marine volcanic rocks exposed in the Southern Rainbow Mountain area. The bounding fault on the south side of this fault block (F) brings Permian rocks of the McCallum Creek sequence into contact with both Tertiary rocks and sub-horizontal Triassic? altered basic lavas. Strata within the fault block thus defined strike generally northwest and dip to the southwest between 20 and 55 degrees. These beds are disturbed by only a few minor faults which locally affect their attitude. In addition to the coral zones described below, Fusulinidae have been found in abundance at several horizons (notably in association with rugose corals at localities RC-17 and DR-15); random samples suggest that these may be distributed throughout the entire exposed section. A detailed study of the Fusulinidae within the study area was completed as a doctoral dissertation at the University of Alaska by Ronald G. Petocz.

The lower part of this section, about 750 feet thick, consists of regularly interbedded silty limestones and shales. Few individual beds in this interval

are more than 5 feet thick. Thin interbeds of siltstone occur throughout. Fossils are scarce, but a few productid brachiopods occur in the dark shales. Approximately 450 feet stratigraphically higher than the lowest exposed beds in the steep south side of Rainy Creek a single fossiliferous limestone is exposed (locality RC-17, Text-fig. 4), which contains numerous examples of solitary rugose corals described here as *Caninia petoczi* n. sp. This bed also contains abundant fusulinids which have been tentatively identified as including ?*Eoparafusulina* sp., *Pseudofusulinella*, *Schubertella*, and *Schwagerina*. Identified brachiopods include only *Linoproductus* sp. and *Stenosisma* sp. This bed can be recognized on the east side of Delta River (locality DR-14), where it contains an identical coral and fusulinid fauna. A minor fault at the latter locality locally has steepened the dip of adjacent strata.

At about 300 feet stratigraphically higher, at locality RC-18, rocks consist of a succession of thick limestones and intervening calcareous shales. A single identifiable coral was collected from limestones approximately 30 feet above this contact (?*Clisiophyllum* sp. A). Associated brachiopods include ?*Spiriferella* sp., *Spiriferellina* sp., *Camerisma* sp., *Neospirifer* sp., and *Antiquatonia* sp. These strata may be approximately equivalent to poorly exposed limestones on the west side of Delta River (locality DR-16), where *Clisiophyllum* is associated with corals described here as *Auloclisia deltense* n. sp. Schwagerinid fusulinids, as well as fossil sponges (?*Hindia*) and a few productid brachiopods, occur in the rock matrix at locality DR-16.

A third coral zone occurs approximately 170 feet stratigraphically higher on the west side of Delta River (locality DR-15) in which colonial Rugosa are present (*Durhamina sutherlandi* n. sp.) and scattered fragmental tabulate corals tentatively referred to *Sinopora* sp. The limestones are overlain by about 50 feet of dark, concretionary shales similar in appearance to those overlying *Durhamina*- and *Sinopora*-bearing limestones in the McCallum Creek area (locality VV-21b); these zones are considered to be biostratigraphic equivalents. The massive- and thick-bedded limestones and thinner siltstones in the upper part of the section have not been examined in detail but are at least 850 feet thick. The lower beds are believed to be essentially equivalent to the upper limestone sequence exposed in the McCallum Creek area.

Age and correlation. Strata exposed in the Upper Delta River area are considered to comprise the middle and upper parts of the McCallum Creek sequence. The fusulinid and coral fauna indicates a Lower Permian age, possibly transcending the Wolfcampian-Leonardian boundary. This section thus may include the youngest known Permian strata both in the study area and in the Alaska Range.

The section exposed in this area has a minimum thickness of at least 1,850 feet and possibly more. There is neither lithological nor palaeontological evidence that these rocks are lateral equivalents of any part of the Permian rocks exposed in the Southern Rainbow Mountain area; on the contrary, both palaeontological and structural evidence suggest that they are entirely younger. Combined with the estimated thickness of the lower part of the McCallum Creek sequence (4,000 feet), the total thickness of Permian section in this region must be at least 5,850 feet. The aggregate thickness of Lower Permian and Pennsylvanian rocks in the study area may therefore be as much as 12,850 feet.

PART II

Biostratigraphy and Palaeontology

Faunal analysis and coral zonation. As recently as 1962 Carboniferous and Permian rocks were considered to be of minor importance in the Alaska Range, and rocks of Pennsylvanian age were believed to be absent altogether. The establishment in the study area of the presence of both Pennsylvanian and Permian sections, with a combined thickness of at least 12,850 feet, is thus of considerable interest in itself.

In addition to Fusulinidae and locally abundant fossil invertebrates, the Permian strata contain at least eleven "zones" of rugose and tabulate corals. Some of these fossiliferous horizons undoubtedly are of limited lateral extent and are of only local value. Other zones, however, that extend throughout the study area may be of use in future biostratigraphic studies in adjacent parts of the Alaska Range. The potential value of these coral zones is greatly enhanced by (1) the associated Fusulinidae, which are under study, and (2) the absence of widespread lithological horizons which might otherwise serve as the basis of stratigraphic correlations.

Most of the coral zones appear to be remarkably restricted with respect to their coral faunas, and are characterized by only one or two species, which, however, occur in abundance. *Bothrophyllum* seems to be the only genus not confined to a narrow stratigraphic interval. It is hoped that these zones will be of considerable use in future biostratigraphic studies in adjacent parts of the Alaska Range. The stratigraphic distribution of the zones is shown on page 27.

These coral faunas also assume disproportionately great importance because of their location in a region not heretofore studied palaeontologically. The intermediate position of Alaska with respect to the comparatively well known coral faunas of similar age in other parts of North America and in Asia is of particular significance in this respect.

Most coral species that occur in this area are foreign to other regions in North America and are almost totally dissimilar to the endemic coral faunas of the Permian of the Mid-Continent region. In contrast, the described corals from the Lower Permian of the Ural Geosyncline and Moscow Basin of Russia include many closely similar forms. It thus is pertinent to consider briefly the significance of the presence of this "Asiatic" fauna in Alaska and its relationship to intercontinental distributional patterns during the early Permian.

The Asiatic character of fossil invertebrates of Permian age from Alaska was noted some time ago by G. H. Girty (reported by Moffit, 1954, p. 115), who had occasion to examine a brachiopod fauna from the Alaska Range. Subsequently, the limits of this Lower Permian seaway were brought into

<i>Intervening stratigraphic interval (ft)</i>	<i>Coral species and localities</i>	<i>Distance from base of section (ft)</i>
	(fault contact with younger strata)	
800-900	<i>Durhamina alaskaensis</i> (VV-21b), <i>Durhamina sutherlandi</i> (DR-15), <i>Sinopora minatoi</i> (VV-21b)	5,680
170	<i>Timania</i> cf. <i>T. schmidtii</i> (VV-21a)	5,510
30	<i>Auloclisia deltense</i> (DR-16), <i>Clisiophyllum</i> sp. A (DR-16), ? <i>Clisiophyllum</i> sp. B (RC-18)	5,480
300	<i>Caninia petoczi</i> (RC-17, DR-14)	5,180
1,270	<i>Timania</i> sp. A (MC-0)	3,900
2,300	<i>Bothrophyllum</i> sp. A (MC-1), ? <i>Pseudobradiphyllum</i> sp. A (MC-1), ? <i>Bradyphyllum</i> sp. A (MC-1)	1,600
600	<i>Bothrophyllum</i> cf. <i>B. pseudoconicum</i> (MC-3)	1,000
50	<i>Syringopora katoi</i> (MC-5)	950
100	<i>Timania rainbowensis</i> (MC-13)	850
480	<i>Heritschioides summitensis</i> (MC-6)	370
70	<i>Bothrophyllum</i> cf. <i>B. pseudoconicum</i> (MC-7)	300
300 (approx.)	(fault contact with Pennsylvanian rocks)	

sharper focus by Wilson and Langenheim. These authors, following a study of rugose and tabulate corals from east-central Nevada, stated (1962, p. 516):

"The Permian coral fauna of this study has three species in common with that described by Easton (1960) from Nevada and California and is closely akin to the assemblage reported by Merriam (1942) from Oregon. Descriptions of . . . corals . . . by Smith (1935) and Harker and McLaren (1950) suggest that the Canadian and Alaskan parts of the geosyncline are similar. The Permian coral faunas of Kansas and Texas, however, are not closely related to the fauna of this study, and have been considered endemic, although alike in some elements to Asiatic corals. The Early Permian coral fauna from the Ural geosyncline in Russia is strikingly similar to that of this study. Many species are closely comparable. The fauna of the Moscow Basin, however, is somewhat less similar. Permian corals of the Asiatic Tethyan province . . . are totally unlike faunas of the Russian province and that of this study."

With reference to the stratigraphic distribution of rugose and tabulate corals throughout Wolfcampian and lower Leonardian strata in the Ely Quadrangle, these authors conclude (p. 517):

"Thus the four zonules (1) *Caninia hansenii*; (2) *Syringopora mccutcheonae* - *Thysanophyllum princeps*, (3) *Durhamina cordillerensis*, and (4) *Heritschioides billae* - *Orionastrea hudsoni* may prove of more than local interest."

Some elements of the fauna described by Wilson and Langenheim are altogether absent from the fauna of this study. It is undoubtedly significant,

however, that several species described here have as their closest morphological counterparts *Syringopora mccutcheonae* (*Syringopora katoi* n. sp.), *Durhamina cordillerensis* (*Durhamina alaskaensis* n. sp.), and *Heritschioides billae* (*Heritschioides summitensis* n. sp.) Considering the distance separating Nevada from Alaska, the close similarity of these important faunal elements is all the more striking. Equally striking, however, is the near identity of *Bothrophyllum* cf. *B. pseudoconicum* to *Bothrophyllum pseudoconicum* Dobrolyubova, described from the Upper Pennsylvanian? or Lower Permian of Russia. Similarly, *Timania* and *Sinopora* are Asiatic genera, and also occur in the Lower Permian of the U.S.S.R.

Recently, the intercontinental distribution of the newly proposed Family Durhaminidae was summarized by Minato and Kato (1965b). Two genera, *Durhamina* and *Heritschioides*, appear best to define the limits of this faunal realm during Wolfcampian and Leonardian time. The presence of both *Durhamina* and *Heritschioides* in the study area thus is entirely consistent with the distributional pattern of the early Permian seaway depicted by these authors for the *Pseudoschwagerina* and *Pseudofusulina* zones (Minato and Kato, 1965b, text-figs. 21, 22). The southeastern limits of this seaway may have corresponded closely to the shelf limestones and coral fauna of east-central Nevada described by Wilson and Langenheim (1962). Its western margins unfortunately are obscured by the Mesozoic and Cenozoic rocks of the coastal regions of the Pacific Northwest of the United States and in Canada.

The Fusulinidae that occur throughout the Permian strata in the study area also appear, on the basis of preliminary study, to have chiefly Asiatic affinities. The significance of this element of the fauna, as well as full realization of their stratigraphic utility, must await the completion of a detailed study.

Methods of study. The preservation of fossil corals and other invertebrates is, in general, very poor. Most coral specimens are incomplete and with rare exceptions embedded in rock matrix. These were found not to be amenable to any practical method of extraction. Procedures that can be followed under ideal conditions of preservation were therefore usually not possible, including photographs of corallite exteriors and accurate measurements of the distance from the proximal end (apex) at which transverse thin sections were made. However, most standard measurements used in coral studies were made, including corallite diameter (d), septal counts (n) and, when applicable, the diameter of the dissepimentarium (d^d). These data, and computed measures derived from them, such as septal ratios, are shown in graphic form for most coral species. When possible, the relationship of septal ratio to height is also illustrated in this manner. All raw data for the rugose corals are recorded in Appendix I.

Terminology used in the systematic description of corals follows that proposed by Moore, Hill, and Wells (*in* Hill, 1956), with a few exceptions: (1) septal microstructure is described in terms proposed by Kato (1963); (2) axial tabellae, wide tabellae, periaxial tabellae, peripheral tabellae, and clinotabellae (not to be confused with clinotabulae) are used as defined by Minato and Kato (1965b, p. 22); and (3) stages of coral ontogeny are designated as brephic (contain only protosepta), neanic (juvenile), and ephebic

(mature). The precise point in the development of a given coral species at which the ephebic characters appear is necessarily subjective. Septal formulae are used to describe as economically as possible the number, arrangement, and relative numbers of major septa in the four quadrants defined by the cardinal, counter, and alar septa. This notation was described by Moore and Jeffords (1945).

The fossil corals described here will form the nucleus of a permanent research collection for future studies in the Alaska Range. All coral specimens therefore have been assigned a University of Alaska catalogue number (UA). Other prefixes denote coral type specimens borrowed for comparative study. Photographic techniques used to illustrate the corals were somewhat varied due to the wide differences in rock matrix and preservation. Inking and bleaching of duplicate prints was necessary for illustrations of thin sections in which dark matrix and recrystallization obscured critical morphological features.

PART III

Systematic Descriptions

Phylum COELENTERATA

Class ANTHOZOA Ehrenberg, 1834

Subclass ZOANTHARIA DeBainville, 1830

Order RUGOSA Milne-Edwards and Haime, 1850

Family HAPSIPHYLLIDAE Grabau, 1928

Genus *Bradyphyllum* Grabau, 1928

Type species. *Bradyphyllum bellicostatum* Grabau, 1928, pp. 35–6, Pl. 2, figs. 11a–e, 12a–c, 13, 14–18c: Middle Carboniferous, Moukou, Fu-I-Hsien, Kansu, China.

Diagnosis. Amplexoid Hapsiphyllidae with locally rhopaloid septa whose arrangement is metriophylloid (“fasciculate”) in early stages of growth. Alar septa on convex and concave sides of corallites. Neither dissepiments nor a columella is present (modified slightly from Easton, 1962, p. 29).

Discussion. *Bradyphyllum* has been reported on two occasions from North America, by Easton (1962) and by Hoare (1964). For this reason, and because there is some confusion pertaining to the relationship between *Bradyphyllum*, *Pseudobradyphyllum*, and *Stereocorypha*, a short summary of the taxonomic history of these genera is given here.

The genus *Bradyphyllum* was proposed by Grabau (1928) for a group of simple “streptelasmoid” corals from rocks of Middle Carboniferous age in China. The designated genotype species is *B. bellicostatum*. Grabau’s description is as follows (1928, pp. 35–6):

“Simple, streptelasmoid corals, forming straight or slightly curved cones, and, in the typical form, very gradually expanding. The radial arrangement of the septa is early acquired, the septa mostly reaching the center, where they are united by stereoplasm as in Devonian *Stereolasma*, of which they may possibly be derivatives. There is, however, no distinctive columella formed, but the solid center is due chiefly to the strong thickening of the septa themselves and to their lateral junction. Counter quadrants always accelerated even in the young, but alar pseudo-fossulae are not well-marked. The principal septa are, however, indicated by the costal grooves. In the adult, the cardinal as well as the counter septum become yoked, by strong dissepimental bars, to the adjoining secondaries, and both tend to become more or less aborted, with a production of a cardinal as well as a counter fossula. It is this characteristic of the two primary septa, as well as the thickening of the secondaries, which forms the distinctive character of this genus.”

Tabulae are not mentioned in this description; however, in his comparison of *Bradyphyllum* to *Zaphrentis omaliusi* Edwards and Haime and *Hadrophyl- lum edwardsianum* de Koninck, Grabau noted the absence of tabulae in all three forms.

Although Grabau stated (1928, p. 41) that widely spaced dissepiments are present in the type species of *Bradyphyllum*, Dobrolyubova (1940, p. 13) and Easton (1962, p. 29) have both observed that the regular concentric arrangement of "dissepiments" in Grabau's figured transverse sections of *B. bellicostatum* represent tabulae that are not intersected in his longitudinal sections due to improper orientation. This interpretation is almost certainly correct, and is borne out by Hill's description and illustrations of this species (1956, fig. 174, 12b). Dobrolyubova, however, concluded (1940, p. 13) that the genus *Pseudobradiphyllum* would assume the status of a junior synonym to *Bradyphyllum* if restudy of Grabau's type material established the presence of tabulae in the type species. This ignores the basically polycoelid septal arrangement of *Pseudobradiphyllum*, which is referred by Hill (1956, p. 262) to the Family Polycoeliidae for this reason. *Bradyphyllum*, with its fundamentally metriophylloid septal arrangement is assigned by Hill (1956, p. 258) to the Metriophyllidae. However, in a subsequent restudy of this genus, Easton (1962, pp. 29-31) concluded that *Bradyphyllum* not only lacks dissepiments, as noted above, but also lacks the steriocolumella implied by Grabau's original description. Easton's emendation, which is followed here, requires the assignment of *Bradyphyllum* to the Family Hapsiphyllidae.

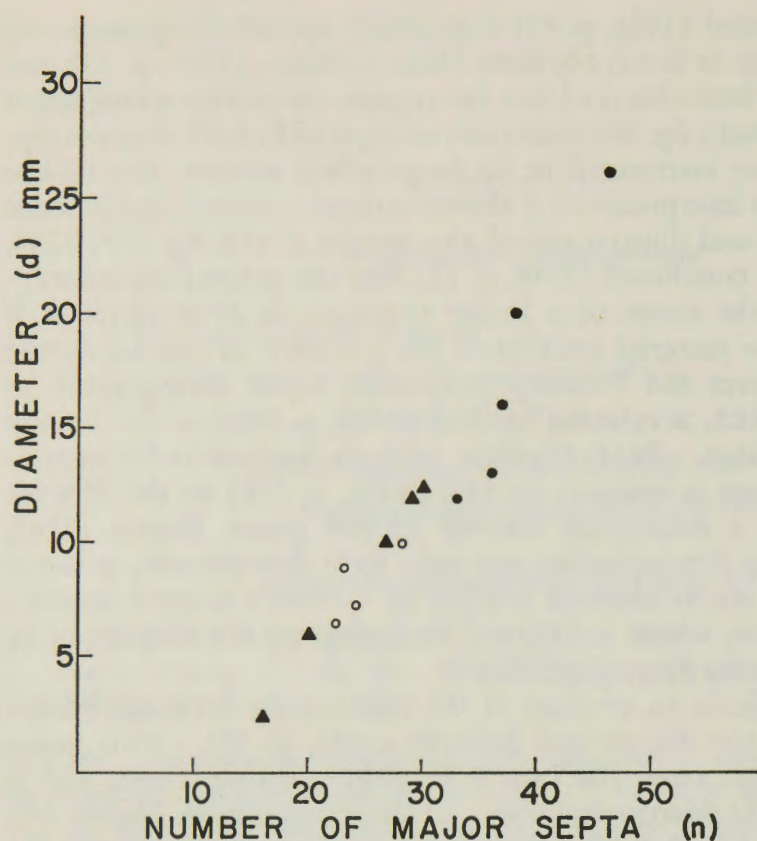
Somewhat more difficult to evaluate is the relationship between *Bradyphyllum* and *Stereocorypha* Moore and Jeffords (1945, p. 86). This genus was based on *S. annectans*, from the Lower Pennsylvanian of Texas, and is also referred by Hill to the Metriophyllidae. In their description, Moore and Jeffords stated (1945, p. 86) that "*Bradyphyllum* differs from *Stereocorypha* in the shortening of both the cardinal and counter septa at mature growth stages so as to develop cardinal and counter fossulae." However, my study of the type material for *S. annectans* in connection with a study of Morrowan corals in southern Oklahoma (Rowett and Sutherland, 1964) indicated that the development of fossulae does not provide a consistent basis of distinguishing this genus from *Bradyphyllum*. If Easton's emendation of this genus is followed, however, the presence of an axial structure in *Stereocorypha* sets this genus apart from *Bradyphyllum*. Likewise, species of *Lophamplexus*, although similar to *Bradyphyllum* in the ephebic stage, can be distinguished by the presence of a palicolumella (axial rod) in their early growth stages.

Recently Hoare described several corallites from rocks of Lower Permian age in northern Nevada as *Bradyphyllum gracilium* (1964, p. 495, Pl. 75, figs. 1-6). The neanic stages of this species strongly resemble *Stereocorypha annectans*, in particular with respect to septal arrangement. However, *B. gracilium* develops several ranks of dissepiments in the ephebic stages which would seem to preclude its assignment to *Stereocorypha* and, as discussed, to *Bradyphyllum*.

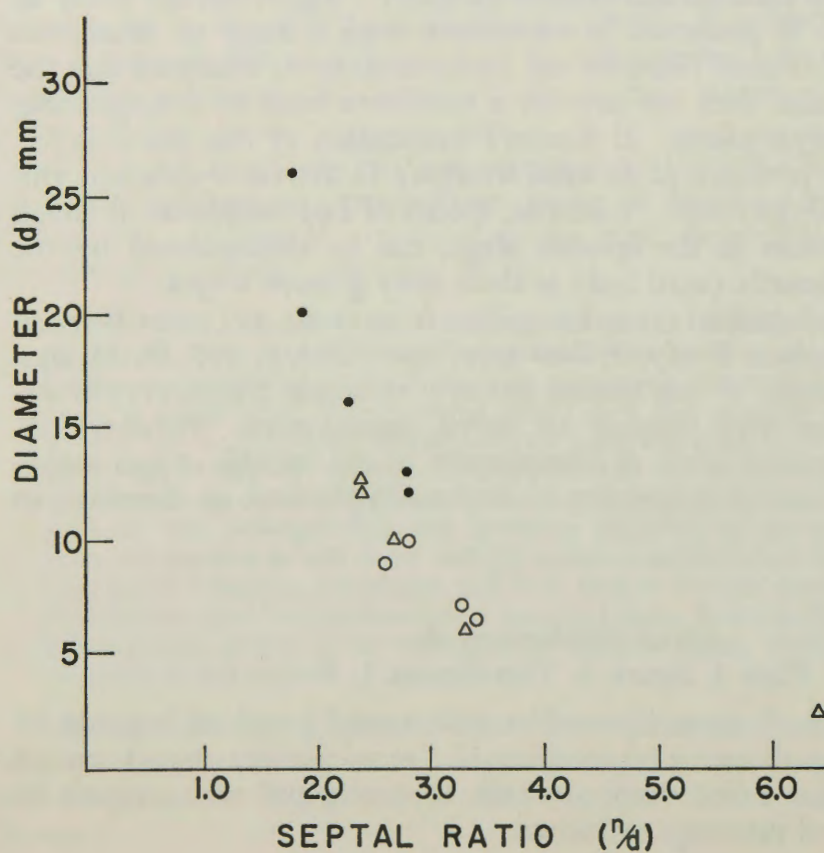
?*Bradyphyllum* sp. A

Plate 1, figure 1; Text-figures 5, 6

External. Solitary, small, ceratoid corallite with a total length of between 45 and 50 mm; maximum diameter of corallite, 12.5 mm; epitheca thin, 1 mm or less in ephebic stages; calice deep; position of protosepta with respect to curvature and external markings unknown.



Text-fig. 5. Relationship of number of major septa (n) to increasing corallite diameter (d) in *Cryptophyllum striatum* n. sp. (○), *Bradyphyllum* sp. A (△), and *Pseudobradiphyllum* sp. A (●).



Text-fig. 6. Relationship of septal ratios (n/d) to increasing corallite diameter (d) in *Cryptophyllum striatum* n. sp. (○), *Bradyphyllum* sp. A (△), and *Pseudobradiphyllum* sp. A (●).

Transverse sections. Major septa metriophylloid in arrangement, grouped into four distinct quadrants in all but late ephebic stages, where septa are withdrawn and subequal in length. In the neanic and early ephebic stages the alar, counter, cardinal, and counter-lateral septa join at the axis of the corallite and metasepta impinge primarily upon the cardinal-lateral and alar septa. All protosepta are straight, thin (0.1 to 0.25 mm), and non-rhopaloid. Narrow alar, cardinal, and counter fossulae are present in the ephebic stages of growth.

Major septa range from a recorded minimum of sixteen at a diameter of 2.5 mm (septal ratio, 6.4) to twenty-nine at a diameter of 12.0 mm (septal ratio, 2.4). Strong acceleration of septal insertion in the counter quadrants is shown by the septal arrangement in the ephebic stage (diameter, 10 mm), which is indicated by the formula $K\ 8\ A\ 4\ C\ 4\ A\ 7\ K$. Minor septa are present only in the ephebic stages, where they are contratingent and as much as 1 mm long. Septal microstructure may be lamellar, but septa are slightly recrystallized.

An axial structure is simulated by the union of major septa at the axis of the corallite in some neanic and early ephebic growth stages. There is little or no thickening of the axial region by stereoplasm, however, and it is doubtful that a continuous steriocolumella is present.

Longitudinal sections could not be prepared from the single corallite available for study; however, as many as five or six tabulae are intersected by transverse sections through the ephebic stages. Tabulae appear to be complete and are inclined steeply upward axially in the peripheral area. Dissepiments are absent.

Discussion. Re-collection of this locality thus far has failed to produce additional specimens upon which a new species of *Bradyphyllum* might be based. Moreover, the assignment of the single available corallite to this genus is provisional because of the lack of longitudinal sections to confirm the absence of a steriocolumn. Within the limits of Easton's diagnosis of *Bradyphyllum*, the only species clearly referable to this genus is *B. clavigerum* (Easton, 1962, p. 31) from the Carboniferous of Montana. The corallite from the Alaska Range described here differs from *B. clavigerum* in several respects, including the presence of a more pronounced metriophylloid septal arrangement, more numerous septa, and amplexoid withdrawal of septa at a later stage of growth than in Easton's species. In addition, minor septa are developed in this Permian form and major septa are non-rhopaloid.

Material and occurrence. One corallite (UA 1001) from locality MC-1, Southern Rainbow Mountain area: Lower Permian (Wolfcampian), McCallum Creek sequence.

Family POLYCOELIIDAE Roemer, 1883

Subfamily PLEROPHYLLINAE Koker, 1924

Genus *Pseudobradiphyllum* Dobrolyubova, 1940

Type species. *Pseudobradiphyllum nikitini* (Stuckenberry) Dobrolyubova, 1940, p. 13, Pl. I, figs. 7-9; Pl. II, figs. 1-28; Pl. III, figs. 1-3; Pl. XXI, figs. 1-17: Upper Carboniferous, Moscow Basin, Russia.

Diagnosis. "Septa metriophylloid in arrangement in early stages but withdrawn slightly from axis in adult stages, cardinal and counter being shortest; longest septa are counter-laterals, alars, and metasepta nearest cardinal." (Hill, 1956, p. 262).

Discussion. According to Hill's recent classification (1956, pp. 259-62) the Family Polycoeliidae includes approximately twenty recognized genera. Many of these, in particular those included in the Subfamilies Tachylasmatinae and Endotheciinae, are reasonably distinct forms, and a few, such as *Tachylasma* Grabau (1922), *Cryptophyllum* Carruthers (1919), and *Pseudocryptophyllum* Easton (1944), have been adequately described. In contrast, many genera now assigned to the Subfamilies Polycoeliinae and Plerophyllinae are poorly understood at best. Comparative studies of these forms will, however, require re-study of original type materials much of which is obtainable only with great difficulty. It nevertheless is probable that such studies, if undertaken, would result in revision of these groups.

The parallelism of adult morphological characters has been well documented. A good discussion of this problem is given by Jeffords (1942, p. 190), and the recognition of the importance of the early stages of growth (brepheic and neanic) in taxonomic and phylogenetic studies has led to rapid advances in some groups—notably the lophophyllid corals of the Mid-Continent region. A major part of the problem in working with polycoelid corals is in establishing the distinguishing characters of the early growth stages; this applies to both the generic and super-generic levels. For example, genera comprising the Subfamily Polycoeliinae are stated by Hill to have "Four protosepta (cardinal, counter and 2 alar) longer and commonly thicker than other septa, especially near axial edges." The members of the Subfamily Plerophyllinae are stated to be characterized by "Five protosepta (cardinal, 2 alar and 2 counter-lateral) longer and thicker than other septa . . ." However, illustrations by Hill (1956, fig. 176) show no basic difference in the early growth stages of these two groups, and a detailed study of the involved genera is needed to clarify the relationship of these two subfamilies. As descriptions of genera commonly are inadequate with respect to the character of the early stages, generic assignments are problematical. These difficulties are reviewed here only in so far as they are pertinent to this study.

The genus *Pseudobradiphyllum*, although assigned by Hill (1956, p. 262) to the Family Polycoeliidae, was proposed by Dobrolyubova (1940, p. 12) to include corals primarily characterized by a metriophylloid arrangement of septa in the early growth stages. In her description of the genotype species, *P. nikitini*, Dobrolyubova stated that the genus differs from *Bradyphyllum* Grabau (1928, p. 35), which has as its type species *B. bellicostatum*, in (1) possessing well defined tabulae and (2) in lacking dissepiments. However, Dobrolyubova (1940, p. 13) pointed out the possibility that imprecise orientation of thin sections may have resulted in the mistaken interpretation of obliquely intersected tabulae as "dissepiments." The possible consequences of restudy of Grabau's type material are discussed under the genus *Bradyphyllum*.

Generic assignment of polycoelid corals from the Alaska Range is further complicated by the close similarity of *Pseudobradiphyllum* to *Plerophyllum* Hinde (1890, p. 195), which has as its type species *P. australe* (subsequent designation by Grabau, 1928). Although Dobrolyubova stated (1940, p. 17)

that the adult (ephebic) stages of *Pseudobradiphyllum* are indistinguishable from *Plerophyllum*, this is not borne out by comparison of her illustrations of this genus with those of the type species of *Plerophyllum* by Hinde (1890, Pl. VIIIA, figs. 1a-f). Earlier stages are, however, closely similar. Although not cited above, Schindewolf's (1942) important study of Permian plerophyllid corals and Fomichev's (1953) monograph on Donetz Basin Carboniferous and Permian corals should be reviewed in any general survey of the Metriophyllidae and Polycoeliidae.

Polycoelid corals are represented in the collections from the Alaska Range by only a few poorly preserved corals that are encased in limestone. One corallite shows some characters described as present in *Plerophyllum* and others that characterize *Pseudobradiphyllum*; still other features of this coral are not altogether typical of either genus. It is considered important to record these uncommon and interesting corals from the region, but the material available for study is insufficient for any attempt to clarify the actual relationships between polycoelid corals.

?*Pseudobradiphyllum* sp. A

Plate 1, figure 2; Text-figures 5, 6

External. Corallite solitary, medium in size, ceratoid; maximum diameter recorded, 26 mm; epitheca thick (up to 2 mm), marked externally by pronounced septal grooves and interseptal ridges; direction of curvature with respect to protosepta not known; brephic stage not preserved.

Transverse sections. Major septa polycoelid in arrangement, thick (up to 1 mm adjacent to epitheca), non-rhopaloid, with marked pinnate arrangement in counter quadrants in neanic stages, becoming more nearly radial in disposition in ephebic stages; the major septa are joined axially in early growth stages but withdraw from the axial region in later stages; the cardinal septum is thick (1 mm), equalling or exceeding the lengths of adjacent metasepta in early stages; in the late ephebic stage the cardinal septum is only slightly shortened; the counter septum is also long, but thin (0.2 mm) in early stages and much shortened in the ephebic stage, where it may be as much as 1 mm thick. Alar septa are intermediate in length and distinguishable by their position between the radially arranged septa of the cardinal quadrants and the pinnate arrangement of septa in the counter quadrants. Counter-lateral septa are as much as 2 mm thick and 6 mm long; in the ephebic stages (diameters of 16 mm or more) counter-lateral septa are approximately 1.5 mm thick and as much as 10 mm long.

Major septa range from a recorded minimum of thirty-three at a diameter of 12 mm (septal ratio, 2.8) to a maximum of approximately forty-six at a diameter of 26 mm (septal ratio, 1.8). The insertion of septa in the counter quadrants is only slightly accelerated, as indicated by the following septal formulae: K, KL, 7 A 6 C 7 A 7 KL, K (diameter, 12 mm); K, KL, 8 A 7 C 7 A 8 KL, K (diameter, 16 mm). Minor septa are not present in any growth stage observed. Septal microstructure apparently is diffusotrabecular.

There is no axial structure, although the ends of some of the major septa join axially in the neanic stages; secondary deposits of stereoplasm in the axial region are absent. Tabulae, apparently complete, appear in transverse sections

of the ephebic stages as thin, steeply inclined skeletal elements between the thick major septa. It was not possible to prepare longitudinal sections of this corallite to confirm the attitude and spacing of tabulae. Dissepiments are absent.

Discussion. Although tentatively referred to *Pseudobradiphyllum*, there is considerable doubt as to the correct assignment of this corallite. The specimen corresponds in several respects to the type species of this genus, *P. nikitini*, which originally was described as "*Zaphrentis*" *nikitini* by Stuckenberg (1888, p. 8, Pl. III, figs. 34-88). Similarities include (1) overall form and size, (2) thick epitheca, (3) pinnate arrangement of septa in the counter quadrants, (4) elongate counter-lateral septa, (5) slight acceleration of septal insertion in counter quadrants, (6) withdrawn counter and cardinal septa in late ephebic stages, and (7) number and attitude of tabulae. In general, however, *Pseudobradiphyllum nikitini* has thinner septa and less prominent counter-lateral septa and pinnate arrangement of septa in the counter quadrants; moreover, minor septa are present in the ephebic stages in that species. In these respects, the corallite described here is more similar to *Plerophyllum* Hinde (1890) (see also discussion of *Cryptophyllum*).

Material and occurrence. One corallite (UA 1002) from locality MC-1, Southern Rainbow Mountain area: Lower Permian (Wolfcampian), McCallum Creek sequence. In addition to the corallite described here as ?*Bradyphyllum* sp. A, several other specimens were collected at this locality which, although clearly belonging to the Polycoeliidae, are too fragmentary for generic identification. The only other polycoelid coral recognized during this study, described below as *Cryptophyllum striatum* n. sp., was collected from rocks believed to be of Lower Pennsylvanian (post-Morrowan, pre-Missourian) age at locality RM-8 in the Northern Rainbow Mountain area.

Subfamily TACHYLASMATINAE Grabau, 1928

Genus *Cryptophyllum* Carruthers, 1919

Type species. *Cryptophyllum hibernicum* Carruthers, 1919, p. 440, Pl. XI, figs. 1-6; Text-figs. 1-6: Lower Carboniferous, Ireland, Wales, and England.

Diagnosis. Small, scolecoid polycoelid corals in which the cardinal, alar, and counter-lateral septa are very prominent and much longer than other septa in the ephebic stages; the counter septum is short and does not appear until after a pentaseptate stage is reached in which the cardinal, alar, and counter-lateral septa meet at the axis of the corallite.

Discussion. Fossil corals from the study area that are referred to the Family Polycoeliidae comprise only a small part of the total coral fauna and do not merit lengthy discussion. Their presence in this region is, however, of importance in evaluating the origin and affinities of the fossil corals of the Alaska Range.

In addition to the poor preservation of the material at hand, discussion of this group is hindered by many inconsistencies in the literature pertaining to the Polycoeliidae. A general discussion of the morphology, classification, and stratigraphic distribution of both the Polycoeliidae and Petraliidae in Asia was presented by Soshkina, Dobrolyubova, and Porfiriev (1941, p. 218), but

their classification subsequently was greatly modified by Hill (1956). Taxonomic problems relating to *Bradyphyllum* Grabau, *Pseudobradiphyllum* Dobrolyubova, and *Stereocorypha* Moore and Jeffords have already been discussed; although some repetition is unavoidable, the present discussion is limited as far as possible to problems relating to the polycoid genera *Ufimia* Stuckenberg, *Plerophyllum* Hinde, and *Cryptophyllum* Carruthers.

Ufimia was described by Stuckenberg (1895) from the "Carboniferous" (Permian) Ober Kohlenkalk in the western Ural Mountains of the U.S.S.R. The genotype species is *U. carbonaria* Stuckenberg (1895, p. 27, Pl. II, figs. 2, 3; Pl. III, fig. 3). Although *Ufimia* is undoubtedly a polycoid coral, the genus is referred by Hill to the Subfamily Plerophyllinae. Hill states (1956, p. 262) that this genus is "Like *Plerophyllum* but with cardinal septum short in adult stages, leaving only four outstanding protosepta (2 alars, 2 counter-laterals)." This is not, however, consistent with the original description of the type species by Stuckenberg. In particular, a late ephebic stage illustrated by Stuckenberg (1895, Pl. II, fig. 2b) shows little or no differentiation of septa, and an illustration of a section through an early neanic stage (Pl. II, fig. 2d) shows an open axial area. Because septa are stated to meet at the axis in the early growth stages in representatives of the Plerophyllinae (Hill, 1956, p. 262), the assignment of *Ufimia* to this subfamily is questionable.

Plerophyllum was described by Hinde (1890, p. 195) from rocks in the Victoria district of Australia now believed to be of Permian age. Hill (1956, p. 262) referred *Plerophyllum* to the Subfamily Plerophyllinae and gave the following brief generic diagnosis: "Of the 5 dominant protosepta the 2 counter-lateral are outstanding." However, study of Hinde's original description and illustrations of *P. australe*, the type species, indicates that the protosepta were in most instances misidentified. For example, Hinde stated (1890, p. 196) that "The cardinal septum is small, with a prominent septum on either side." Study of his illustrations of this species (1890, Pl. VIIIA, figs. 1a-f), however, shows the cardinal septum to be located at the bottom of the section shown by fig. 1d, at the lower left in fig. 1e, and at the lower right in fig. 1f. It is the counter septum, opposite in position in each of these sections, which is flanked by two prominent septa, i.e., counter-laterals. Therefore, Hill's diagnosis of *Plerophyllum*, although not incorrect, is incomplete; if the interpretation of Hinde's illustrations of *Plerophyllum australe* given here is borne out by restudy of the type material, it would probably be necessary to regard this genus as a member of the Subfamily Tachylasmatinae.

Cryptophyllum was described by Carruthers (1919) from the Carboniferous of the British Isles. His original description of the genus (1919, p. 439) is sufficiently brief to reproduce in full here:

"Corallum simple. Five septa, all primary, but variable in sequence, appear before the others, and remain predominant until the growth of the corallum is completed: their disposition is not quite symmetrical, two (the counter-lateral primaries) being closer than the others. The remaining primary (the counter septum) appears subsequently, or may be entirely absent. The development scheme of both metasepta and minor septa (if any) agrees with that of other Rugose corals. There are tabulae, but no dissepiments."

Carruthers discussed several similar genera, including *Pentaphyllum* de Koninck, 1872, which is now generally regarded as a synonym of *Cryptophyllum*, and *Plerophyllum* Hinde (1890). Although Carruthers noted (1919,

p. 440) the apparent reversal in septal orientation between *Plerophyllum* and *Cryptophyllum*, he apparently did not consider the possibility, as discussed above, that the elongate septa on either side of the "cardinal" septum in Hinde's illustrations were counter-lateral septa.

In Grabau's extensive studies of Palaeozoic corals of China (1922, 1928), however, Hinde's illustrations of *Plerophyllum australe* are reproduced in Plate I (figs. 5, 6) and are labelled and oriented as is suggested here. Grabau also discussed (1928, p. 46) the probable incorrectness of Hinde's original determination of the protosepta in this species.

Cryptophyllum striatum n. sp.
Plate 1, figure 3; Text-figures 5, 6

External. Corallite solitary, small, ceratoid, with a total length of about 50 mm; maximum diameter recorded, 10 mm; epitheca thick, up to 1 mm in ephebic stages, marked externally by prominent septal grooves and interseptal ridges; calice deep; position of protosepta with respect to curvature unknown.

Transverse sections. Major septa polycoelid in arrangement; in the early neanic stage (diameter, 6.5 mm) the counter-lateral septa, alar septa, and cardinal septum are joined axially. In this stage and in all subsequent stages throughout which these septa are joined, the dark median lamellae of the counter-lateral septa can be observed to join each other at the axis of the corallite (Pl. 1, figs. 3g, h). Although joined axially, the median lamellae of the alar septa and cardinal septum are not joined in this manner. The counter septum is long (2 mm in the early neanic stage) but does not extend to the axis of the corallite. The arrangement of septa in the early neanic stage is indicated by the formula K, KL, 5 A 3 C 4 A 4 KL, K (total of twenty-two major septa). Septal ratios range from 3.4 in the neanic stage to 2.8 in the ephebic stage.

Septal microstructure is distinctly lamellar, and the dark median lamellae of major septa end abruptly at the inner margin of the epitheca. The skeletal microstructure of the epitheca is concentrically lamellar, which produces an abrupt interface between the epitheca and major septa. Minor septa were not observed at any stage of growth.

The disposition of septa in the neanic stages persists throughout the middle ephebic stage, the only variation being the insertion of a few additional meta-septa. At no stage of growth does the counter septum reach the axis of the corallite. In the late ephebic stage (diameter, 10 mm) septa withdraw from the axis: however, the counter-lateral and alar septa are very prominent and between 4 and 5 mm long even in this stage of growth. The cardinal septum is somewhat shorter than in earlier stages of growth, but is still 1 mm or more longer than adjacent metasepta in the cardinal quadrants. Septal arrangement in the ephebic stage is indicated by the formula K, KL, 6 A 5 C 4 A 7 KL, K (total, twenty-eight septa).

Owing to the close spacing of transverse sections, usable longitudinal sections could not be prepared. However, tabulae clearly are present and appear in several transverse sections. These are complete and inclined upward toward the axial area.

Discussion. The morphology of this corallite incorporates all of the significant generic characters of the genus *Cryptophyllum* as described by Carruthers in 1919. Although the brephic stages are not preserved, some aspects of the neanic and ephebic stages are similar to the type species, *C. hibernicum*. The present corallite, however, has an additional series of metasepta in the late ephebic stage, making a total of twenty-eight septa; this is four more than are present in the latest ephebic stages illustrated by Carruthers of *C. hibernicum*. Also, the counter septum, although short, is present throughout all stages of growth observed in the corallite from the Alaska Range; this septum commonly is absent in the type species. The present form, moreover, is ceratoid and possesses a thick epitheca that bears pronounced septal grooves and interseptal ridges, in sharp contrast to the scolecoïd form and thin, smooth concentrically ribbed epitheca of *C. hibernicum* (Carruthers, 1919, Pl. XI, fig. 5).

Collectively, these seem to constitute significant differences between the present form and *C. hibernicum*, which is also a somewhat older (Dinantian) species. Although only a single corallite is available, it is exceptionally well preserved and is here designated as the holotype of a new species, *Cryptophyllum striatum*. Corals are uncommon in the post-Morrowan Pennsylvanian strata from which this specimen was collected, but it seems probable that topotype specimens can be obtained by further collecting.

Material and occurrence. One corallite (UA 1003) from locality RM-8, Northern Rainbow Mountain area: Lower Pennsylvanian (post-Morrowan, pre-Missourian), Rainbow Mountain sequence.

Family DURHAMINIDAE Minato and Kato, 1965

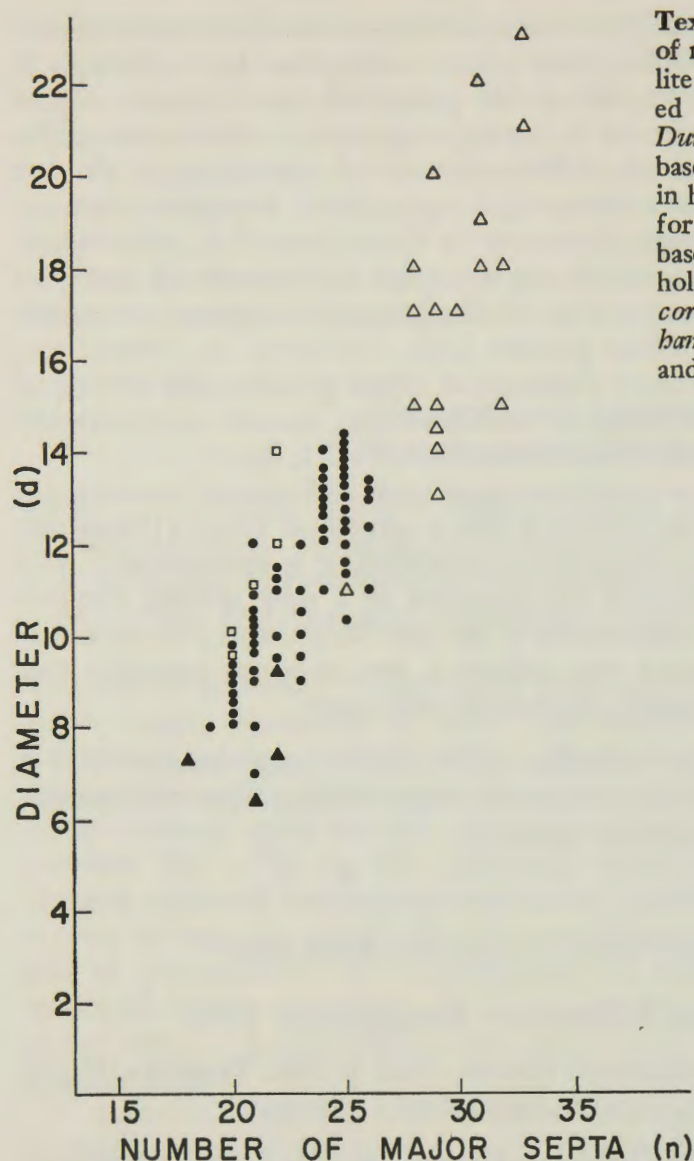
Genus *Durhamina* Wilson and Langenheim, 1962

Type species. *Lonsdaleia cordillerensis* Easton, 1960, p. 580, Text-figs. 17, 18: Lower Permian (Wolfcampian, Lower Leonardian?), Nevada.

Diagnosis. Fasciculate, with two orders of septa, variable aulophylloid axial structure, poorly developed axial and periaxial tabellae, herringbone, pseudo-herringbone, and (rarely) lonsdaleoid dissepiments.

Discussion. Wilson and Langenheim (1962) based the genus *Durhamina* on corals described by Easton (1960, p. 580) as *Lonsdaleia cordillerensis*. The essential difference between *Durhamina* and similar forms, such as *Nemistium* Smith (1928, p. 114) and *Tschussovskenia* Dobrolyubova (1936b, p. 48) can be summarized as follows: (1) *Nemistium* contains a complex axial structure composed of two distinct and continuous zones of axial and periaxial tabellae; both *Durhamina* and *Tschussovskenia* lack this pronounced and regular zonation as a consequence of their impersistent axial columns; (2) *Tschussovskenia*, in addition to having an axial structure less well developed than *Durhamina*, is characterized by an impersistent dissepimentarium and numerous complete tabulae.

Corwenia Smith and Ryder (1926, p. 149), *Yatsengia* Huang (1932, p. 56), *Pseudoyatsengia* Yabe (1951, p. 200), and *Huangia* Yabe (1950, p. 76) are also similar to *Durhamina*. With the exception of *Pseudoyatsengia*, however, these



Text-fig. 7. Relationship of number of major septa (n) to increasing corallite diameter (d) in new and described species of *Durhamina*. Data for *Durhamina alaskaensis* n. sp. (●) based on twelve of sixteen corallites in holotype corallum (UA 1004); data for *Durhamina sutherlandi* n. sp. (△) based on seven of eight corallites in holotype (UA 1006). "*Lonsdaleia*" *cordillerensis* Easton, 1960 (▲); *Durhamina cordillerensis* (Easton) Wilson and Langenheim, 1962 (□).

genera are all characterized by complex axial structures which is in contrast to that of *Durhamina*. *Pseudoyatsengia* differs from *Durhamina* in that complete tabulae and lonsdaleoid dissepiments are common in the former and rare or absent in the latter.

It must be mentioned that owing to the general similarity and inadequate original descriptions of several of the genera discussed above, notably *Tschusovskenia*, many species assignments in recent years have subsequently required restudy and revisions. These problems have been resolved in part by a recent study by Minato and Kato in which a new family (Durhaminidae) is proposed (1965b, p. 18) to include *Durhamina* Wilson and Langenheim (1962), *Amandophyllum* Heritsch (1941), *Heritschioides* Yabe (1950), *Protolonsdaleiastraea* Gorsky (1932), and *Kleopatrina* McCutcheon and Wilson (1961, 1963). The Durhaminidae is also proposed to include two genera newly described by Minato and Kato, *Tanbaella* (1965 b, p. 55) and *Yabeiphyllum* (p. 45). The proposed classification of the Durhaminidae in this study makes a clear distinction between lithostrotionid, durhaminid, and waagenophyllid corals that

appears to be consistent with the known phylogenetic relations and stratigraphic distribution of these groups. Although the classification of Rugosa in Hill (1956) is followed wherever possible in this study, the proposed separation of the Family Durhaminidae by Minato and Kato undoubtedly is a desirable and necessary one: it therefore is followed here.

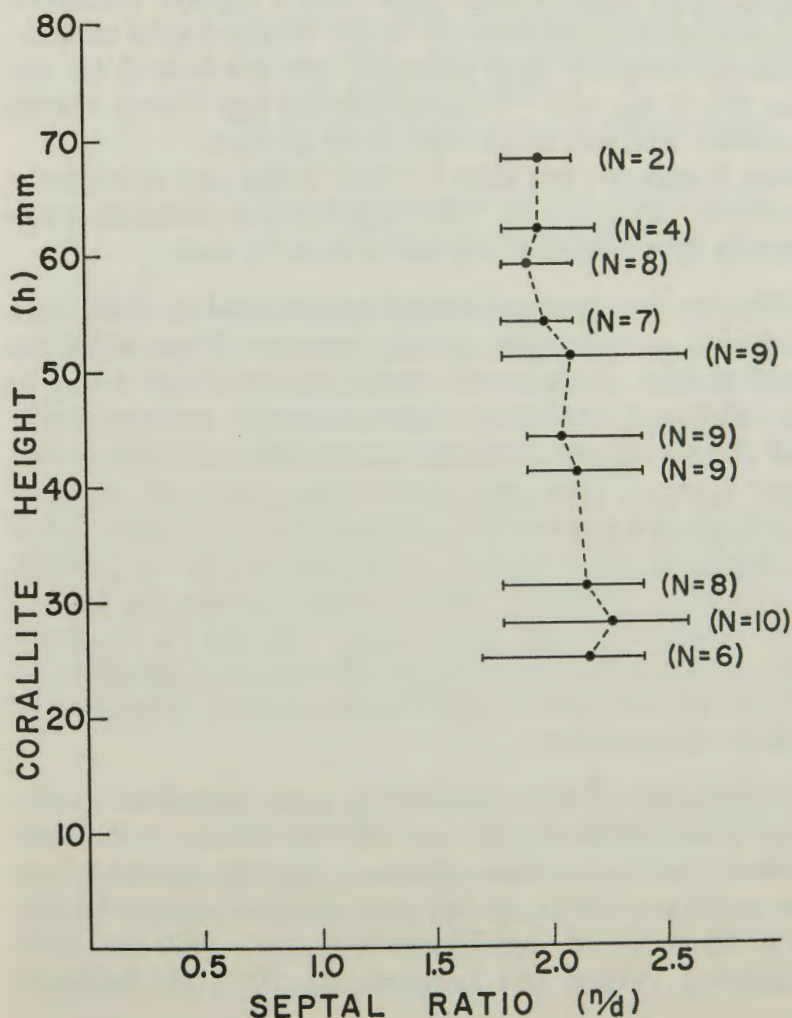
The foregoing analysis of the genus *Durhamina* is based on Easton's original description and illustrations of the type species, *Lonsdaleia cordillerensis*, and study of hypotype specimens (UC 34638 through UC 34643) of *Durhamina cordillerensis* Wilson and Langenheim (1962).

Durhamina alaskaensis n. sp.

Plate 2, figure 1, Text-figures 7, 8, 9

External. Corallites fasciculate, cylindrical in mature parts, subparallel or scolecoïd, commonly more than 50 mm long; the maximum diameter recorded for this species is 14.2 mm; increase lateral; epitheca thin, marked externally by fine growth lines.

Transverse sections. Major septa radially disposed, commonly sinuous, zigzag or coiled axially, thin (0.1 mm) and crooked across dissepimentarium, dilated slightly (0.2 to 0.3 mm) at inner margin of dissepimentarium to form a weak inner wall; in mature stages of growth major septa are subequal in length



Text-fig. 8. Comparison of mean and extreme values in septal ratios (n/d) with increasing corallite height (h) in *Durhamina alaskaensis* n. sp. Data based on the number of corallites indicated for each height increment.

(3 to 4 mm) and equal to approximately three-quarters the radius of corallites. The cardinal and counter septa commonly are identifiable only in growth stages in which the axial structure is fully developed; at these points the counter septum may be continuous with an irregular median lamella in the axial structure and the cardinal septum slightly shortened to produce a weak open fossula. Alar pseudofossulae are not developed and alar septa ordinarily are not recognizable.

Major septa range from a recorded minimum of nineteen at a diameter of 8 mm (septal ratio, 2.4) to a maximum of twenty-six at a diameter of 13.4 mm (septal ratio, 1.9). Minor septa appear in the early stages of growth and are well developed throughout the neanic and ephebic stages, extending across the dissepimentarium and commonly penetrating the tabularium for a distance of up to 1.5 mm. In a few corallites minor septa have a total length of 2 mm. Septal microstructure is obliterated by recrystallization, but a distinct light median line is visible in most major septa.

The axial structure in this species is basically aulophylloid but highly variable in its development. In the early growth stages (brepheic and neanic) a single sinuous or irregular septal lamella, commonly arising from the counter septum, may be present in the axial area, or this area may be devoid of septa. This condition may persist throughout the ephebic stages or may develop even after a comparatively complex axial structure has been formed; in a few corallites as many as eight septal lamellae may arise from a slightly thickened medial plate; these, combined with several tiers of steeply inclined axial tabellae, produce an open, commonly irregular axial structure not penetrated by the axial ends of major septa (Pl. 2, fig. 1d). Periaxial tabellae are widely spaced and transverse sections seldom intersect more than three or four.

The dissepimentarium is narrow, less than 2.5 mm wide, and dominantly composed of anguloconcentric dissepiments. Herringbone and pseudoherringbone dissepiments are locally developed but are uncommon or rare.

Longitudinal sections. Only a few poorly oriented longitudinal sections were obtained due to the scolecoid growth habit of this species. These show up to three ranks of subequal globose dissepiments which average about 1 mm in their longest dimension. Periaxial tabellae are inclined gently to moderately upward toward the axis (20 to 45 degrees) and are spaced vertically at between two and four per 5 mm. Two, and rarely three, tiers of periaxial tabellae are present. Axial tabellae are steeply inclined (60 to 90 degrees) and highly variable in their degree of development. Clinotabulae are not present.

New corallites are produced by lateral increase; these points are marked in the parent corallite by slight dilation of major septa adjacent to the point of increase and by the local development of irregular, inosculating dissepiments that may interrupt both major and minor septa; these cannot, however, be regarded as true lonsdaleoid dissepiments.

Discussion. This species is similar in some respects to most described species of *Durhamina*, including corallites described here as *Durhamina sutherlandi* n. sp. The key to species of *Durhamina* shown below is slightly modified from that presented by Minato and Kato (1965b, p. 34) and provides a general guide to the following species: "*Lonsdaleia*" *cordillerensis* Easton, 1960 (= *Durhamina cordillerensis* (Easton) Wilson and Langenheim, 1962; *D. hasimotoi*

(Nagao and Minato) Minato and Kato, 1965b; *D. hessensis* (Ross and Ross) Minato and Kato, 1965b; *D. uddeni* (Ross and Ross) Minato and Kato, 1965b; *D. kitakamiensis* Minato and Kato, 1965b; *D. amphferri* (Heritsch) Minato and Kato, 1965b; *D. alaskaensis* n. sp.; and *D. sutherlandi* n. sp.

- I. Axial tabellae not highly cystose at maturity
 - A. Comparatively small corallites with few septa
 - 1. Relatively complex axial structure
 - (1) Short minor septa, weak inner wall
 "L." *cordillerensis* (= *Durhamina cordillerensis*)
 - (2) Minor septa and stereozone variable in development
 *D. cordillerensis*
 - 2. Relatively simple axial structure
 - (1) Long minor septa, well developed inner wall *D. alaskaensis* n. sp.
 - B. Comparatively large corallites with numerous septa
 - 1. Relatively complex axial structure, lonsdaleoid dissepiments absent *D. sutherlandi* n. sp.
 - 2. Relatively simple axial structure, lonsdaleoid dissepiments present *D. hasimotoi*
- II. Axial tabellae highly cystose at maturity
 - 1. Short minor septa at maturity
 - (1) Numerous septa, well developed inner wall *D. hessensis*
 - (2) Fewer septa, poorly developed inner wall *D. uddeni*
 - 2. Long minor septa at maturity
 - (1) Elongate dissepiments and clinotabellae well developed *D. kitakamiensis*
 - (2) Elongate dissepiments and clinotabellae poorly developed or absent *D. amphferri*

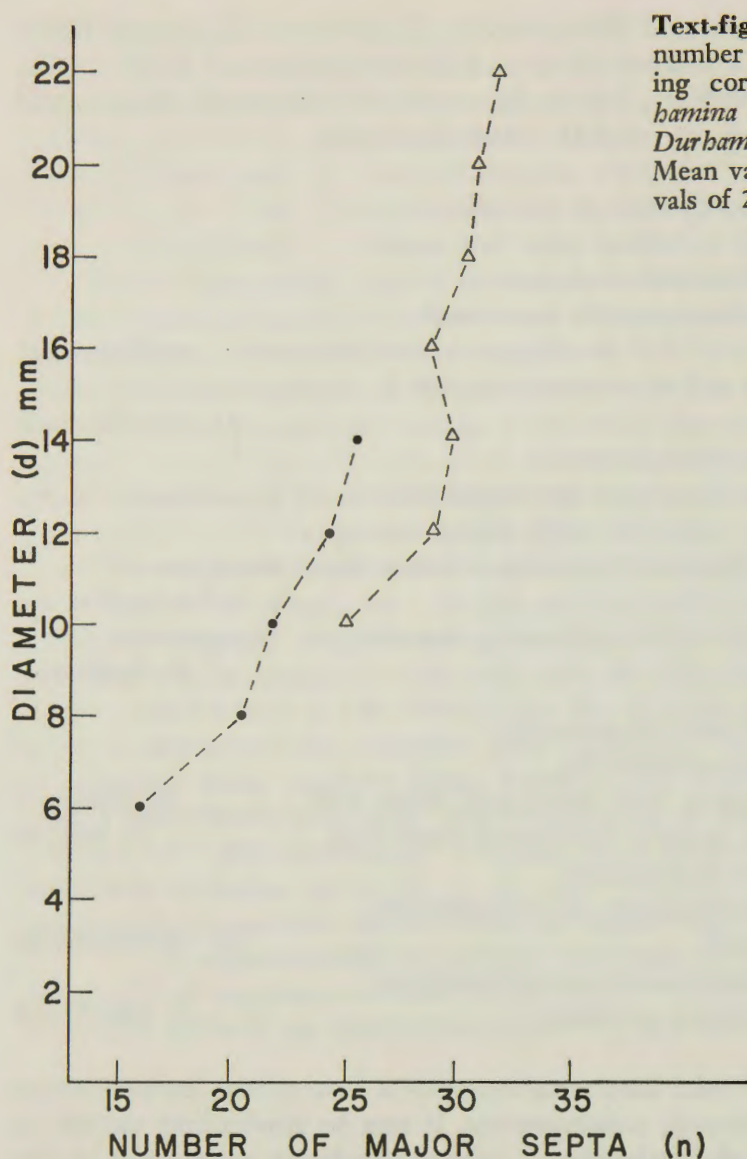
This arrangement can take into account only a few of the criteria upon which these species were based; consequently, it can be misleading except as a general guide to species of *Durhamina*. Additional details pertaining to the distinguishing characters of *D. alaskaensis* n. sp. and *D. sutherlandi* n. sp. are given in the description of the latter species and in Text-figs. 7-9.

Material and occurrence. Holotype UA 1004 and paratype UA 1005. In the holotype corallum sixteen corallites were studied in thin sections and on numerous cut and polished surfaces. Approximately ten corallites are present in the second corallum (paratype UA 1005) but are less well preserved and irregularly oriented. Both coralla are from locality VV-21b, McCallum Creek area: Lower Permian (Wolfcampian or ?Lower Leonardian), McCallum Creek sequence.

Durhamina sutherlandi n. sp.

Plate 2, figure 2; Plate 3, figure 1; Text-figures 7, 9

External. Corallites fasciculate, cylindrical at maturity, commonly subparallel or slightly scoleocoid, more than 70 mm long, up to 23 mm in diameter; epitheca thin, smooth externally except for fine growth lines; calice not observed; increase lateral.



Text-fig. 9. Relationship of average number of major septa (n) to increasing corallite diameter (d) in *Durhamina alaskaensis* n. sp. (●) and in *Durhamina sutherlandi* n. sp. (△). Mean values computed for class intervals of 2 mm.

Transverse sections. Major septa radially disposed, straight except at axial ends, thin (0.1 mm) and slightly crooked across dissepimentarium, thickened to as much as 0.7 mm at inner margin of dissepimentarium to form an inner wall; in ephebic stages major septa are subequal in length (5 to 7 mm) but do not extend to the axis of the corallites; cardinal and counter septa recognizable only when medial plate is developed in axial structure; alar septa not usually recognizable.

Major septa range from a recorded minimum of twenty-five at a diameter of 11 mm (septal ratio, 2.3) to a maximum of thirty-three at a diameter of 23 mm (septal ratio, 1.4). Minor septa are well developed, as much as 4 mm in overall length in ephebic stages, also thickened at inner margin of the dissepimentarium and penetrate tabularium up to 1 mm. Septal microstructure obscure except for a dark median line in major septa.

The brephic stages of this species were not observed; however, it is probable that the axial structure is not developed until the early neanic stage;

thereafter the axial structure is aulophylloid and composed of steeply inclined axial tabellae and a few (four to six) highly irregular septal lamellae at some growth stages. A distinct medial plate is not commonly developed. Although variable in its complexity, the axial structure is more or less continuous once developed in all corallites studied.

The dissepimentarium is from 3 to 4 mm wide and in the ephebic stages consists of up to seven tiers of anguloconcentric dissepiments. A few pseudo-herringbone dissepiments are sporadically developed between major and minor septa but these are uncommon.

Longitudinal sections. Dissepiments are globose, subequal in size (average length, 1 mm; maximum, about 1.5 mm), arranged in from four to seven tiers throughout neanic and ephebic stages; from four to six dissepiments occur per 5 mm vertically in longitudinal sections. Periaxial tabellae rise toward the axial region at angles ranging from approximately 25 to 45 degrees; these are typically arranged in two or three tiers, but an occasional single tabella spans the entire distance between the innermost dissepiments and the periaxial tabellae ("wide tabellae" of Minato and Kato, 1965b, p. 22). From four to six periaxial tabellae occur per 5 mm measured vertically adjacent to the dissepimentarium. Axial tabellae are sinuous, vertical or near-vertical, and arranged in from three to six irregular tiers. A few small clinotabellae occur, but are uncommon. Clinotabulae are absent.

Discussion. Specimens of *Durhamina sutherlandi* n. sp. not only achieve greater diameters and have more numerous septa than those of *D. alaskaensis*, but septa also are more closely spaced at comparable diameters (see Text-figs. 7 and 9). For example, the septal ratios (number of major septa per 1 mm diameter) of *D. alaskaensis* between diameters of 12 and 14 mm range from 2.0 to 1.8, whereas this measure ranges from 2.4 to 2.0 at equivalent diameters in *D. sutherlandi* n. sp. Additionally, periaxial tabellae in *D. sutherlandi* n. sp. are more numerous and more closely spaced with the result that as many as five to seven commonly are intersected by transverse sections. Minor differences between these two species include (1) a wider dissepimentarium in *D. sutherlandi* n. sp., (2) thicker and less sinuous major septa in this species, (3) a more persistent axial structure, and (4) a more prominent inner wall. (A comparison of *D. sutherlandi* n. sp. with other species of *Durhamina* is given in the discussion of *D. alaskaensis*). The species name is in honour of Dr. Patrick K. Sutherland, University of Oklahoma.

Material and occurrence. One corallum (holotype, UA 1006) in which eight corallites were studied in thin sections and on polished surfaces. Locality DR 15, Upper Delta River area: Lower Permian (Wolfcampian), McCallum Creek sequence.

Genus *Heritschioides* Yabe, 1950

Type species. *Waagenophyllum columbicum* Smith, 1935, p. 38, Pl. 8, fig. 9; Pl. 9, figs. 1-10: Upper Carboniferous or Lower Permian of British Columbia, Canada. (Subsequent designation by Yabe, 1950, p. 75.)

Diagnosis. Fasciculate, with two orders of septa, regular dissepimentarium, compact clisiophylloid axial structure, ascending axial and periaxial tabellae, rare clinotabellae; dissepimental pattern is dominantly pseudoherringbone; clinotabulae are absent.

Discussion. There has been both confusion and diversity of opinion as to the distinguishing characters and taxonomic position of a number of structurally similar upper Palaeozoic corals now variously classified in the families Lonsdaleiidae, Waagenophyllidae, and Durhaminiidae. These problems pertain to, but are not restricted to, the following genera: *Waagenophyllum* Hayasaka, 1924 (type species, *Lonsdaleia indica* Waagen and Wentzel, 1886); *Corwenia* Smith and Ryder, 1926 (type species, *Lonsdaleia rugosa* M'Coy, 1849); *Yatsengia* Huang, 1932 (type species, *Y. asiatica* Huang, 1932); *Huangia* Yabe, 1950 (type species, *Corwenia chütsingensis* Chi, 1931); *Heritschioides* Yabe, 1950 (type species, *Waagenophyllum columbicum* Smith, 1935); *Heritschiella* Moore and Jeffords, 1956 (type species, *Heritschia girtyi* Moore and Jeffords, 1941); and *Pseudohuangia* Minato and Kato, 1965a (type species, *Waagenophyllum chitralicum* Smith, 1935).

A detailed discussion of the taxonomic history of these genera is not attempted here. It is necessary, however, to review this history as it affects the present taxonomic status of the genus *Heritschioides*, which is represented in Permian rocks in the Alaska Range by *H. summitensis* n. sp.

An effort to provide a consistent means of distinguishing several of these genera was made by Yabe (1950), who proposed a classification based on the attitude of axial and periaxial tabellae. His study indicated that forms with horizontal or axially descending periaxial tabellae included *Huangia*, *Waagenophyllum*, and *Heritschiella*, whereas forms with ascending tabellae included *Corwenia*, *Yatsengia*, and *Heritschioides*. Most of these genera, however, continued to be variously interpreted in subsequent studies. Within Yabe's first group, for example, *Heritschiella* was described by Hill (1956, p. 310) as possessing tertiary septa. This character subsequently was cited by Wilson and Langenheim (1962, p. 509) as being in contrast with both *Heritschioides* and *Waagenophyllum*, in which only two orders of septa are present. However, Minato and Kato (1965a, p. 86) state that true tertiary septa are absent in *Heritschiella* and proposed reassignment of all described species of *Heritschiella* to *Pseudohuangia*, thereby restricting the former genus to its type species, *Heritschia girtyi*. Similarly, Igo (1961) considered *Huangia* to be a junior synonym of *Liangshanophyllum*; this occasioned a restudy of these forms by Minato and Kato (1965a, p. 72) who stated that although *Huangia* is distinct from *Liangshanophyllum*, the genus was too broadly based. Their restudy of *Huangia* resulted in the restriction of this genus to the genotype species, *Corwenia chütsingensis*. The study of waagenophyllid corals by Minato and Kato (1965a) is of particular significance to the present study, as is discussed below.

Yabe's second group of corals (*Corwenia*, *Yatsengia* and *Heritschioides*) is, in contrast with the first group, distinct at the generic level. *Corwenia* and *Yatsengia* seem clearly to belong to the Aulophyllidae, and are so classified by Hill (1956). Prior to the study of the Waagenophyllidae by Minato and Kato (1965a), however, the position of *Heritschioides* was problematical. Wilson and Langenheim (1962) tentatively referred several species of *Heritschioides* to the Waagenophyllidae, but with the reservation that clinotabulae

(termed "large clinotabellae" by those authors) were not developed in *Heritschioides*, although a few clinotabellae (of present usage) were observed.

The recent publication of a comprehensive study of the Waagenophyllidae and proposal of a new family, the Durhaminidae, by Minato and Kato (1965a, b) has considerably clarified many of these problems. By emphasizing the importance of clinotabulae as a distinguishing character of the Waagenophyllidae (originally stressed by Hudson, 1958, p. 178, in the definition of this family), the work of Minato and Kato provides a more consistent basis of classification than heretofore has been possible. Their study of this large group of corals also reveals the distinctness of the Permian Tethys faunal realm as compared with the "Uralian" realm of similar age. Subsequently, Minato and Kato (1965b) proposed the family Durhaminidae for corals of this group that lack clinotabulae but possess, in some species, clinotabellae. Structural elements such as clinotabulae, clinotabellae, axial and peripheral tabellae, and "wide" tabellae are also further defined (1965b, p. 22). Using the criteria provided by these authors, *Heritschioides* can be assigned to the Durhaminidae, whereas *Huangia*, *Pseudohuangia*, *Heritschiella*, and *Liangshanophyllum* (as a subgenus of *Waagenophyllum*) belong to the Waagenophyllidae. This classification, although possibly subject to refinement as further studies of waagenophyllid and durhaminid corals are made, is followed here.

In a recent study of Permian (Leonardian) colonial corals from Nevada, Stevens (1967) proposed that all described species of *Heritschioides* should be assigned to one of two subgenera: *H.* (*Heritschioides*) spp., and *H.* (*Eoheritschioides*) spp. Stevens (p. 428) gave the following diagnosis of *H.* (*Heritschioides*):

"The subgenus *Heritschioides* (*Heritschioides*) is proposed for those species of *Heritschioides* possessing an axial structure that is composed of several ranks of steeply dipping axial tabellae. In transverse section the columella is quite compact, and the medial plate is commonly dilate."

Heritschioides (*Heritschioides*) *columbicum* (Smith) is the designated type species. Other species assigned to the proposed subgenus are *H. woodi* Wilson and Langenheim (1962) and *H. buttensis* Stevens (1967).

The subgenus *Heritschioides* (*Eoheritschioides*) is diagnosed as follows (Stevens, 1967, p. 429):

"The subgenus *Heritschioides* (*Eoheritschioides*) is here proposed for those corals possessing the general characteristics of *Heritschioides* . . . but having an axial structure that is composed of long, rather flat axial tabellae generally in one rank on each side of the medial plate. The axial tabellae slope gently away from the medial plate, and their peripheral edges are downturned. In transverse section the clisio-phylloid axial structure generally is very large and diffuse. The medial plate most commonly is obscure, and sinuous septal lamellae may or may not be obvious."

The type species of this subgenus is designated as *Heritschioides* (*Eoheritschioides*) *moormanensis* Stevens (1967). *Heritschioides hillae* Wilson and Langenheim (1962), *H. ochocoensis* (Merriam) (1942), *H. washburni* (Merriam) (1942), and *H. parvum* Stevens (1967) were included in this subgenus.

Among Permian corals from the Alaska Range described in this study, the small, compact axial structure, distinct medial plate, and steeply inclined axial tabellae of *Heritschioides summitensis* n. sp. suggest its assignment to the

subgenus *H. (Heritschioides)*. For several reasons, however, Stevens' proposed subgeneric division does not appear to be applicable to the genus *Heritschioides* and is not followed here:

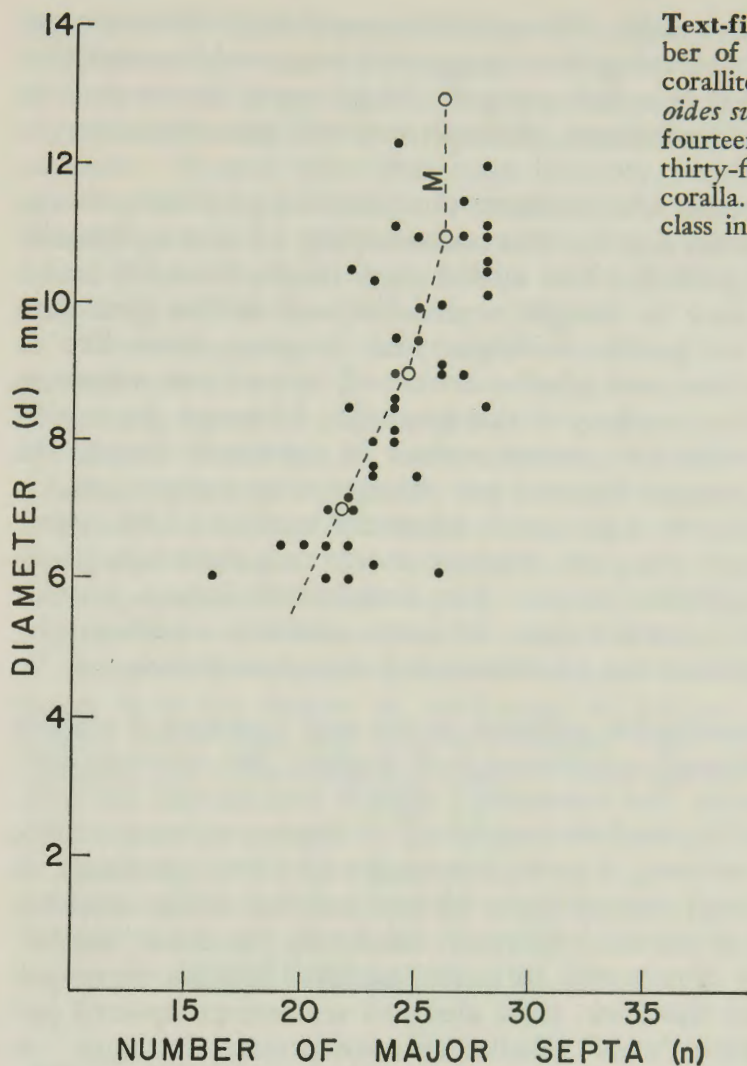
(1) *Heritschioides summitensis* n. sp. occurs in the Permian of the Alaska Range an estimated 5,000 feet stratigraphically lower than upper Wolfcampian or lower Leonardian corals (*Durhamina* spp.) and fusulinids, but the known ranges of species of *H. ("Eoheritschioides")* in Nevada and elsewhere is confined to Leonardian strata. Although this distribution does not, of itself, invalidate the morphological basis of the proposed subgenera, the assignment of the new species from Alaska to *H. (Heritschioides)* would result in an unfortunate stratigraphic situation; i.e., this subgenus, assumed by Stevens to be the more evolutionarily advanced, apparently occurs in older strata than *H. ("Eoheritschioides")* spp.

(2) The attitude and spacing of internal structural elements in corals commonly is influenced by thin section orientation. In scolecoid corals such as *Heritschioides*, parts of longitudinal sections almost inevitably are oblique, which results in the apparent "flattening", "steepening" or otherwise affecting the actual attitude of tabulae and tabellae. This effect, particularly in longitudinal sections, is difficult to evaluate. Consequently, the proposal of taxa higher than the species level should be avoided if differences can be defined only (or primarily) on the attitude of structural elements. Even in the definition of species, attitude is a less desirable criterion than one not influenced by thin section orientation, such as number, or presence or absence of a given character.

(3) The number of ranks of axial tabellae present in described species of *Heritschioides* is rather variable, not only from one species to another but within the same corallum or even the same corallite. My impression is that the size and complexity of the axial structure is a function of both ontogenetic change and also the degree of crowding of adult (ephebic) corallites. It also seems probable that among most corals characterized by a clisiophylloid axial structure the degree of complexity, symmetry, and diameter of the column may be influenced by periodic constriction resulting from rejuvenescence or other types of reproduction (Rowett and Minato, 1968).

(4) Two morphological "extremes" are present within species referred to the proposed subgenera. The *H. ("Eoheritschioides")* configuration of axial tabellae, for example, is present in Stevens' re-illustrated specimens of *H. hillae* (1967, Pl. 53, figs. 2a-d), while the *H. (Heritschioides)* condition is present in *H. woodi* (Stevens, 1967, Pl. 53, figs. 3a, b). However, examination of other described species suggests that several transitional forms also are present. This appears to be confirmed by the observation that one of Stevens' species, *H. ("Eoheritschioides") parvum* (1967, p. 430, Pl. 53, fig. 1) cannot be distinguished from *H. ("Heritschioides") buttensis* Stevens (1967, p. 429, Pl. 52, fig. 4) on the basis of the proposed subgeneric distinctions. Stevens, in discussing these two species (1967, p. 430) stated:

"From *H. buttensis* this species may be differentiated by the greater dilation of major septa in the tabularium and the greater coarseness of all other structures. *H. parvum* possesses some features of both subgenera of *Heritschioides*. The steeply dipping axial tabellae suggest *H. (Heritschioides)*, but the few ranks of these tabellae is a feature of *H. (Eoheritschioides)*."



Text-fig. 10. Relationship of number of major septa (n) to increasing corallite diameter (d) in *Heritschioides summitensis* n. sp. Data based on fourteen corallites (UA 1025) and thirty-five corallites in five paratype coralla. Mean values computed for class intervals of 2 mm.

Heritschioides summitensis n. sp.

Plate 4, figures 1-3; Text-figure 10

External. Coralla fasciculate; corallites are cylindrical, subparallel or scolecoid, 60 mm or more in length, and as much as 12.3 mm in diameter; the epitheca is thin (0.2 mm or less) and smooth externally except for fine growth lines and subdued rugae; calices are deep, with an axial boss; reproduction by lateral increase. Brephic and early neanic stages unknown.

Transverse sections. In the neanic and ephebic stages major septa are radially disposed and subequal in length (commonly 3 to 4 mm in the ephebic stages); the cardinal septum is slightly shorter than adjacent metasepta (2 to 3 mm) and occupies a weak open fossula; septa are thin (0.1 mm or less) and crooked throughout the dissepimentarium, but somewhat thicker (up to 0.25 mm) in the tabularium, where they may be slightly lanceolate or rhopaloid. Major septa do not reach the axial structure in the neanic or ephebic stages. Alar septa are not usually differentiated.

Major septa range from an observed minimum of sixteen at a diameter of 6.1 mm (septal ratio, 2.6) to a maximum of twenty-eight at diameters ranging

from 8.5 to 12.0 mm (septal ratios, 3.3 and 2.3 respectively). Minor septa are well developed in all observed growth stages and commonly extend into the tabularium 0.5 to 1.5 mm in ephebic stages. Major septa have a dark or light median line; septal microstructure, although not well preserved, appears to be fibro-normal.

The axial structure consists of a persistent compact clisiophylloid column, commonly about 1.5 mm in alar diameter but not exceeding 2.5 mm in diameter in any observed stages of growth. The medial plate ranges from 0.5 to 1.5 (rarely 2 mm) in length, may be straight or crooked, and is thin (less than 0.1 mm); septal lamellae are poorly developed and irregular; from five to twelve occur in most corallites; axial tabellae are closely spaced and numerous (see discussion of longitudinal sections of this species). Although the medial plate may be continuous with the counter septum in the neanic stages, the axial structure typically is independent and not penetrated by major septa.

A single row of dissepiments is present in transverse sections of the neanic stages (diameters 6 to 8 mm); this zone develops slowly to a maximum width of 1.5 mm or less in the ephebic stages. The dissepiments form a pseudo-herringbone pattern in the ephebic stages. In many corallites a narrow (0.2 mm or less) inner wall separates the tabularium and dissepimentarium.

Longitudinal sections. Considerable variation in the axial structure is evident in longitudinal sections; although continuous in all sections, this structure may be narrow and well defined or (less commonly) slightly broader and less compact. Periaxial tabellae are inclined at from 40 to 50 degrees upward axially, whereas the axial tabellae are vertical or near-vertical. In a few specimens, as many as eight steeply inclined sinuous ranks of axial tabellae occur on either side of the median lamella of the axial structure; these may present a "tented" appearance (Pl. 4, fig. 1a). From nine to twelve periaxial tabellae occur per 5 mm vertically throughout this zone; these elements are convex upward and occur in two or three series; "wide" tabellae also are present, but rare. A discontinuous outer zone of clinotabellae is present in most corallites. The average size of dissepiments is about 0.5 mm, but a few reach 1.0 mm in their longest dimension; from ten to fifteen dissepiments occur per 5 mm vertically.

Discussion. Comparatively few species of *Heritschioides* have been described to date, and several of these are similar in morphology. *H. summitensis* n. sp. is readily distinguished from the type species of *Heritschioides*, *Waagenophyl-lum columbicum* Smith (1935), by its smaller size, more numerous clinotabellae, and lack of lonsdaleoid dissepiments. *Heritschioides washburni* (Merriam) (1942, p. 375, Pl. 55, figs. 2, 5, 7, 9, 11, 13) and *H. ochocoensis* (Merriam) (1942, p. 375, Pl. 55, figs. 8, 10; Pl. 56, fig. 3) are both considerably larger forms and possess more numerous septa than *H. summitensis*; also, *H. ochocoensis* lacks the well developed minor septa of the new species. *H. woodi* Wilson and Langenheim (1962, p. 509, Pl. 87, figs. 9, 10) and *H. hillae* Wilson and Langenheim (1962, p. 510, Pl. 88, figs. 1-3) are both closely similar in some respects to *H. summitensis*, and the holotype specimens of these species (UC 34652 and 34653) were therefore borrowed for study. Although *H. hillae* is comparable with the present species in size of corallites and number of major septa, it differs markedly in the configuration of its axial structure; in *H. hillae* this structure is broad, asymmetrical, and contains up to twenty-five long, straight septal

lamellae, which is in sharp contrast to the column of *H. summitensis*. *Heritschioides woodi* is somewhat larger than *H. summitensis* and has a much broader axial structure (4 to 5.5 mm as compared with 1.5 to 2.5 mm); additionally, septal lamellae are fewer in number, shorter, and more irregular in *H. summitensis*. In most other characters, however, these two species agree.

A corallite described by Ross and Ross as *Heritschioides* sp. (1963, p. 417, Pl. 50, figs. 1, 8, 10, 12) possesses carinate septa and has, on the basis of this and other characters, been described as *Yabeiphyllum rossi* by Minato and Kato (1965b, p. 49, Pls. 3, 4, Text-figs. 13-15).

Several species of *Heritschioides* described by Stevens (1967) from Permian (Leonardian) of Nevada also bear comparison with *H. summitensis* n. sp. In general, it can be said that the new species differs from all three of Stevens' species (*H. buttensis*, *H. moormanensis*, *H. parvum*) in having a consistently much more compact, spindle-shaped axial structure. *Heritschioides summitensis* is a considerably smaller form than *H. moormanensis*, which attains 17 mm in diameter; Stevens' species also has a broader axial structure, commonly asymmetrical, fewer peripheral tabellae and poorly developed minor septa. *Heritschioides parvum* Stevens is here considered to be conspecific with *H. buttensis* Stevens, since the only observable difference between these two forms is in the degree of thickening of internal structures. The Alaskan species differs from this form in possessing more numerous septa, fewer septal lamellae, and more numerous ranks of axial tabellae.

Material and occurrence. Holotype corallum (UA 1025), consisting of parts of fourteen corallites, and six additional fragments of coralla (paratypes 1026 through 1031) in which a total of thirty-five corallites are partly preserved. All specimens are from locality MC-6, Southern Rainbow Mountain area; Lower Permian (Wolfcampian), McCallum Creek sequence.

Family AULOPHYLLIDAE Dybowski, 1873

Subfamily AULOPHYLLINAE Dybowski, 1873

Genus *Auloclisia* Lewis, 1927

Type species. *Auloclisia mutatum* Lewis, 1927, p. 31, Pl. I, figs. 1a-h; Pl. II, figs. 1-6: Lower Carboniferous, NW England and Isle of Man.

Diagnosis. Solitary, with a regular dissepimentarium and well developed minor septa; axial structure a simple swelling of axial end of counter septum in early neanic stage, becoming clisiophylloid through the early ephebic stage and finally aulophylloid in late growth stages; cardinal septum long in earliest stages but shortened thereafter and occupying an open fossula; cardinal septum at or near convex side of corallites.

Discussion. It is well established that similar or identical morphological characters may appear in related groups of corals, although at different stages of growth, or may develop as the result of parallel evolutionary trends. Consequently, in the study of fossil corals comparison of dissimilar stages of growth can lead to erroneous assignments. This has occurred repeatedly in certain

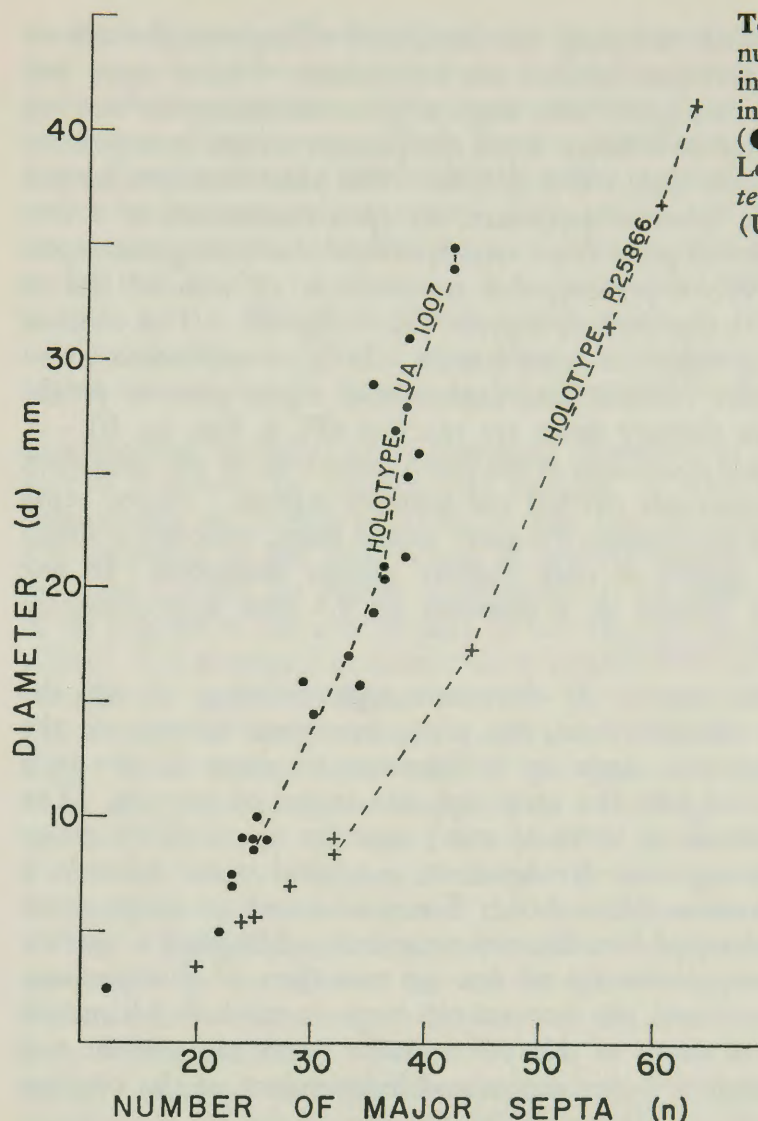
aulophylloid corals, in which this phenomenon seems to be common, and is particularly true of *Dibunophyllum* Thompson and Nicholson, *Aulophyllum* Milne-Edwards and Haime, *Auloclisia* Lewis, and *Clisiophyllum* Dana. A brief discussion of these problems, as they relate to this report, is given below.

Dibunophyllum is a widespread genus that is common in upper Palaeozoic rocks in many regions throughout the world. Although individual specimens exhibit the plasticity that characterizes many corals, there seems to be general agreement that only corals in which the axial structure includes a distinct long medial plate, comparatively few (four to eight in most examples) septal lamellae, and degenerate minor septa should be referred to this genus. This is in sharp contrast to *Clisiophyllum*, which has well developed minor septa, a regular dissepimentarium, and numerous septal lamellae that originate from a short, thick medial plate. The genus *Aulophyllum*, in contrast with both *Dibunophyllum* and *Clisiophyllum*, is distinguished by its "aulophylloid" axial structure, in which a medial plate is not developed.

In 1927, however, with the description of *Auloclisia* by Lewis, it was made apparent that characters typical of *Clisiophyllum*, *Aulophyllum*, and *Dibunophyllum* could occur in a single corallite. Although Lewis did not specifically mention a "dibunophylloid" phase in the development of *Auloclisia*, Hill in her diagnosis of this genus (Hill, 1956, p. 286) stated that the axial structure in young stages has a dibunophylloid medial plate and did not mention a clisiophylloid phase of development in the axial structure of this genus. The original description and illustrations of the type species, *A. mutatum* Lewis (1927, p. 31, Pls. I and II), however, show that although certain early phases in the development of the axial structure (see, for example Pl. I, fig. 1a, Pl. II, figs. 5a, 6c) might be described as dibunophylloid, subsequent growth stages clearly are clisiophylloid (Pl. II, figs. 2a, 3a). Both the author of the genus and Hill agree that the latest stages of growth are characterized by an aulophylloid axial structure in which the medial plate is absent. It follows that both ephebic and neanic stages must be observed to distinguish *Auloclisia* from *Aulophyllum* and *Clisiophyllum*; without a study of the brephic and earliest neanic stages of growth even the criteria discussed above probably provide an artificial classification at best.

Comparatively recent studies have shown that it is chiefly the earliest growth stages (brephic and early neanic) that may provide reliable clues to the phylogenetic relations of similar corals. Unfortunately, this part of corallites is often absent or poorly preserved. Because emphasis traditionally has been placed on description of the ephebic stages, earlier stages seldom have been described even when available. The actual relationship of *Clisiophyllum*, *Aulophyllum*, *Dibunophyllum*, and *Auloclisia* is thus obscure, and although Hill's (1956) classification is probably the most practical grouping of these corals at this time the need for an extensive restudy of this group is evident.

A rather large group of corallites from Permian rocks in the Alaska Range is here assigned to *Auloclisia* Lewis. These specimens incorporate what is considered to be the essential characteristic of this genus, i.e., an axial structure that is clisiophylloid in the early stages of growth but becomes aulophylloid in late stages. Several corallites in which the late aulophylloid stages do not develop (and in which there are other minor differences from *Auloclisia*) are referred to *Clisiophyllum* Dana.



Text-fig. 11. Relationship of number of major septa (n) to increasing corallite diameter (d) in *Auloclisia deltense* n. sp. (●) and in *Auloclisia mutatum* Lewis (+). Data for *A. deltense* n. sp. based on holotype (UA 1007) and ten paratypes.

Auloclisia deltense n. sp.

Plate 5, figures 1, 2; Plate 6, figures 1-5; Text-figure 11

External. Corallites solitary, medium to large, cylindrical in upper mature parts (distal, 30 to 40 mm), commonly exceeding 80 mm in overall length; the maximum diameter recorded is 35 mm; curvature in proximal parts is in the cardinal-counter plane, with the cardinal septum at or near the convex side of corallites; the calice is deep, with an axial boss; epitheca thin (0.2 mm or less), marked externally by fine growth lines and subdued rugae; septal grooves and ridges are faint or absent.

Transverse sections. Because of the variability of the internal characters of this species throughout its ontogenetic development, its morphology is best described in stages:

(1) *early neanic stage*. One transverse section (diameter, 2.5 mm) shows this stage of growth (Pl. 6, fig. 3b). Sixteen septa are arranged in a zaphrentoid pattern as follows: K 5 A 1 C 1 A 5 K (septal ratio, 6.4). The column consists of a simple lophophyllid-like swelling of the axial end of the elongate counter

septum; the cardinal septum is also long (0.8 mm) and extends to the axis of the corallite. Only two periaxial tabellae are intersected. Minor septa and dissepiments are absent. In a slightly later stage of growth (diameters ranging from 5.0 to 7.5 mm), twenty-two major septa are present whose arrangement is indicated by the formula $K\ 7\ A\ 3\ C\ 3\ A\ 6\ K$. The axial structure in this earliest transitional stage is, in some specimens, an open framework of a few axial tabellae and a long medial plate from which several short irregular septal lamellae may originate. When present, this structure is 1.5 mm or less in diameter and is connected to the counter septum (Pl. 6, fig. 4a). The counter septum is withdrawn and occupies an open fossula. In other specimens, however, the lophophyllid-like column and zaphrentoid septal pattern persist until diameters of 9 mm or slightly more are reached (Pl. 6, figs. 2a, b). A characteristic feature in these specimens is the sharp deflection of the axial ends of septa in the counter quadrants toward the counter septum. Minor septa and dissepiments are absent throughout the early neanic stage, although a single row of dissepiments may appear at only slightly greater diameters. In one specimen dissepiments are present at a diameter of 8.5 mm, approximately 5 mm from the base of the corallite.

(2) *middle and late neanic stages*. At diameters approximating 10 mm the axial structure is basically clisiophylloid; this phase continues throughout the neanic stage (here considered to range up to diameters of about 20 mm or a height of about 30 mm) and into the early ephebic stages of growth. The middle neanic stage (diameters of 10 to 15 mm) contains up to thirty major septa which are now radial in their arrangement; a typical septal formula is $K\ 8\ A\ 5\ C\ 5\ A\ 8\ K$ (septal ratios, 2.0 to 3.0). The axial structure ranges from 4 to 5 mm in diameter and septal lamellae are numerous. Although a narrow dissepimentarium is present, consisting of one or two tiers of dissepiments, minor septa do not appear until the late neanic stage is reached (diameters of 15 to 20 mm) where as many as thirty-five major septa are present and the axial structure is as much as 7 mm across and independent of the counter septum (Pl. 6, fig. 5c).

(3) *early and middle ephebic stages*. The clisiophylloid axial structure reaches its maximum development in the early or middle ephebic stages, with as many as twenty-six straight, radially disposed septal lamellae abutting against a short medial plate. However, these become irregular, and this phase of development is replaced by an aulophylloid column at diameters ranging from about 25 to 30 mm. As many as thirty-eight major septa are present in the early and middle ephebic stages, and minor septa are well developed; these cross the entire width of the dissepimentarium which, however, remains 2 mm or less wide (Pl. 5, figs. 1c, d; Pl. 6, figs. 5a, b). The cardinal septum is short (4 mm or less) and occupies a distinct open fossula. A typical septal formula (diameter, 28 mm) is $K\ 11\ A\ 6\ C\ 6\ A\ 11\ K$ (septal ratio, 1.4).

(4) *late ephebic stage*. At diameters in excess of about 30 mm all corallites have a broad aulophylloid axial structure in which the medial plate is aborted and septal lamellae are highly irregular, reduced in number, or absent (Pl. 5, figs. 1a, b). This structure, commonly oval in form, is as much as 15 mm across (alar direction). Major septa increase to a maximum of forty-two (septal ratio, 1.4 +) and are subequal in length (9 to 11 mm) except for the shortened

cardinal septum. The width of the dissepimentarium increases abruptly (up to 7 mm) in the late ephebic stages due to the appearance of as many as twelve ranks of dissepiments. Minor septa are 3 to 4 mm long but do not cross the innermost dissepiments, which form a herringbone pattern. Pseudoherringbone dissepiments are present in the outer region of the dissepimentarium, between major and minor septa. Both major and minor septa are thin and crooked throughout the dissepimental zone, but the former thicken to as much as 0.6 mm in the tabularium. A narrow inner wall is formed at the inner margin of the dissepimentarium which tends to be better developed in the cardinal quadrants. Major septa have a dark, commonly sinuous median line; septal microstructure appears to be diffusotrabecular.

Longitudinal sections. The changing character of the axial structure of this species is shown by longitudinal sections, in which a median lamella is distinguishable to heights of 45 to 55 mm but thereafter becomes irregular and discontinuous in the latest stages of growth (aulophylloid phase). Axial and periaxial tabellae are sharply differentiated; the former are steeply inclined (45 to 80 degrees in the central part of the axial structure and vertical at its periphery) and arranged in numerous irregular tiers on either side of the median lamella; the periaxial tabellae are more gently inclined upward toward the axis (30 degrees or less), strongly convex upward, and arranged in two or three tiers. Axial and periaxial tabellae are separated by a vertical "wall" at the outer margin of the axial structure in some stages of growth (chiefly neanic and early ephebic); the space occupied by periaxial tabellae is not wider than 5 or 6 mm in any specimen observed. From eight to eleven periaxial tabellae originate at the inner margin of the dissepimentarium in a vertical distance of 10 mm. Longitudinal sections show the dissepimentarium to be much better developed on the convex side of corallites, where dissepiments can be seen within a few millimetres of the base; on the concave side, dissepiments appear only when a diameter of about 20 mm or more is reached (height, approximately 30 mm) and the dissepimental zone on this side remains narrower throughout all subsequent growth stages (Pl. 5, fig. 2a; Pl. 6, fig. 1a). Individual dissepiments are up to 1.5 mm in their longest dimension (average, about 1 mm) except for a few elongate dissepiments which appear at the inner margin of the dissepimentarium in the late ephebic stage; these are several millimetres long. A few clinotabellae are present in the zone of periaxial tabellae.

Discussion. Since Lewis's (1927) description of *Auloclisia* few corals have been referred to this genus, and most of these possibly could, if restudied, be assigned to *Clisiophyllum* Dana. This appears to be true of corals described from the Carboniferous (*Yuanophyllum* zone) of China by Yü as "*Auloclisia*" *multiplexum* (Yü, 1933, p. 117, Pl. XXII, figs. 5a-c; Pl. XXIII, figs. 2a-b), "*A.*" *densum* (Pl. XXII, figs. 7a-c; Pl. XXIII, figs. 1a-c), "*A.*" *circularis* (Pl. XXII, figs. 6a-c; Pl. XXIII, figs. 4a-c), and "*A.*" *tentatum* (Pl. XXIII, figs. 6a, b). In each of these species, Yü's descriptions and illustrations indicate that a clisiophylloid axial structure is present throughout all stages of growth. "*Auloclisia*" *ellipticum* Yü (1933, Pl. XXIII, figs. 5a-c), which unfortunately is based on only one incomplete corallite, appears to be referable to neither this genus nor *Clisiophyllum*.

Auloclisia deltense n. sp. does not compare closely with any species known to the writer, including the type species, *A. mutatum* Lewis (1927) which is a much larger form with more numerous septa (as many as 63) in the ephebic stages. *A. mutatum* also has more crowded septa throughout all growth stages and consequently a higher septal ratio than *A. deltense* (Text-fig. 11; see also Appendix I). The same criteria distinguish *A. concentricum* (Garwood and Goodyear) Lewis (1927, p. 39, Pl. II, figs. 7a, b) from *A. deltense* n. sp.

Material and occurrence. Numerous corallites were collected, thirteen of which were studied in thin section. Holotype, UA 1007; paratypes, UA 1008–UA 1020. Locality DR-16, Upper Delta River area: Lower Permian (Wolfcampian or ?lower Leonardian), McCallum Creek sequence.

Genus *Clisiophyllum* Dana, 1846

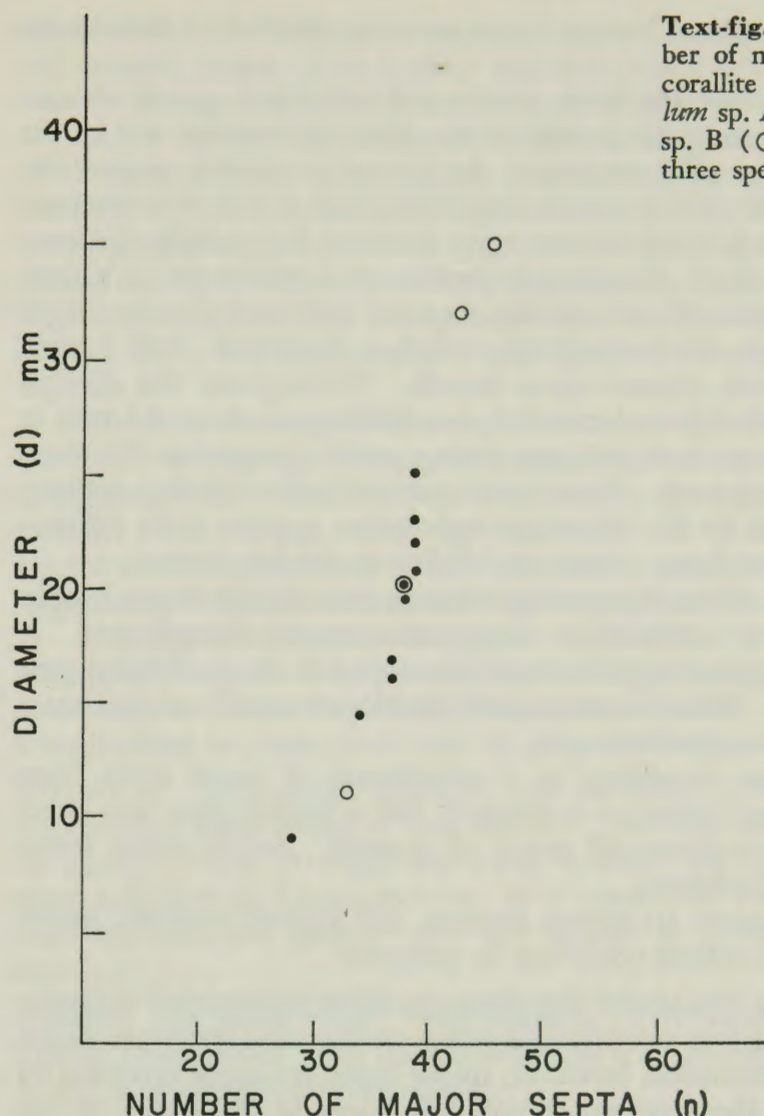
Type species. *Clisiophyllum keyserlingi* M'Coy, 1849, p. 2; 1851, p. 94, Pl. III C, figs. 4, 4a (subsequent designation by Dingwall, 1926, p. 14): Carboniferous (Visean–Namurian), England.

Diagnosis. "Solitary, with normal minor septa in a regular dissepimentarium; axial structure wide, with thin septal lamellae about half as numerous as major septa, commonly convolute and abutting on a short, thickened median plate." (Hill, 1956, p. 286).

Discussion. The relationship of *Clisiophyllum* to several similar genera in the Aulophyllidae is summarized elsewhere (see discussion of *Auloclisia*). In his original description of *Auloclisia*, Lewis (1927, pp. 41, 42) compared that genus with *Clisiophyllum* as follows:

"*Auloclisia* agrees with *Clisiophyllum* . . . in the following details:— (a) the size of the dissepiments; (b) the non-continuity of major septa and septal lamellae and the greater number of major septa than septal lamellae; (c) a limiting wall usually enclosing the central column. It differs from *Clisiophyllum*, however, in (a) the better defined cardinal fossula; (b) the wider dissepimental zone; (c) the absence of a median plate at a late stage, and the denser and less regular construction of the central column."

Lewis also pointed out that in *Auloclisia* the early zaphrentoid stage is followed by the development of an axial structure with a "spider-web" pattern that is "at first continuous with the cardinal septum but not with the counter septum" (1927, p. 42). However, this is an anomalous relationship rarely seen in rugose corals and is not supported by his illustrations of the type species, *A. mutatum* Lewis (1927, Pl. I, figs. 1a–h; Pl. II, figs. 1–6). Although this relationship is cited by Lewis as a further distinguishing feature of *Auloclisia* in comparing this genus with *Clisiophyllum*, it should be verified by restudy of his type material. Corallites here referred to both *Auloclisia* (*A. deltense* n. sp.) and *Clisiophyllum* (*C. sp.*) have axial structures continuous in early stages of growth with the counter septum, which is, however, located on the concave side of the corallites. This configuration of protosepta, which is unusual but not rare in rugose corals, could lead to misinterpretation of the relations of protosepta and axial structure in early stages.



Text-fig. 12. Relationship of number of major septa (n) to increasing corallite diameter (d) in *Clisiophyllum* sp. A (●) and in ?*Clisiophyllum* sp. B (○). Data based on a total of three specimens.

Clisiophyllum sp. A

Plate 7, figures 1, 2; Text-figure 12

External. Corallites solitary, curved, cylindrical in upper part, with an overall length of about 75 mm; maximum diameter recorded is 23 mm; the calice is deep, with a prominent axial boss and cardinal fossula; the cardinal septum is at or near the convex side of the corallites; epitheca thin (0.2 mm or less) and marked externally by growth lines and faint septal grooves and rugae.

Transverse sections. The earliest stage preserved is neanic (diameter, 8.0 mm), in which the axial structure consists of a long, irregular medial plate, several septal lamellae, and only a few axial tabellae (Pl. 7, figs. 1f, g). The alar diameter of this open structure is 1.7 mm; the medial plate is continuous with the counter septum; the cardinal septum is withdrawn from the axis and is slightly shorter than adjacent septa in the cardinal quadrants. A total of twenty-eight major septa are present whose arrangement is indicated by the formula K 7 A 5 C 5 A 7 K; these are from 2.5 to 3.0 mm long and reach but do not penetrate the axial structure. A single rank of dissepiments are present at this

stage, as are short minor septa. Two to three periaxial tabellae are intersected by transverse sections.

Development throughout the later neanic and ephebic stages is characterized by a gradual increase in the width of the dissepimentarium and in the size and complexity of the axial structure. In the early ephebic stage (diameters of 18 to 22 mm) the axial structure is up to 9.5 mm in alar diameter and consists of an irregular medial plate and as many as thirty-five radially disposed septal lamellae (Pl. 7, fig. 2a). Major septa increase to a maximum of thirty-nine in the ephebic stages and are radially disposed and subequal in length (5 to 6 mm) except for the cardinal septum, which is shortened (3 to 5 mm) and occupies a narrow but distinct open fossula. Throughout the dissepimentarium major septa are thin and crooked, but thicken to about 0.3 mm in the outer tabularium. A narrow (0.2 mm) inner wall is present at the inner margin of the dissepimental zone. Septal arrangement in the ephebic stages is as follows: K 11 A 6 C 6 A 11 K. Septal microstructure appears to be diffusotrabecular, and major septa have a dark medial line in the tabularium.

The maximum width of the dissepimentarium in the ephebic stages is only 4.0 mm, and consists of four to five tiers of anguloconcentric dissepiments. A very few pseudoherringbone dissepiments are developed in the peripheral part of the dissepimentarium. Minor septa are well developed and cross the entire zone of dissepiments in the ephebic stages.

The late ephebic stage is marked by a withdrawal of major septa from the axial region. The axial structure is isolated, but a medial plate and short septal lamellae persist throughout all stages of growth. Septal ratios range from 3.5 (neanic) to 1.7 (ephebic).

Because of closely spaced transverse sections and limited material, longitudinal sections of these corallites could not be prepared.

Discussion. It was at first considered that these corallites represented examples of *Auloclisia* in which the late aulophylloid phase of the axial structure failed to develop. As already discussed, however, major septa are more crowded in all stages of growth and there are consistent differences in the width of the dissepimentarium, nature of dissepiments, and development of minor septa. Although the presence of an inner wall and a well developed cardinal fossula are not typical of most species of *Clisiophyllum*, the corallites described here appear to incorporate the essential features of this genus.

Material and occurrence. Two corallites (UA 1021, 1022), one of which is incomplete, from locality DR-16, Upper Delta River area: Lower Permian (Wolfcampian or ?Lower Leonardian), McCallum Creek sequence.

?Clisiophyllum sp. B

Plate 7, figure 3; Text-figure 12

External. Corallite of medium size, trochoid, with cardinal septum at or near the convex side; overall length is 60 mm, but the brephic stage and upper calice are not preserved; the maximum diameter is about 35 mm; however, the epitheca and most of the dissepimentarium are eroded.

Transverse sections. Major septa are radially disposed in the ephebic stages with a slight trend toward pinnate arrangement in the neanic stages; septa are subequal in length (8 to 10 mm), thin in the dissepimentarium but up to 1.5 mm

thick in the tabularium; the cardinal septum is short throughout the neanic and ephebic stages (2 to 5 mm) and occupies a prominent open fossula; the counter septum and alar septa are not differentiated.

Major septa number from an estimated thirty-three at a diameter of about 11 mm (septal ratio, approximately 3.0) to a maximum of forty-six at a diameter of about 35 mm (septal ratio, approximately 1.3). The septal formula in the early ephebic stage (diameter, c. 32 mm) is K 12 A 7 C 7 A 12 K, which indicates strong acceleration of septal insertion in the counter quadrants. Minor septa are short but cross the narrow dissepimentarium in all observed growth stages. They do not penetrate the tabularium. Septal microstructure is fibro-normal.

The axial structure in this corallite is as much as 9 mm across and occupies essentially all the tabularium; it is composed of numerous irregular and discontinuous septal lamellae (up to thirty in the ephebic stages) and steeply inclined axial tabellae. Although the axial end of the counter septum is extended as an irregular lamella into the central part of the corallite in the neanic stages, only a short isolated medial plate is present in later stages.

The dissepimentarium has been removed for the most part by abrasion, but appears to have been 3 mm or less wide and composed of anguloconcentric dissepiments. Innermost dissepiments are thickened to produce an inner wall. Longitudinal sections could not be prepared because of the limited material.

Discussion. This single specimen was collected at locality RC-18 and is the only rugose coral found at that locality. Its axial structure seems basically to be clisiophylloid, although the septal lamellae are somewhat more numerous than is typical of *Clisiophyllum*. It is tentatively referred to this genus, but does not compare closely with any species of *Clisiophyllum* known to the writer.

Material and occurrence. One corallite (UA 1024), from locality RC-18, Upper Delta River area: Lower Permian (Wolfcampian or ?Lower Leonardian), McCallum Creek sequence.

Family CYATHOPSIDAE Dybowski, 1873

Genus *Caninia* Michelin in Gervais, 1840

Type species. *Caninia cornucopiae* Michelin in Gervais, 1840, p. 485; and Michelin, 1847, p. 256, Pl. LIX, fig. 5: Lower Carboniferous (Tournaisian), Belgium.

Diagnosis. Solitary, trochoid to cylindrical cyathopsid corals that lack an axial structure; major septa radially disposed, do not extend to the axis, may be narrow, dilated, straight or sinuous; minor septa variable in development but typically degenerate in late stages of growth; cardinal septum typically short, occupies an open or closed fossula; dissepimentarium variable in development, but non-lonsdaleoid; tabulae mostly complete, subhorizontal in central part of tabularium.

Discussion. Taxonomic problems pertaining to *Caninia* and several similar genera have a long history of discussions, revisions, and proposed reinterpretations. Earlier discussions include those by Carruthers (1908, p. 158),

Lewis (1924, p. 389; 1931, p. 226), and Hill (1939, p. 103). Moore and Jeffords (1945, p. 145) presented a detailed review of these problems and proposed restricting *Caninia* to only those forms exhibiting the essential characters of the type species, *C. cornucopiae*; this is a small species with an open cardinal fossula and a narrow, discontinuous dissepimentarium. Larger corals with a wide tabularium and well developed dissepimentarium would be referred to *Pseudozaphrentoides* Stuckenberg (1904, p. 90; type species, *P. jerofoewi*) according to this procedure, and corals with a well developed siphonofossula and a partly or wholly lonsdaleoid dissepimentarium to *Siphonophyllia* Scouler (*in* McCoy, 1844; type species, *S. cylindrica*). This view was followed, but with reservations, by both Wang (1950, p. 210) and Sutherland (1958, p. 63). However, the actual phylogenetic relationships of these genera are obscure and the stratigraphic utility of the proposed restriction by Moore and Jeffords remains to be demonstrated. In recent literature many palaeontologists continue to interpret *Caninia* broadly, which allows the inclusion in this genus of forms that might otherwise be referred to several other genera, notably *Pseudozaphrentoides* and *Caninophyllum*. *Siphonophyllia*, because of its lonsdaleoid dissepimentarium, seems to be distinct from *Caninia*; both this genus and *Caninophyllum* are listed among the Cyathopsidae by Hill (1956), but *Pseudozaphrentoides* is regarded by Hill as a junior synonym of *Caninia*.

The fossil corals from the Alaska Range referred here to *Caninia* seem not to fall in any of the "species groups" outlined by Hill (1939) and incorporate features typical of both *Caninia* and *Pseudozaphrentoides* (*sensu stricto*). Until such time as the actual relationships between these forms are better understood, it seems best to follow Hill's broader interpretation of *Caninia*.

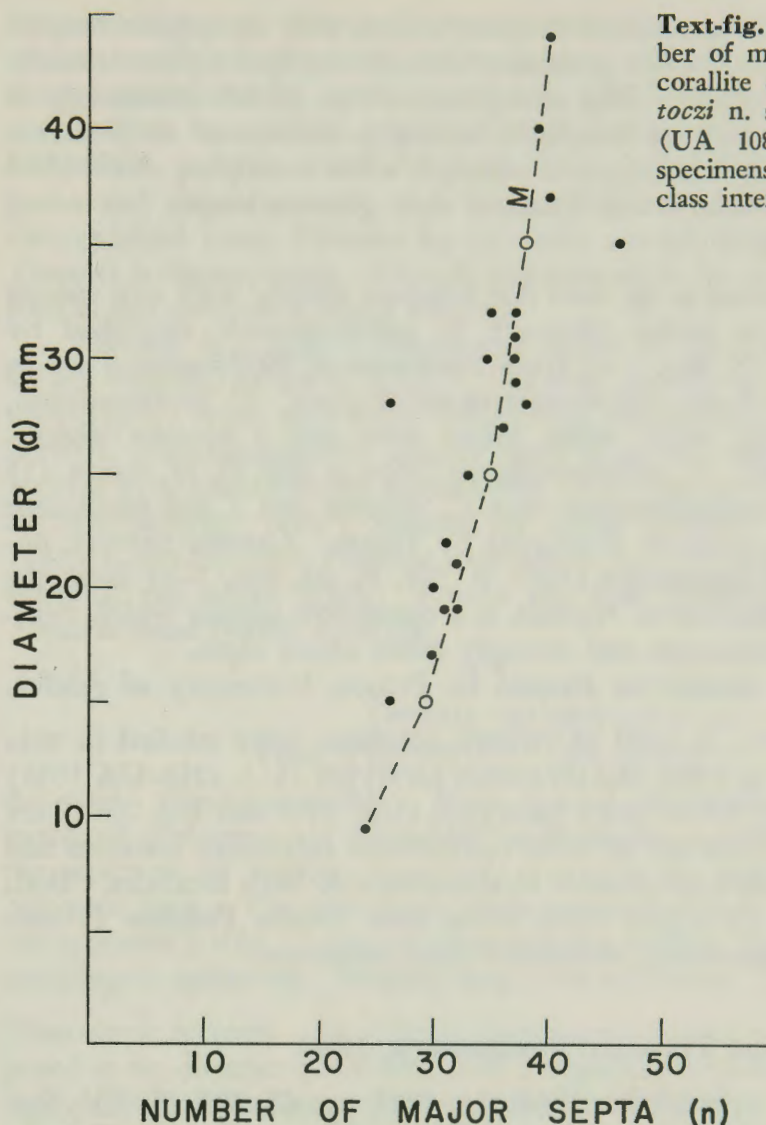
Caninia petoczi n. sp.

Plate 8, figures 1-6; Text-figure 13

External. Corallites solitary, large, trochoid to cylindrical (ephebic stages); complete specimens commonly more than 100 mm long; the maximum diameter recorded is 44 mm; the epitheca is thin (1 mm or less), and marked externally by growth lines and rugae; calices are broad and deep.

Transverse sections. Major septa are radially disposed, commonly sinuous, and subequal in length except for the cardinal septum, which is shortened in all growth stages, and alar septa, which in some corallites are longer than metasepta. Major septa extend approximately two-thirds the distance to the axis of the corallites in the early ephebic stages but are withdrawn in later stages. The cardinal fossula is invariably recognizable, but may be open or closed. Alar fossulae are not developed.

Major septa range from a recorded minimum of twenty-four at a diameter of 9.5 mm (septal ratio, 2.5) to a maximum of forty-six at a diameter of approximately 35 mm (septal ratio, 1.3). Major septa in the neanic stages are about 2.5 mm long and are well developed, normally crossing the entire dissepimental zone and extending a short distance (up to 1.2 mm) into the tabularium. Both major and minor septa are thin and crooked in the dissepimentarium but are thickened at the inner margin of this zone to produce a narrow inner wall; major septa are dilate in the tabularium and may be as



Text-fig. 13. Relationship of number of major septa (n) to increasing corallite diameter (d) in *Caninia petoczi* n. sp. Data based on holotype (UA 1084) and nineteen paratype specimens. Mean values computed for class intervals of 10 mm.

much as 1 mm thick adjacent to the inner wall. Septal microstructure appears to be fibro-normal.

The dissepimentarium does not appear in these corals until the middle neanic stage; thin sections of the early neanic stage (diameters of 9.5 mm or less) show no dissepiments, whereas this zone is between 1.5 and 2.5 mm wide in the late neanic and early ephebic stages (diameters of approximately 15 to 25 mm). Thereafter the dissepimentarium ranges from 3.0 to 5.0 mm in width (average, 3.5 mm), except for a single specimen in which this zone broadens to 9.0 mm at a diameter of about 35 mm (Pl. 8, fig. 6a). Dissepiments are dominantly anguloconcentric but an irregular herringbone pattern is produced by dissepiments in the inner part of the dissepimental zone in the late stages of growth. Minor septa do not reach the tabularium in the ephebic stages, and in most corallites are degenerate in the late ephebic stages.

Longitudinal sections. The tabularium consists of a broad central area, in width slightly more than one-third of the total corallite diameter, across which tabulae are closely spaced (one to ten per 10 mm), subhorizontal, and complete.

In the peripheral part of the tabularium (4 to 7 mm wide in ephebic stages) two to three ranks of tabellae are present which are inclined upward axially from about 15 to 40 degrees. The dissepimentarium, which commonly is broadest on the convex side of corallites, normally consists of only a few tiers of dissepiments, with as many as ten tiers in a few examples. Individual dissepiments average between 2 and 3 mm in their greatest length, but a few are as much as 6 mm long.

Discussion. *Caninia petoczi* n. sp. does not compare closely with any species of *Caninia* known to the writer, although *C. goldcreekensis*, described by Hoare (1964, p. 449, Pl. 76, figs. 1-4) from limestones of Wolfcampian age in Nevada is similar in overall size and number of major septa. *C. goldcreekensis*, however, has considerably more dilate major septa and a broader dissepimentarium than *C. petoczi*. *C. elkoensis* Hoare (1964, p. 499, Pl. 75, figs. 8-11) has a much broader dissepimentarium than *C. petoczi* and a less prominent cardinal fossula in those sections illustrated by Hoare. *Caninia hansenii*, described by Wilson and Langenheim (1962, p. 508, Pl. 87, figs. 3-8) from the Lower Permian Ely Limestone of Nevada, is a distinctive species which combines a narrow dissepimentarium and strongly dilate major septa.

The new species is named for Ronald G. Petocz, University of Alaska.

Material and occurrence. A total of twenty corallites were studied in thin section: the holotype (UA 1084) and seventeen paratypes (UA 1032-UA 1048) were collected at locality RC-17; two paratypes (UA 1049 and UA 1050) are from locality DR-14. These are believed to represent equivalent horizons and Lower Permian Fusulinidae are present in abundance at both localities. Both localities are located in the Upper Delta River area: Lower Permian (Wolfcampian or ?Lower Leonardian), McCallum Creek sequence.

Genus *Timania* Stuckenberg, 1895

Type species. *Timania schmidtii* Stuckenberg, 1895, pp. 62, 205; Pl. XV, figs. 4a, b; Pl. XVI, fig. 7; Pl. XVII, fig. 4: Upper Carboniferous, Ober Kohlenkalk, Timan, Russia.

Diagnosis. Large solitary corals with a prominent cardinal fossula closed by the strongly deflected axial ends of adjacent metasepta in the cardinal quadrants; in some growth stages the counter septum is elongate but is not thickened axially; major septa typically straight, but may be strongly dilated, especially in cardinal quadrants; minor septa variable in development in early growth stages, short in ephebic stages; dissepimentarium variable in width, composed of anguloconcentric, herringbone or pseudoherringbone dissepiments that may be thickened to produce an inner wall; axial area open.

Discussion. The diagnosis of *Timania* by Hill (1956, p. 292) is properly based upon characters exhibited by the type species, *T. schmidtii* Stuckenberg (1895). Other species of *Timania*, however, incorporate features that seem to require a somewhat broader interpretation of this genus than that given by Hill. For example, *T. mosquensis* Dobrolyubova (1937) has major septa that are strongly dilated in the cardinal quadrants and a well developed inner wall, whereas these features are not present in the type species. *Timania* nevertheless is distinct

from allied genera, such as *Bothrophyllum* Trautschold, which invariably possesses a weak aulophylloid axial structure. *Gshelia* Stuckenberg (1888), although similar in the ephebic stages to *Bothrophyllum*, has a well developed columella in the neanic stages. Although *Caninophyllum* Lewis is listed by Hill (1956, p. 292) as a valid genus, Campbell (1957, p. 92) stated that this genus may be congeneric with *Bothrophyllum*. *Caninophyllum* is, however, distinguished from *Timania* by its weak aulophylloid axial structure. Also, *Timania* is characterized, although not invariably, by its well developed cardinal fossula and elongate counter septum.

Timania is a widely distributed genus in the Upper Carboniferous and Lower Permian of the U.S.S.R. The type species was described by Stuckenberg (1895) from the upper Moscovian Myatshkovo (C_{II}^4) horizon in the north Urals; subsequently, species were described from the lower Moscovian Vereya (C_{II}^1) horizon by Kabakovich (1937) in the Moscow Basin and from the Teguliferina (C_{III}^0) horizon by Dobrolyubova (1940). Dobrolyubova (1936a) also reported *Timania* from the Lower Permian Sakmarian and Artinskian of the north Urals. This is the first published report of the genus *Timania* from North America.

Timania rainbowensis n. sp.

Plate 9, figures 1-4; Text-figures 14, 16, 17

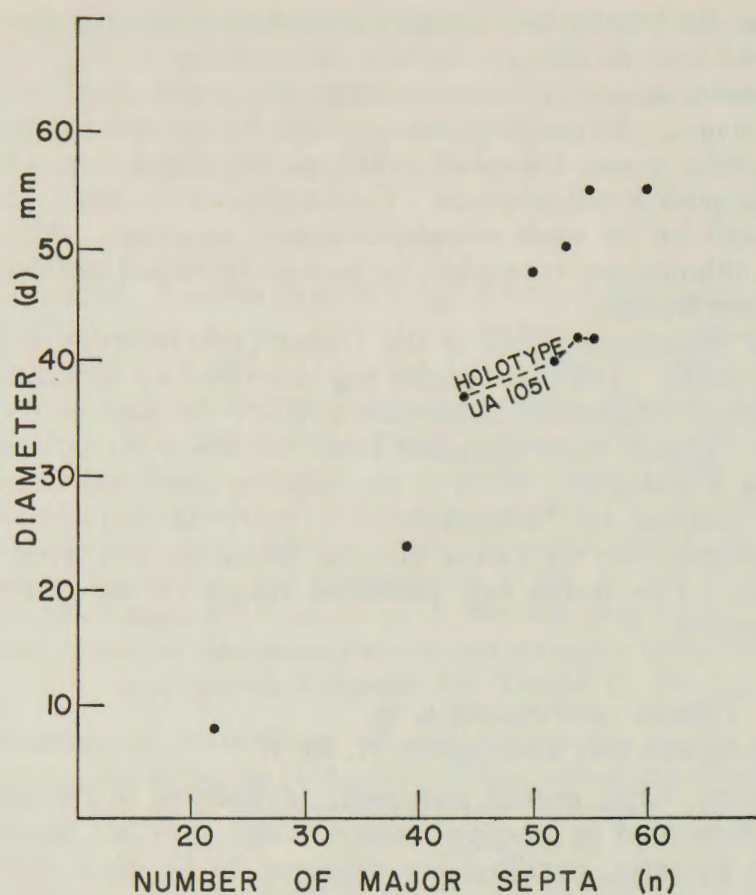
External. Corallites solitary, large, curved proximally, cylindrical in mature parts; all specimens are embedded in limestone matrix which prevents direct measurement of lengths; however, corallites are estimated to be more than 150 mm long. The maximum diameter recorded is approximately 70 mm; the epitheca is thin (1 mm or less in ephebic stages), but the nature of external markings is unknown. Brephic stages not preserved.

Transverse sections. In ephebic stages major septa are straight, radially disposed in the counter quadrants, with a slight trend toward pinnate arrangement in the cardinal quadrants; septa are dilate in all quadrants throughout the neanic and early ephebic stages, but dilation is limited to the cardinal quadrants in later stages of growth. The cardinal septum is short (one-third to one-half the length of adjacent metasepta) and occupies a prominent open fossula. The counter septum commonly is several millimetres longer than adjacent metasepta. Alar septa commonly are recognizable, but pseudofossulae are not developed.

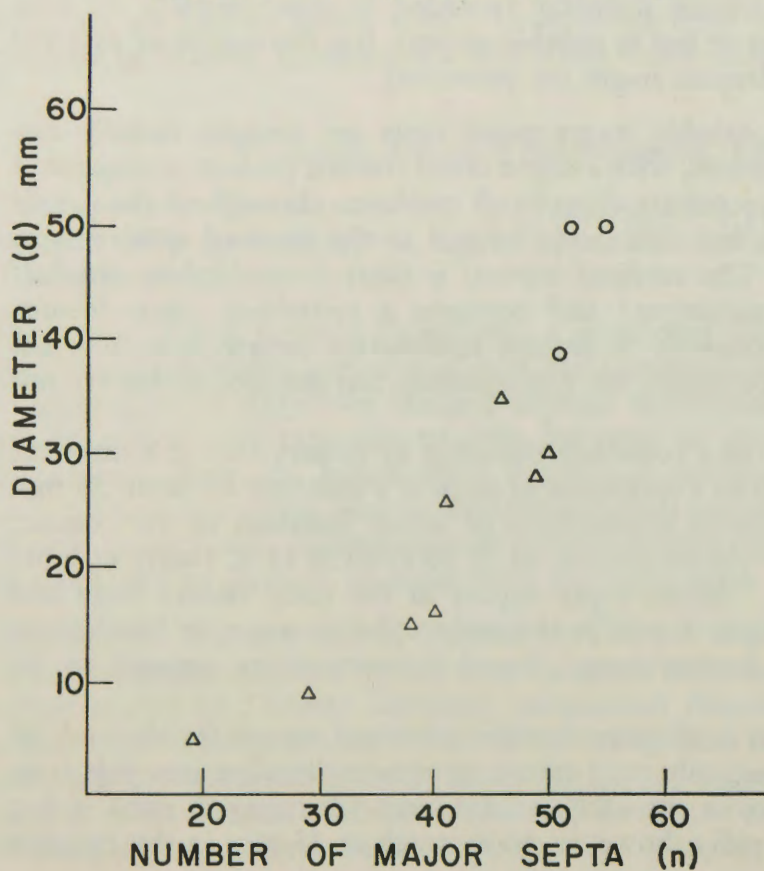
Major septa range from a recorded minimum of twenty-two at a diameter of 8 mm (septal ratio, 2.8) to a maximum of sixty at a diameter of about 55 mm (septal ratio, 1.1). Moderate acceleration of septal insertion in the counter quadrants is indicated by the formula K 15 A 10 C 10 A 15 K (early ephebic stage, diameter 42 mm). Minor septa appear in the early neanic stage and lengthen thereafter to about 2 mm in the early ephebic stage; in later stages minor septa are 1 mm or less long. Septal microstructure appears to be diffusotrabeular.

The axial area is open in all growth stages observed except for the ends of major septa which uncommonly may extend as sinuous lamellae into this area.

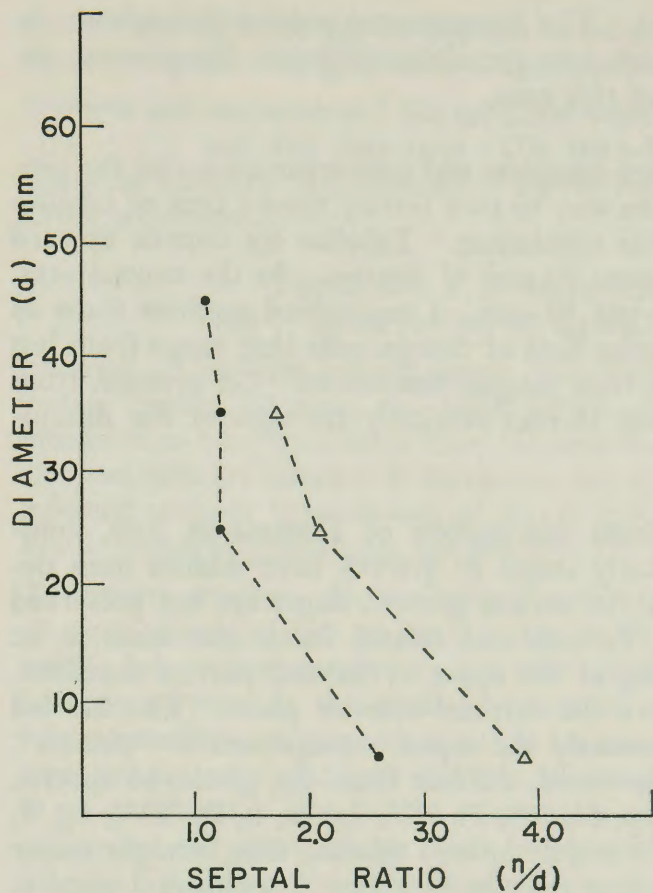
The dissepimentarium in the early neanic stage (diameter, 8 mm) is but 2 mm wide; it widens rapidly, however, to as much as 15 mm in the ephebic



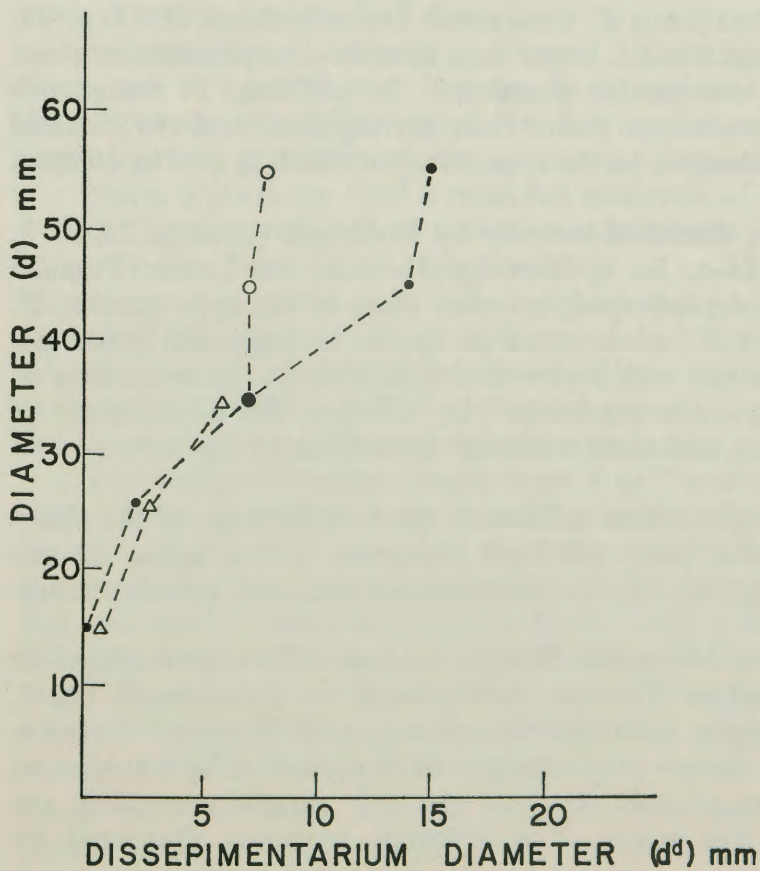
Text-fig. 14. Relationship of number of major septa (n) to increasing corallite diameter (d) in *Timania rainbowensis* n. sp. Data based on holotype (UA 1051) and six paratype specimens.



Text-fig. 15. Relationship of number of major septa (n) to increasing corallite diameter in *Timania* cf. *T. schmidt* Stuckenberg (O) and in *Timania* sp. A (Δ). Data based on a total of eight corallites.



Text-fig. 16. Comparison of change in septal ratios (n/d) with increasing corallite diameter (d) in *Timania rainbowensis* n. sp. (●) and in *Timania* sp. A (△). Mean values for septal ratios computed for class intervals of 10 mm.



Text-fig. 17. Comparison of dissepimentarium diameter (d^d) with increasing corallite diameter (d) in species of *Timania*. Mean values for d^d computed for class intervals of 10 mm. *Timania rainbowensis* n. sp. (●), *Timania* cf. *T. schmidtii* Stuckenberg (○), *Timania* sp. A (△).

stages (diameters of 40 to 50 mm). The dissepimental pattern throughout the ephebic stages is herringbone with rare pseudoherringbone dissepiments developed in the peripheral 1 mm of this zone.

Longitudinal sections. Tabulae are complete and subhorizontal across the central part of the tabularium but give way to two (rarely three) tiers of tabellae in the peripheral 5 to 8 mm of the tabularium. Tabellae are convex upward and inclined upward axially between 30 and 45 degrees. In the central area, from eight to ten tabulae occur per 10 mm. Longitudinal sections show as many as eighteen to twenty irregular tiers of dissepiments that range from less than 1 mm to more than 5 mm in their longest dimensions. On average, from four to six dissepiments occur per 10 mm vertically throughout the dissepimentarium.

Discussion. Despite the widespread distribution of *Timania* in Asia, comparison of species is difficult. Early stages of growth have seldom been described or illustrated, and indeed, the earliest growth stages are not preserved in the material described here. *Timania* and related forms also seem to be particularly susceptible to crushing of the upper cylindrical part of corallites, most commonly at right angles to the cardinal-counter plane. This has led several authors to describe erroneously the septal arrangement as "pinnate". *Timania rainbowensis* n. sp. is, however, distinct from the genotype species, *T. schmidtii* Stuckenberg (1895, pp. 62, 205; Pl. XV, fig. 4a, b; Pl. XVI, fig. 7; Pl. XVII, fig. 4), which has more widely spaced tabulae, thin, straight major septa and an anguloconcentric rather than herringbone dissepimental pattern. This species is distinguished from *T. mosquensis* Dobrolyubova (1937, p. 74; Pl. II, figs. 1-7) by its overall much larger size, broader dissepimentarium, and more numerous septa at comparable diameters. In addition, *T. mosquensis* has anguloconcentric dissepiments rather than herringbone, and the cardinal septum in that species is elongate in the neanic stages which is also in contrast to *T. rainbowensis*.

Timania multiseptata, described recently by Fedoroski (1965, p. 22, Pl. 1, fig. 6; Pl. 3, figs. 1a-e, 2a-c, 3a, b; Text-fig. 3) from the Lower Permian Treskelodden beds of Vestspitsbergen, is rather close to the type species, *T. schmidtii*. It differs from *T. rainbowensis* n. sp. in having more numerous septa at comparable diameters and is also distinguishable by its restriction of thickened septa to the counter quadrants. In addition, the dissepiments of *T. multiseptata* are smaller and more vesicular than those of the new species described above.

Several corallites described here as *Timania* sp. A differ from all the above species of *Timania* in that they combine lanceolate major septa, an extremely short cardinal septum, narrow dissepimentarium, and pseudoherringbone dissepiments.

Corals from the lower Moscovian Kashira horizon (C_{11}^2) in the Moscow Basin that were described as *Timania stuckenbergi* by Kabakovich (1937, p. 95, Pl. III, figs. 1-5) appear not to be representatives of *Timania*. Kabakovich's illustrations show a distinct axial structure to be present in both transverse and longitudinal sections of this species, which is inconsistent with the established diagnosis of this genus. The holotype specimen illustrated by

Kabakovich (Pl. III, fig. 5) appears to be a representative of *Bothrophyllum pseudoconicum* (compare with Dobrolyubova, 1937, Pl. XIII, figs. 1-6).

Material and occurrence. Six corallites were studied in thin section: holotype (UA 1051) and five paratypes (UA 1052-UA 1055) from locality MC-13, Southern Rainbow Mountain area: Lower Permian (Wolfcampian), McCallum Creek sequence.

Timania cf. *T. schmidtii* Stuckenberg, 1895

Plate 9, figure 5; Plate 10, figure 3; Text-figures 15, 17

External. Corallites solitary, large, cylindrical in ephebic stage; maximum diameters exceed 60 mm; the total length of one (incomplete) specimen is estimated to have been more than 150 mm; the epitheca is thin (1 mm or less); all specimens are encased in limestone, but the exterior of the epitheca can be inferred to have been devoid of septal grooves and ridges; the brephic and neanic stages of growth are not preserved.

Transverse sections. In the early ephebic stage major septa are long (12 to 14 mm), thin (0.3 mm or less) except in the cardinal quadrants, and straight except for deflection of the axial ends of septa around the cardinal fossula. Dilation of septa in the cardinal quadrants is marked, and septa in this part of the corallites are as much as 1.0 to 1.5 mm thick. In later stages of growth septa are uniformly straight and thin (0.2 mm or less) and are radially arranged in all quadrants. The cardinal septum is only slightly shorter than adjacent metasepta and occupies an open but prominent fossula; it is thick (1.0 to 1.3 mm) in the early ephebic stage but thin in later stages. The counter septum is thin, straight, and remarkably long (up to 20 mm in one transverse section which has a diameter of 40 mm) (Pl. 9, fig. 5a); this may extend as much as 6 to 8 mm farther into the open axial area than adjacent metasepta. Alar septa are not differentiated but can be recognized in the early ephebic stages by their position with respect to the thickened cardinal quadrants.

Major septa range from a recorded minimum of fifty-one at a diameter of 39 mm (septal ratio, 1.3) to a maximum of about fifty-five at a diameter of about 50 mm (septal ratio, approximately 1.1). The septal formula for one specimen at a diameter of 51 mm (ephebic) is K 13 A 11 C 11 12 K, which is typical of this species. Minor septa are up to 6 mm long in the early ephebic stage but are withdrawn (2 to 4 mm) in later stages of growth; they do not penetrate the tabularium in any observed growth stage. Septal microstructure is diffusotrabecular. There is no axial structure.

The dissepimentarium ranges from 3 to 7 mm wide in the early ephebic stage and is up to 9 mm across in later stages of growth. This zone is not sharply differentiated except in the early ephebic stage where an inner wall is developed in the cardinal quadrants. Dissepiments are both anguloconcentric and, rarely, pseudoherringbone in the early ephebic stage; in later stages only anguloconcentric and herringbone dissepiments are present. In the latest stages of growth the large anguloconcentric dissepiments at the inner margin of the dissepimentarium can be distinguished only with difficulty from the steeply inclined tabellae of this region.

Longitudinal sections. Tabulae are mostly complete, subhorizontal to slightly domed across the axial area and deflected downward near the margins of the

tabularium. Complete tabulae are locally replaced by tabellae in the peripheral 3 to 5 mm of the tabularium, but this zone is poorly developed. A few clinotabellae are present. The central region is crossed by from four to six tabulae per 10 mm. Dissepiments are arranged in irregular tiers and vary from 1 to 6 mm in length.

Discussion. These corallites incorporate the essential characters of *Timania*, i.e., the absence of an axial structure, pronounced cardinal fossula, and elongate counter septum. Characters observed in five transverse and four longitudinal sections compare closely with the genotype species, *T. schmidt* Stuckenberg (1895), in particular with respect to (1) the straight, thin major septa, (2) well developed minor septa, (3) prominent cardinal fossula, and (4) absence of an inner wall in the late stages of growth. Unfortunately the attitude and spacing of tabulae cannot be compared with *T. schmidt* as only the brephic and neanic stages are illustrated in longitudinal section (Stuckenberg, 1895, Pl. XVII, fig. 4). Efforts to borrow the type material were not successful, and it thus was impossible to ascertain whether *T. schmidt* compares closely with this form in the early ephebic stage. Differences in the late stages of growth appear to be slight, although Stuckenberg's species has more (up to seventy-five) major septa. These corals compare most closely with *T. multiseptata* Fedoroski (1965, p. 22) from the Lower Permian of Vestspitsbergen but can be distinguished from that species by their elongate and thin counter septum, narrow dissepimentarium and incipient alar pseudofossulae. *Timania mosquensis* Dobrolyubova (1937, p. 74, Pl. II, figs. 1-7) is a much smaller form with a narrow dissepimentarium and uniformly dilated septa that does not require detailed comparison. *Timania* cf. *T. schmidt* differs from *T. rainbowensis* n. sp. in having mostly complete tabulae, a narrower dissepimentarium, more pronounced thickening of septa in the cardinal quadrants in the early ephebic stages, and thinner septa in the late ephebic stage.

Material and occurrence. Four corallites (UA 1056 through UA 1059) from locality VV-21a, McCallum Creek area: Lower Permian (Wolfcampian or ?Lower Leonardian), McCallum Creek sequence.

Timania sp. A

Plate 10, figures 1, 2; Text-figures 15-17

External. Corallites solitary, medium size, cylindrical in ephebic stage; the maximum diameter recorded is 30 mm; the length of the largest specimen, which is incomplete, probably was in excess of 80 mm; direction of curvature and external markings could not be determined as all specimens are encased in limestone; brephic and early neanic stages are not preserved; the epitheca is between 0.2 and 0.3 mm wide in transverse sections.

Transverse sections. Major septa are radially arranged in the counter quadrants but deflected toward the cardinal fossula in the cardinal quadrants; septa are thin and crooked across the dissepimentarium, where they are 0.2 mm or less wide; in the tabularium major septa are lanceolate in all quadrants and up to 1.6 mm wide. The cardinal septum is short in all observed stages of growth and approximates two-thirds the length of adjacent metasepta; it occupies a prominent fossula which in some stages is closed by the axial ends of metasepta. The counter septum is longer than adjacent septa in the neanic stages and

extends to the axis of the corallites (Pl. 10, fig. 2d); in later stages it may be only slightly longer or not differentiated; pseudofossulae are not developed.

Major septa range from an observed minimum of nineteen at a diameter of 4.5 mm (septal ratio, 4.2) to a maximum of fifty at a diameter of 30 mm (septal ratio, 1.7). Septal insertion is only moderately accelerated in the counter quadrants throughout the neanic stages as indicated by the formula K 10 A 7 C 7 A 10 K (diameter, 14 mm); septal insertion in later growth stages is nearly equal: K 12 A 10 C 11 A 13 K (diameter, 30 mm). Minor septa are short (1.2 mm or less) in the neanic stages and only slightly longer in the ephebic stages (2.5 mm or less); in no stage do they completely cross the dissepimentarium. Septal microstructure is diffusotrabecular.

The axial area is open but may contain a few sinuous septal ends or the distal end of the elongate counter septum.

The dissepimentarium reaches a maximum width of approximately 7 mm in the ephebic stages and is composed of up to eight tiers of dissepiments; these form a herringbone pattern in the inner part of the dissepimental zone but are dominantly pseudoherringbone in the peripheral region. The dissepimentarium is distinctly set apart from the tabularium by an inner wall formed in the innermost dissepiments. Longitudinal sections could not be prepared from the available material; however, in transverse sections tabulae appear to be mostly complete, subhorizontal in the central part of the tabularium and deflected downward in the peripheral part of this area.

Discussion. Although referable to *Timania* on the basis of gross morphology, these specimens do not compare closely with either *T. cf. T. schmidtii* or *T. rainbowensis* n. sp. Major differences in morphology include the narrow dissepimentarium, lanceolate septa, and septal dilation in all quadrants in the present form. With regard to size, these corals resemble *T. mosquensis* Dobrolyubova (1937, p. 74, Pl. II, figs. 1-7) which has, however, a long cardinal septum in the neanic stage. Also, *T. mosquensis* lacks pseudoherringbone dissepiments and septal dilation is confined to the cardinal quadrants in the ephebic stages. The limited material at hand is not, however, adequate for description of a new species of *Timania*.

Material and occurrence. Parts of four corallites (UA 1060 through UA 1063) from locality MC-0, Southern Rainbow Mountain area: Lower Permian (Wolfcampian), McCallum Creek sequence.

Genus *Bothrophyllum* Trautschold, 1879

Type species. *Bothrophyllum conicum* (Fischer von Waldheim) Trautschold, 1879, p. 30, Pl. V, figs. 1a-f: ?Middle Carboniferous, Moscow Basin, Russia.

Diagnosis. Solitary large cyathopsid corals with a weak aulophylloid axial structure produced by septal ends and axial tabellae; major septa are characteristically dilate, especially in the cardinal quadrants; the cardinal and counter septa are variable in length and may be joined across the tabularium in neanic stages; minor septa are present but also variable in length; the dissepimentarium is composed of predominately anguloconcentric dissepiments but herringbone and pseudoherringbone types may be developed; lonsdaleoid dissepiments are rare.

Discussion. *Bothrophyllum* is a distinct but variable genus that has been believed to be rare or absent in North America. It is common in rocks of Viséan age in western Europe, where it has most often been described as *Pseudocania* Stuckenberg, and in rocks of "Carboniferous" age in China. In the U.S.S.R., *Bothrophyllum* is a common and important element in rugose coral faunas of the upper Carboniferous (Moscovian and Kasimovian) of the Moscow Basin. In that region various species of *Bothrophyllum* have been recognized index fossils for several widespread horizons, including the Podolsk (C_{II}^3) and Kashira (C_{II}^2) (*Bothrophyllum pseudoconicum*) and the higher Myatshkovo (C_{II}^4) and Teguliferina (C_{III}^0) horizons. Short English summaries of the areal distribution and stratigraphic value of this genus in the Moscow Basin of Russia are given by Dobrolyubova (1937, p. 72; 1940, p. 55) and by Kabakovich (1937, p. 109). Full description of species and discussions are in Russian.

Campbell examined the type species of *Caninophyllum* Lewis, which has as its type species *C. archiaci* and concluded (1957, p. 92) that the difference between this species and *Bothrophyllum conicum* may be only specific. The similar distribution of *Bothrophyllum* and *Caninophyllum*, although not conclusive, also suggests that the two genera need further study. *Bothrophyllum* is the older name and is used here.

Corallites from the Alaska Range referred to *Bothrophyllum* are limited to three localities in the McCallum Creek sequence. All are poorly preserved and incomplete, and sections of growth stages earlier than middle neanic could not be made. Since *Gshelia* Stuckenberg, whose type species (*G. rouilleri* Stuckenberg) was emended by Dobrolyubova (1940, p. 41), is apparently identical to *Bothrophyllum* in the ephebic stages but possesses a columella in early (earliest neanic) stages, it is possible that this genus may be represented among the corals described here.

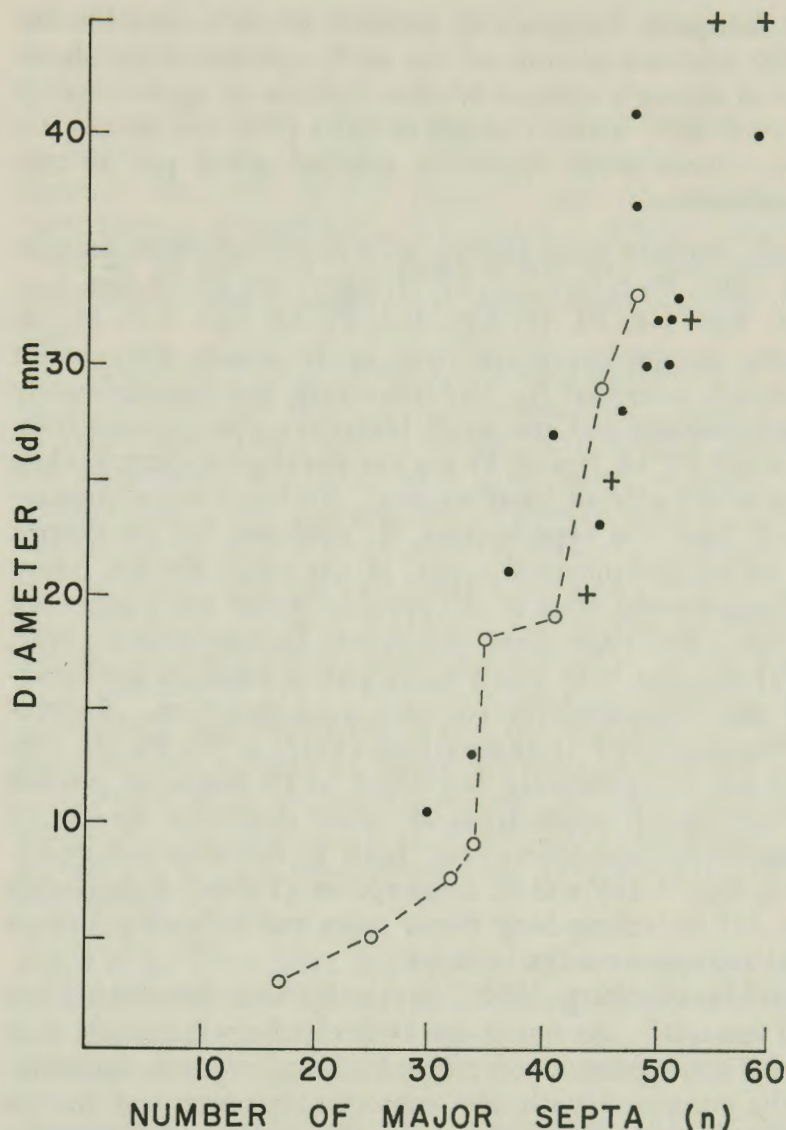
Bothrophyllum cf. *B. pseudoconicum* Dobrolyubova, 1937

Plate 10, figure 6; Plate 11, figures 1, 2; Text-figure 18

External. Corallites are solitary, large, cylindrical in ephebic stages, curved in plane of cardinal and counter septa in earlier stages with the cardinal septum at or near the convex side of corallites; no specimen is complete, but overall lengths probably were 140 mm or more; the maximum diameter recorded is approximately 45 mm; the epitheca is thin (1 mm or less) and marked externally by subdued rugae and faint septal grooves and ridges.

Transverse sections. Major septa are radially disposed, subequal in length (10 to 12 mm in ephebic stages) except for the cardinal septum, which is short (4.0 to 6.5 mm) and occupies a distinct open fossula. In some growth stages the counter septum may be a few millimetres longer than adjacent metasepta and is at times (principally in the neanic and early ephebic stages) joined to the cardinal by a sinuous lamella that crosses the tabularium. Major septa are thickened in the cardinal quadrants and may be slightly lanceolate in the ephebic stages (Pl. 10, fig. 6c; Pl. 11, fig. 1b).

Major septa range from a recorded minimum of thirty at a diameter of 10.5 mm (septal ratio, 2.9) to a maximum of about fifty-nine at a diameter of about 45 mm (septal ratio, approximately 1.3). The rate of septal insertion



+ + Text-fig. 18. Relationship of number of major septa (n) to increasing corallite diameter (d) in the holotype (469) of *Bothrophyllum pseudoconicum* Dobrolyubova, 1937 (○) and in specimens from the Alaska Range referred to this genus. *Bothrophyllum* cf. *B. pseudoconicum* (●), *Bothrophyllum* sp. A (+).

is only slightly greater in the counter quadrants, as indicated by the formulae K 8 A 6 C 5 A 7 K (neanic, 10.5 mm) and K 13 A 10 C 10 A 12 K (ephebic, diameter 30 mm). Minor septa cross the narrow dissepimentarium in the neanic stages but are restricted to the outer part of this zone in the ephebic stages. Septal microstructure is fibro-normal.

The axial structure is weakly aulophylloid and is produced by the sinuous axial ends of from one-fourth to one-third of the major septa and axial tabellae; a sinuous or comparatively straight lamella connecting the cardinal and counter septa is commonly present and in the neanic stages this may bear several short septal lamellae (Pl. 11, fig. 1c); this condition does not persist, however, and in the ephebic stages the axial structure is characteristically highly irregular.

The dissepimentarium is narrow (2.5 to 5.5 mm in ephebic stages) and is composed of predominately anguloconcentric dissepiments; in some areas a herringbone and/or pseudoherringbone pattern is present in the peripheral part of the dissepimentarium; innermost dissepiments are thickened in the cardinal quadrants to produce an inner wall.

Longitudinal sections. Adequate longitudinal sections are not available for description. One poorly oriented section of the early ephebic stage shows from three to five ranks of strongly convex tabellae that rise at approximately 45 degrees toward the axial area, which consists of axial ends and steeply inclined irregular tabellae. From seven to twelve tabellae occur per 10 mm adjacent to the dissepimentarium.

Discussion. These corals compare most closely with *Bothrophyllum pseudoconicum* Dobrolyubova (1937, Pl. 5, figs. 2-7; Pl. 12, figs. 1-10; Pl. 13, figs. 1-6; Pl. 14, figs. 1-2; Pl. 15, figs. 1-8; Pl. 16, figs. 1-3; Pl. 17, figs. 1-2; Pl. 18, figs. 1-8). Although the present specimens have up to almost sixty major septa whereas the maximum recorded by Dobrolyubova was approximately ten fewer for *B. pseudoconicum*, and the small blisterlike dissepiments illustrated by Dobrolyubova (cf. Pl. 14, figs. 1, 2) are not developed, there is close agreement to her species in virtually all other aspects. *Bothrophyllum pseudoconicum* is distinguished from the type species, *B. conicum*, by its shorter minor septa and more varied dissepimental types; in the latter species, minor septa cross the entire dissepimental zone in the ephebic stages and commonly extend into the tabularium. *Bothrophyllum complexum* Dobrolyubova (1937, p. 37, Pl. 10, figs. 12-19) also has long minor septa and in addition is characterized by a persistent and comparatively complex axial structure. *Bothrophyllum trautscholdi* (Stuckenberg) Dobrolyubova (1937, p. 39, Pl. 10, figs. 20-5; Pl. 23, figs. 8-11) has comparatively few septa in all stages of growth which, with other factors, sets it apart from all other described species of *Bothrophyllum*. *B. pseudoconicum* differs from both *B. kashiricum* Kabakovich (1937, p. 102, Pl. 4, figs. 1-10) and *B. longiseptum* (Lewis) Kabakovich (1937, p. 100, Pl. 1, fig. 16) in lacking long minor septa and in having a more prominent dissepimental zone and cardinal fossula.

Bothrophyllum baeri Stuckenberg (1895) originally was described from fragmental and limited material. As noted by Dobrolyubova (1936b), it is probable that two species are represented by Stuckenberg's figures; however, these cannot be usefully compared with any subsequently described species and *B. baeri* may best be regarded as an unrecognizable species until the type material can be restudied and more fully described.

Fedoroski (1965, p. 31, Pl. 3, figs. 4a, b; Pl. 4, figs. 2a, b, 3; Text-fig. 6a-g) recently described *Bothrophyllum permicum* from the Lower Permian Treskelodden beds of Vestspitsbergen. However, the small mature diameters, comparatively few septa, and other morphological features set this small form sharply apart from all other described species of the genus.

Material and occurrence. Seven corallites, all incomplete and lacking the brephic and early neanic stages; three specimens (UA 1064 through UA 1066) are from locality MC-3 and four specimens (UA 1067 through UA 1070) are from locality MC-7. Both localities are in the Southern Rainbow Mountain area: Lower Permian (Wolfcampian), McCallum Creek sequence.

Bothrophyllum sp. A

Plate 10, figures 4, 5; Text-figure 18

External. Corallites solitary, medium to large, cylindrical in ephebic stages, curved proximally with cardinal septum at or near convex side; overall length

probably in excess of 100 mm; epitheca thin (1 mm or less); calice and external markings unknown.

Transverse sections. Major septa radially arranged in ephebic stages, subequal in length (up to 15 mm), distinctly lanceolate; the cardinal septum is very short in the early ephebic stages (3 mm or less) and occupies a prominent open fossula; in later stages the fossula is obscure and the cardinal septum is as much as 10 mm long; the counter septum is not differentiated; however, alar septa are markedly thicker and longer than adjacent metasepta in the ephebic stages.

Major septa range from a recorded minimum of forty-four at a diameter of 20 mm (septal ratio, 2.2) to a maximum of sixty at a diameter of about 45 mm (septal ratio, approximately 1.3). Septal arrangement is indicated by the formula K 14 A 10 C 10 A 15 K (early ephebic stage, diameter 32 mm). Minor septa cross the narrow (1 mm or less) dissepimentarium in the late neanic stages but are short and confined to the outermost part of this zone in the ephebic stages. Septal microstructure is fibro-normal.

The axial structure in this form is weakly aulophylloid and typical of the genus. The dissepimentarium is 1 mm or less wide in the neanic stages and up to 4 mm across in the ephebic stages; dissepiments are highly irregular but dominantly anguloconcentric and herringbone; a few pseudoherringbone dissepiments are present in the peripheral 1 mm of this zone.

Longitudinal sections could not be prepared from the limited material available. However, transverse sections suggest that from two to four tiers of tabellae are present between the irregular axial structure and the dissepimentarium.

Discussion. The gross morphology of these corallites permits their assignment to *Bothrophyllum* Trautschold. However, the poorly preserved material at hand is insufficient for species assignment. The numerous septa and unusual development of alar septa suggest that a new species is represented.

Material and occurrence. Three corallites (UA 1071 through UA 1073) from locality MC-1, Southern Rainbow Mountain area: Lower Permian (Wolfcampian), McCallum Creek sequence.

Order **TABULATA** Milne-Edwards and Haime, 1850

Family **AULOPORIDAE** Milne-Edwards and Haime, 1851

Genus *Cladochonus* M'Coy, 1847

Type species. *Cladochonus tenuicollis* M'Coy, 1847, p. 227, Pl. xi, fig. 8: Lower Carboniferous, New South Wales, Australia (subsequent designation by Milne-Edwards and Haime, 1850, p. 1xxvi).

Diagnosis. "Proximal corallites in reptant ring from which free branches arise; individual corallites trumpet- or pipe-shaped, in contact only at points of origin, each giving rise to another by lateral increase through wall of the expanded calice; each with a thick peripheral stereozone of laminar or reticulate

sclerenchyme. Septal spines and tabulae lacking in the narrow lumen, but septal ridges may appear in the calices." (Hill and Stumm, 1956, p. 472).

Discussion. The history of the taxonomy of *Cladochonus* is well known; it is not reviewed here except to note that the proximal ring of corallites in *Cladochonus* were for many years referred to *Monilipora* ("Monilopora") Nicholson and Etheridge, 1879. Restudy of the type materials by Hill and Smyth (1938) demonstrated the synonymy of *Monilipora* to *Cladochonus*. Although Girty (1925, p. 23) also recognized the identity of these two genera, he incorrectly designated *C. crassus* (M'Coy) (= *Jania crassa* M'Coy, 1844) as the type species of *Cladochonus*. *C. tenuicollis* M'Coy (1847) subsequently was established as the lectotype of the genus by Hill and Smyth (1938).

Cladochonus sp. A
(Not illustrated)

Description. Corallites are slender, trumpet-shaped, and produced by lateral increase to face in opposite directions; new buds arise singly between 1.0 and 2.0 mm from the rim of parent corallites; they are 1.0 to 1.5 mm in diameter at their base and increase slowly in width to a maximum of 3.0 to 3.5 mm at the calice. In overall length corallites range from 8.0 to 11.5 mm. The epitheca bears very fine transverse growth lines and in several examples has faint longitudinal furrows near the calice; corallite walls are approximately 0.25 mm thick in the early growth stage and thin, 0.15 to 0.2 mm, in the mature parts. Septal ridges were not observed but this may be due to poor preservation.

Discussion. The above description is based on fragments of several coralla which are poorly preserved and include a total of only seventeen corallites, mostly incomplete. All specimens are partly embedded in rock matrix and are crushed to varying degrees. These corals can be referred with confidence to *Cladochonus*, but cannot be compared with described species because of the poor condition of the material.

Material and occurrence. Parts of several coralla including seventeen complete and incomplete corallites; all specimens are from locality RM-8, Northern Rainbow Mountain area: Lower Pennsylvanian (post-Morrowan, pre-Missourian) Rainbow Mountain sequence.

Genus *Syringopora* Goldfuss, 1826

Type species. *Syringopora ramulosa* Goldfuss, 1826, p. 76, Pl. 25, fig. 7: Carboniferous of Germany (subsequent designation by Milne-Edwards and Haime, 1850, p. 1xii).

Diagnosis. "Closely or loosely set cylindrical corallites connected in most species by hollow, transverse stolons. Septa lacking or represented by 12 vertical rows of small spinules; tabulae closely set, deeply depressed axially, coalesced in some species to form a continuous axial tube." (Hill and Stumm, 1956, p. 472).

Discussion. For over a century *Syringopora* Goldfuss was considered to be a readily identified and distinct genus. It remains so in many regions, particularly in rocks of Mississippian age or older. In recent years, however, both

Syringopora and the dominantly Asiatic tabulate coral *Multithecopora* Yoh (type species, *M. penchiensis* Yoh, 1925, p. 291, Pl. 1, figs. 1-3) have been recognized and described from rocks of Upper Carboniferous and Permian age in western and northwestern North America. Some confusion has arisen with regard to the distinguishing characters of these two genera; this may continue until the limits of variability in *Multithecopora* are better understood and documented.

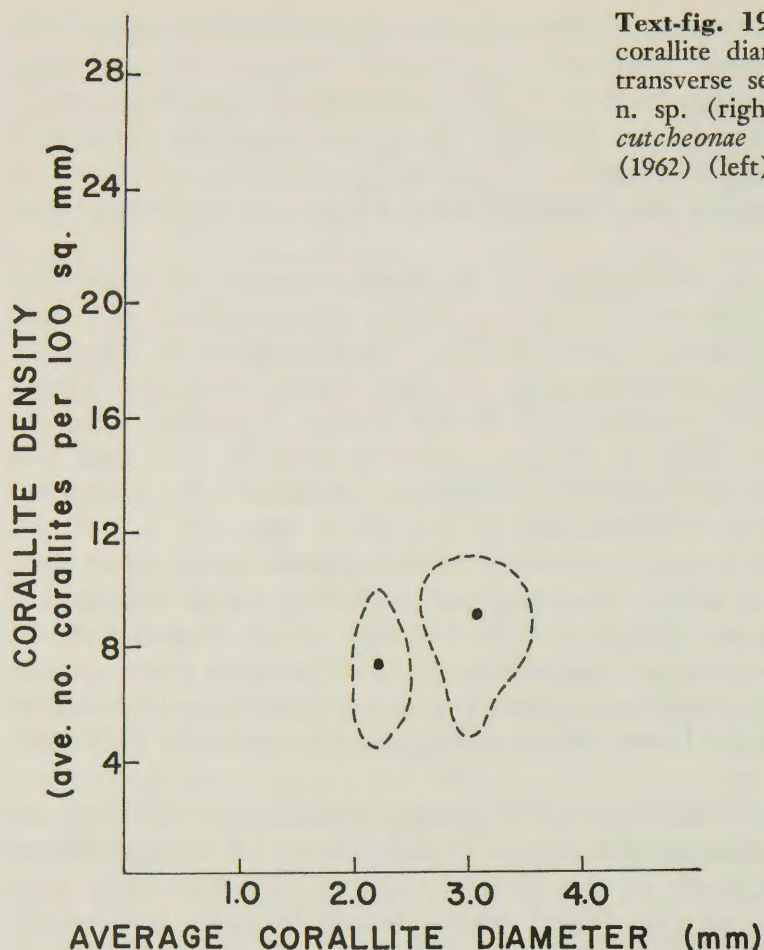
The earliest report of *Multithecopora* in North America of which the writer is aware is that of Moore and Jeffords (1945), who described *M. paucitabulata* from the Lower Pennsylvanian Marble Falls Formation in Texas (p. 189, Text-figs. 204, 205). Subsequently, tabulate corals from the Upper Pennsylvanian (?) Lower Limestone unit in the Yukon Territory were described as *M. penchiensis* Yoh? by Nelson (1962, p. 959, Pl. 138, figs. 1-9; Text-figs. 4a, b) and from the Lower Pennsylvanian (Atokan?) Ely Limestone in Nevada as *M. hypatiae* by Wilson (1963, p. 158, Pl. 21, figs. 1-5, 7-9; Pl. 22, figs. 1-7). Certain other recently described tabulate corals appear to be very close to *Multithecopora* in one or more respects, including corals described as *Syringopora* sp.? by Nelson (1962, p. 962, Pl. 138, figs. 10-14, Text-figs. 4c-h) and as *Bayhaium merriamorum* by Langenheim and McCutcheon (1959, p. 100, Pl. 19, figs. 1-6). These corals were from the Pennsylvanian or Permian of the Yukon Territory and the Lower Permian McLeod Limestone of California, respectively.

With the exception of *Multithecopora paucitabulata* Moore and Jeffords, all these species occur in Carboniferous and Permian rocks of the Cordilleran region to the west and north of the largely endemic Mid-Continent coral faunas. The boundaries of this faunal realm, which includes increasingly numerous "Asiatic" corals toward the west and north, can now be defined much more exactly than was heretofore possible during the Lower Permian, especially for rocks of Wolfcampian and Leonardian age. The details of this distribution are discussed elsewhere in this study. It is, however, important to this discussion to point out that the discovery of tabulate corals morphologically intermediate between Mid-Continent syringoporoids and Asiatic forms such as both *Multithecopora* Yoh and *Sinopora* Sokolov (1955) should not be surprising. Indeed, *Sinopora* is among the tabulate corals represented in the Lower Permian rocks in the east-central Alaska Range and tabulate corals described below as *Syringopora katoi* n. sp. are in some respects very close to *Multithecopora*. Points of correspondence include (1) possession of thick, concentrically lamellar corallite walls, (2) dominantly complete tabulae, and (3) very short connecting processes, or stolons. They are assigned to *Syringopora* primarily on the basis of the presence of infundibular tabulae and rudimentary septa, but this assignment may require modification at some future date.

Syringopora katoi n. sp.

Plate 11, figure 3; Plate 12, figures 1-3; Text-figure 19

Description. The form and overall dimensions of the coralla, which are embedded in detrital volcanic-rich limestones, could not be determined. However, the diameter of one corallum (holotype, UA 1081) is in excess of 100 mm and its



Text-fig. 19. Relationship of average corallite diameter to corallite density in transverse sections of *Syringopora katoi* n. sp. (right) and in *Syringopora mc-cutcheonae* Wilson and Langenheim (1962) (left).

height is more than 80 mm. A second corallum is somewhat smaller but fragmentary. Growth form is fasciculate, with phaceloid corallites in the distal and intermediate parts of the corallum. One section through the proximal part shows reptant corallites.

Transverse sections show cylindrical or subcylindrical corallites distributed at from five to eleven per 100 square millimetres; the average density is between eight and nine corallites in an area of this size. Corallites may be laterally in contact or separated by 5 mm or more. In cross-section they are subcircular except where crowding occurs, where they may be polygonal or flattened on one or more sides. In diameter corallites range from 2.5 to 3.5 mm, with an average close to 3.0 mm. Corallite walls are thick, from 0.2 to 1.2 mm (average, approximately 0.4 mm), and many seem to be composed of concentrically lamellar microstructure. Commonly, however, this seems to be produced by the upturned peripheral margins of distally concave tabulae (Pl. 11, fig. 3b). In most corallites recrystallized (?) calcite fibres are radially oriented. This recrystallization makes the identification of septa difficult, but in a few examples septa seem to have originated at the epitheca and penetrated the sclerenchyme of the walls to extend as much as 0.2 mm into the axial canal. Projections of skeletal tissue into the axial canal not clearly related to septa are common. Tabulae intersected by transverse sections appear as one to four curved or circular elements, commonly "floating" in the open axial area.

Corallites are periodically joined by short connecting processes which have a regular horizontal zonation throughout the corallum. In some transverse thin sections, for example, these processes are altogether absent, whereas in other sections most corallites are interconnected (Pl. 11, fig. 3a). Commonly irregular "chains" of ten or more corallites are connected in this way. The walls of these connective processes are equal or only slightly thinner than corallite walls. The interconnecting canals are short (0.5 to 1.5 mm long) and most are between 0.2 and 0.3 mm wide.

Longitudinal sections of this species show several types of tabulae to be present. Most are complete, 0.1 to 0.5 mm thick, and distally concave. From eight to eleven tabulae of this type may occur within a distance of 5 mm along the axial canal. Incomplete tabulae are also present, as well as strongly infundibular tabulae which coalesce to produce an axial tube, generally adjacent to the corallite wall. Mural pores as much as 0.5 mm in diameter are irregularly distributed throughout both longitudinal and transverse sections.

Discussion. *Syringopora mccutcheonae* Wilson and Langenheim (1962, p. 515, Pl. 89, figs. 11-13) from the Lower Permian (Wolfcampian) of Nevada is the only described species known to the writer that possesses both mural pores and zonation of short connecting processes. This species is also similar to *Syringopora katoi* n. sp. with respect to the variety and spacing of tabulae. However, *S. katoi* n. sp. is a considerably larger form (see Text-fig. 19) and lacks the "coenenchyme-like transverse laminae" of *S. mccutcheonae*. Additionally, corallite walls are thicker in *S. katoi* n. sp., connecting processes are more irregularly zoned, and infundibular tabulae are less well developed. This new species is named in honour of Dr. Makoto Kato, Hokkaido University, Sapporo, Japan.

Material and occurrence. Fragments of two coralla (holotype UA 1081 and paratype UA 1082) from which eighteen transverse and longitudinal sections were prepared. Both specimens were collected at locality MC-5, although their precise occurrence in the near-vertical beds at this locality has not been determined; Southern Rainbow Mountain: Lower Permian (Wolfcampian), McCallum Creek sequence.

Family SINOPORIDAE Sokolov, 1955

Genus *Sinopora* Sokolov, 1955

Type species. *Monilipora dendroides* Yoh, 1932: emend. as *Sinopora dendroides* (Yoh) by Sokolov, 1955, p. 225, Pl. LII, figs. 1-7: Lower Permian Chisya Limestone, southern China.

Diagnosis. Branching coralla; individual corallites attenuate, cylindrical, curved, and terminating in narrow calices with sharp lips; corallites infrequently gemmate but are broadly disposed in diverse directions; new corallites are approximately equal in diameter at their base to parent corallites; connective tubes absent; corallite walls with a thick concentrically wrinkled epitheca and weak longitudinal furrows; sclerenchyme of walls thick, with well defined concentric

microstructure; tabulae sparse and appear as curved plates; septal spines small, locally absent (translated and abbreviated from Sokolov, 1955, p. 226).

Discussion. Sokolov based the genus *Sinopora* on corals described by Yoh and Huang (1932) as *Monilipora dendroides* from the Lower Permian Chisya limestones (Guichshu, Yunshan) of southern China. The family Sinoporidae as defined by Sokolov (1955, p. 225) includes *Sinopora* Sokolov, *Cylindrostylus* Sokolov (= *Edwardsiella* Rukhin, 1937, *non* Andres, 1883), from the Silurian and Devonian, and *Rossopora* Sokolov (1955; type species, *R. alata* Sokolov), from the Middle Carboniferous of the Moscow Basin.

An abbreviated translation of Sokolov's discussion of the genus *Sinopora* is given below (Sokolov, 1955, pp. 226-7).

"Representatives of this form are widely known in China and in several other countries of southern Asia as *Monilipora dendroides* Yoh . . . however, they are far from the type of *Monilipora* which, as is well known, is a synonym for *Cladochonus*. Thanks to the kindness of Professor Yoh Sinsoon, we have had the opportunity to . . . compare [*Monilipora dendroides*] with typical representatives of *Cladochonus*. This comparison shows that . . . '*Monilipora dendroides*' differs so sharply from *Cladochonus* that it is impossible to confuse it even with the family Cladochonidae. It must be added that these peculiarities were pointed out by [Yoh], who noted the difficulty in determining the systematic position of this coral. This problem can now be resolved thus: '*Monilipora dendroides*' belongs to a completely independent type, here described as *Sinopora*.

"From *Rossopora*, to which it is doubtless related, *Sinopora* is distinguished by its non-reptant corallites, . . . small calicular diameters, lateral gemmation and other lesser characters. It is differentiated from the type of *Multithecopora* by its lack of connective tubes and different form of reproduction. From . . . representatives of the Aulocystidae, which are characterized by funnel-shaped tabulae, *Sinopora* is distinguished by the absence of tabulae of that type . . . None of these forms could be confused with the Auloporacea or Syringoporacea, as they are characterized by a combination of unique features . . . their mode of gemmation and absence of connective tubes provides a basis for referring the Sinoporidae to the Order Auloporacea."

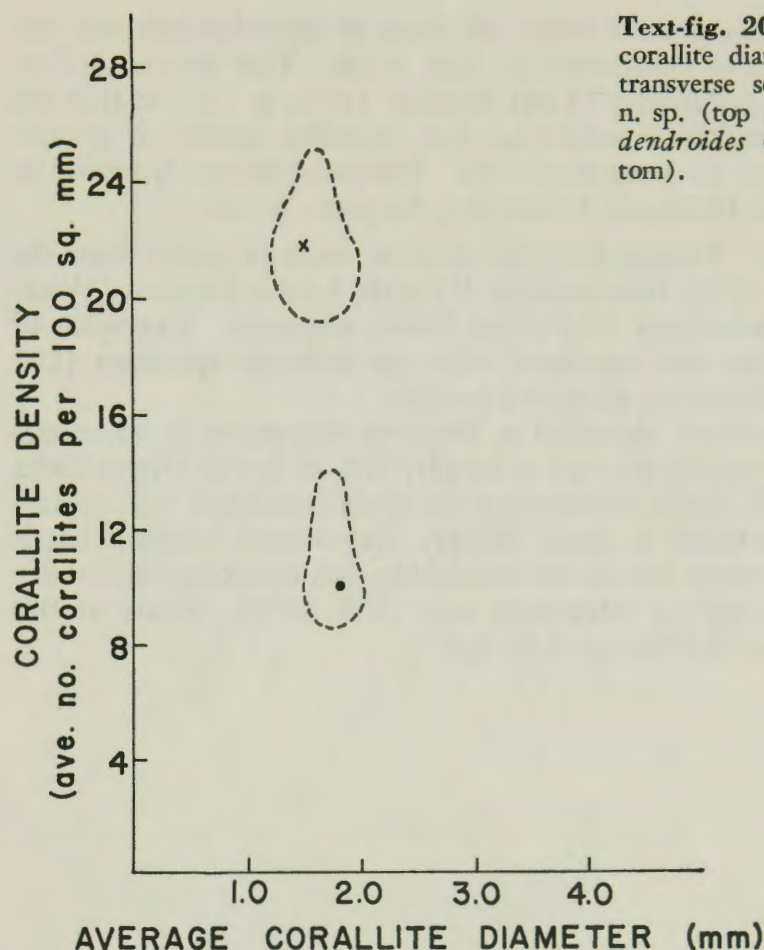
Tabulate corals from the Alaska Range here referred to the genus *Sinopora* are known to occur at several localities and are associated with Lower Permian Fusulinidae and corals.

Sinopora minatoi n. sp.

Plate 13, figures 1-3; Text-figure 20

Description. Corallum encrusts a colony of the rugose coral *Durhamina alaskaensis* n. sp. Individual corallites are subparallel in direction of growth except adjacent to the attachment surface, where growth directions are varied. Corallite exteriors are marked with fine growth lines and faint longitudinal grooves.

In transverse sections corallites are closely spaced at from nineteen to twenty-five per 100 square millimetres in the central part of the corallum; the average corallite density is about twenty-two corallites in an area of 100 square millimetres. Individual corallites are circular or subcircular in well oriented transverse sections and only uncommonly are in contact laterally with adjacent corallites. In diameter corallites range from 1.3 to 2.0 mm.; average is approximately 1.5 mm. Corallite walls are thin, 0.4 mm or less in most regions, but locally thickening to as much as 0.8 mm. The microstructure of the



Text-fig. 20. Relationship of average corallite diameter to corallite density in transverse sections of *Sinopora minatoi* n. sp. (top illustration) and in *Sinopora dendroides* (Yoh) Sokolov (1955) (bottom).

walls is for the most part obliterated by recrystallization but appears originally to have been concentrically lamellar; in a few examples, dark wavy concentric lamellae are preserved (Pl. 13, fig. 3b). Inward projections of stereoplasm, which probably represent septal ridges and/or spines, appear in a few transverse sections.

Longitudinal sections of this species indicate that reproduction was by lateral increase, although at widely spaced intervals. Connecting tubules, or stolons, are absent. Tabulae are mostly complete, non-infundibular, and usually concave distally. Several tabulae may cross the axial area within a distance of 1 mm, but in general the distribution and spacing of tabulae are erratic; the average spacing of tabulae is approximately one or two tabulae per 5 mm. Septal spines are clearly present and project as much as 0.15 mm into the central cavity; up to three septal spines are locally present per 1 mm.

Discussion. The presence of septal spines and absence of both connecting stolons and infundibular tabulae in this species precludes its assignment to *Syringopora* Goldfuss (1826). *Multithecopora* Yoh (1925) also has concentrically lamellar walls and (rare) septal spines, but is especially characterized by its extremely thick walls, commonly comprising as much as four-fifths of the total diameter, and in addition has connecting stolons. The assignment of this species to *Sinopora* Sokolov (1955) is based on close agreement with respect to the following features: (1) absence of connecting stolons; (2) well

developed septal spines; (3) growth form and form of reproduction; and (4) small corallite diameter and comparatively thin walls. This species differs, however, from *Sinopora dendroides* (Yoh) Sokolov (1955, p. 225) in that the average diameter of corallites is somewhat less, corallite density is greater (Text-fig. 20), and tabulae are more numerous. *Sinopora minatoi* is named in honour of Dr. M. Minato, Hokkaido University, Sapporo, Japan.

Material and occurrence. Twenty-five thin sections were prepared from the holotype corallum (UA 1078), from locality VV-21b; Lower Permian (Wolfcampian or ?Lower Leonardian) McCallum Creek sequence. Examples of *Sinopora minatoi* n. sp. are also associated with the holotype specimen (UA 1004) of *Durhamina alaskaensis* n. sp. at this locality.

Tabulate corals tentatively identified as *Sinopora* also occur in limestones believed to be correlative to these strata at locality DR-15 in the Upper Delta River area (specimen UA 1080), where they are again associated with species of *Durhamina* (*D. sutherlandi* n. sp.). Highly fragmented tabulate corals which may represent *Sinopora* also occur in volcanic-rich limestones at locality MC-0 in the Southern Rainbow Mountain area (UA 1079). Strata at this locality are thought to be Wolfcampian in age.

PLATES 1-13

PLATE 1

All illustrations x2; transverse sections oriented with cardinal septum lowermost except where indicated by small arrow

Figure 1

?*Bradyphyllum* sp. A. UA 1001, locality MC-1

- a. Transverse section, ephebic stage; note metriophylloid septal arrangement.
- b. Inked and bleached duplicate of 1a.
- c. Transverse section, early ephebic stage.
- d. Inked and bleached duplicate of 1c.
- e. Transverse section, neanic stage.
- f. Inked and bleached duplicate of 1e.
- g. Transverse section, early neanic stage.
- h. Inked and bleached duplicate of 1g; orientation unclear.

Figure 2

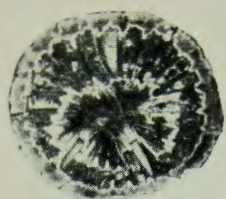
?*Pseudobradiphyllum* sp. A. UA 1002, locality MC-1

- a. Transverse section, ephebic stage.
- b. Inked and bleached duplicate of 2a.
- c. Transverse section, early ephebic stage.
- d. Inked and bleached duplicate of 2c; note thick counter-lateral septa and marked pinnate arrangement in counter quadrants.

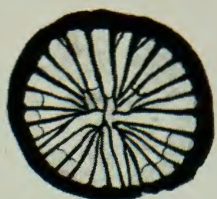
Figure 3

Cryptophyllum striatum new species. UA 1003, locality RM-8

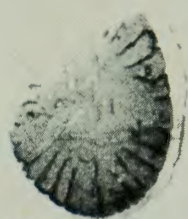
- a. Transverse section, late ephebic stage.
- b. Inked and bleached duplicate (partly restored) of 3a; note prominent alar and counter-lateral septa.
- c. Transverse section, ephebic stage.
- d. Duplicate of 3c; negative print.
- e. Transverse section, early ephebic stage, negative print.
- f. Duplicate of 3e; positive print.
- g. Transverse section, early ephebic stage.
- h. Duplicate of 3g; negative print. Note short counter septum, conjoined cardinal, counter-lateral, and alar septa throughout all illustrated growth stages.



1a



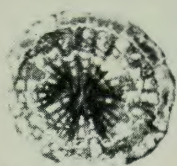
1b



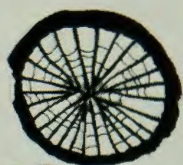
3a



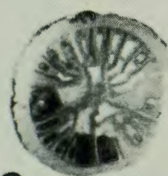
3b



1c



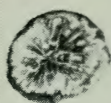
1d



3c



3d



1e



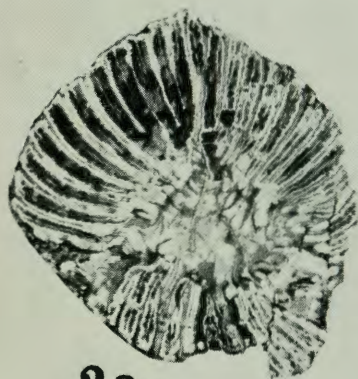
1f



1g



1h



2a



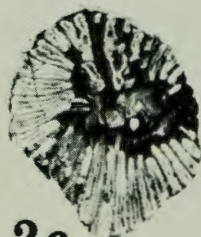
2b



3e



3f



2c



2d



3g



3h

PLATE 2

All illustrations negative prints, x2; orientation of cardinal septum variable

Figure 1

Durhamina alaskaensis new species. Holotype corallum, UA 1004, locality VV-21b.

- a. Transverse sections of several corallites; note variation in development of axial structure.
- b. Longitudinal section, oblique in upper part.
- c. Inked and bleached duplicate of 1b.
- d. Transverse sections of several corallites showing distinct medial lamella in axial structure.
- e. Longitudinal section, slightly oblique.
- f. Inked and bleached duplicate of 1e.
- g. Transverse sections of several corallites (neanic and ephebic).

Figure 2

Durhamina sutherlandi new species. Holotype corallum, UA 1006, locality DR-15.

- a. Transverse section, ephebic stage.
- b. Transverse section, ephebic stage.
- c. Transverse section, ephebic stage; note well developed minor septa in all three specimens. The thickened major septa in 2c are adjacent to a point of lateral increase.

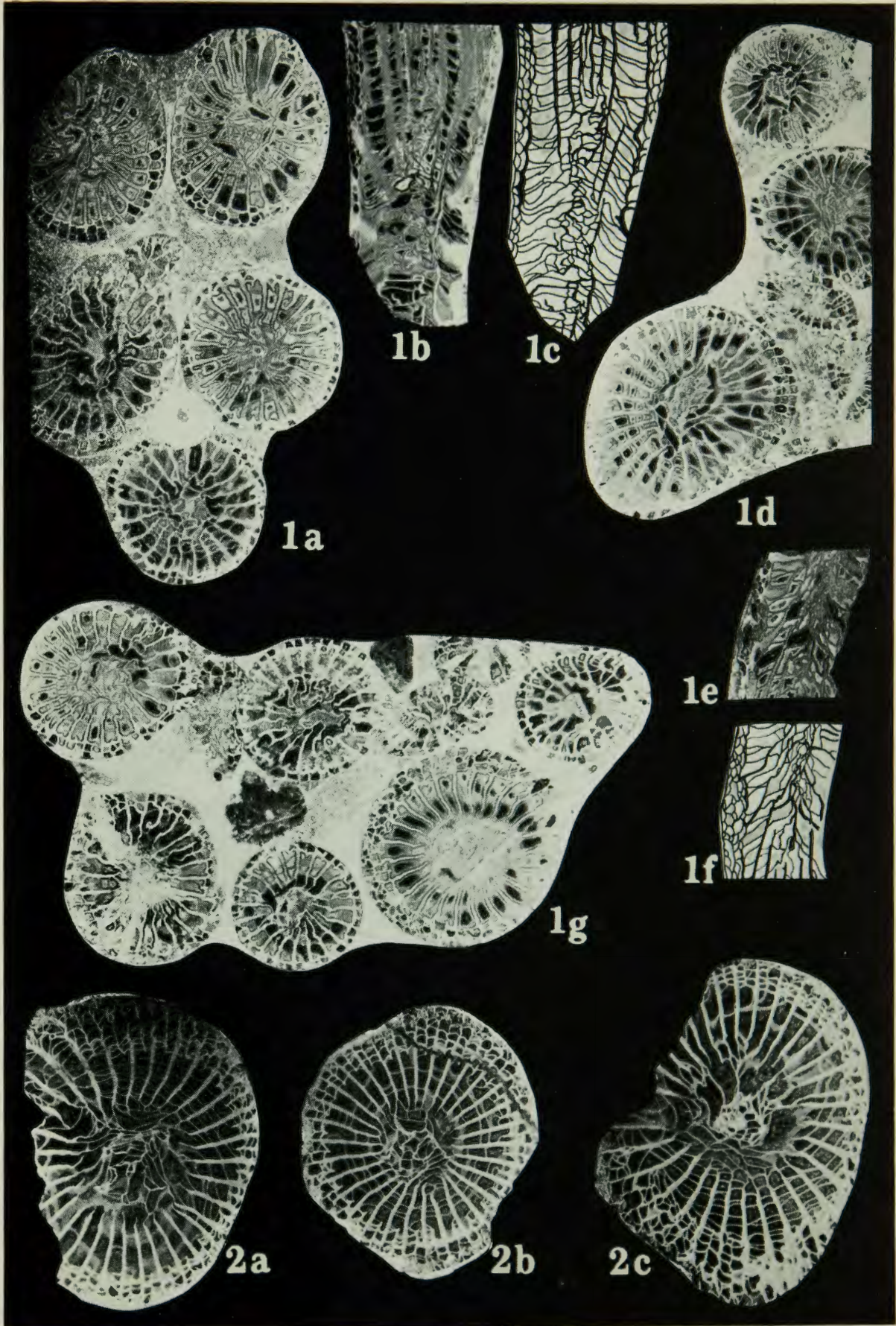


PLATE 3

All illustrations negative prints, x2; orientation of cardinal septum variable

Figure 1

Durhamina sutherlandi new species. Holotype corallum, UA 1006, locality DR-15.

- a. Longitudinal section, slightly oblique.
- b. Longitudinal section; note absence of clinotabulae, presence of small clinotabellae adjacent to dissepimentarium.
- c-h. Transverse sections of several corallites, all ephebic, illustrating variation in development of axial structure; axial and periaxial tabellae are also variable in development. Local thickening of major septa seen in 1e, 1g, and 1h is due to lateral increase of corallites.

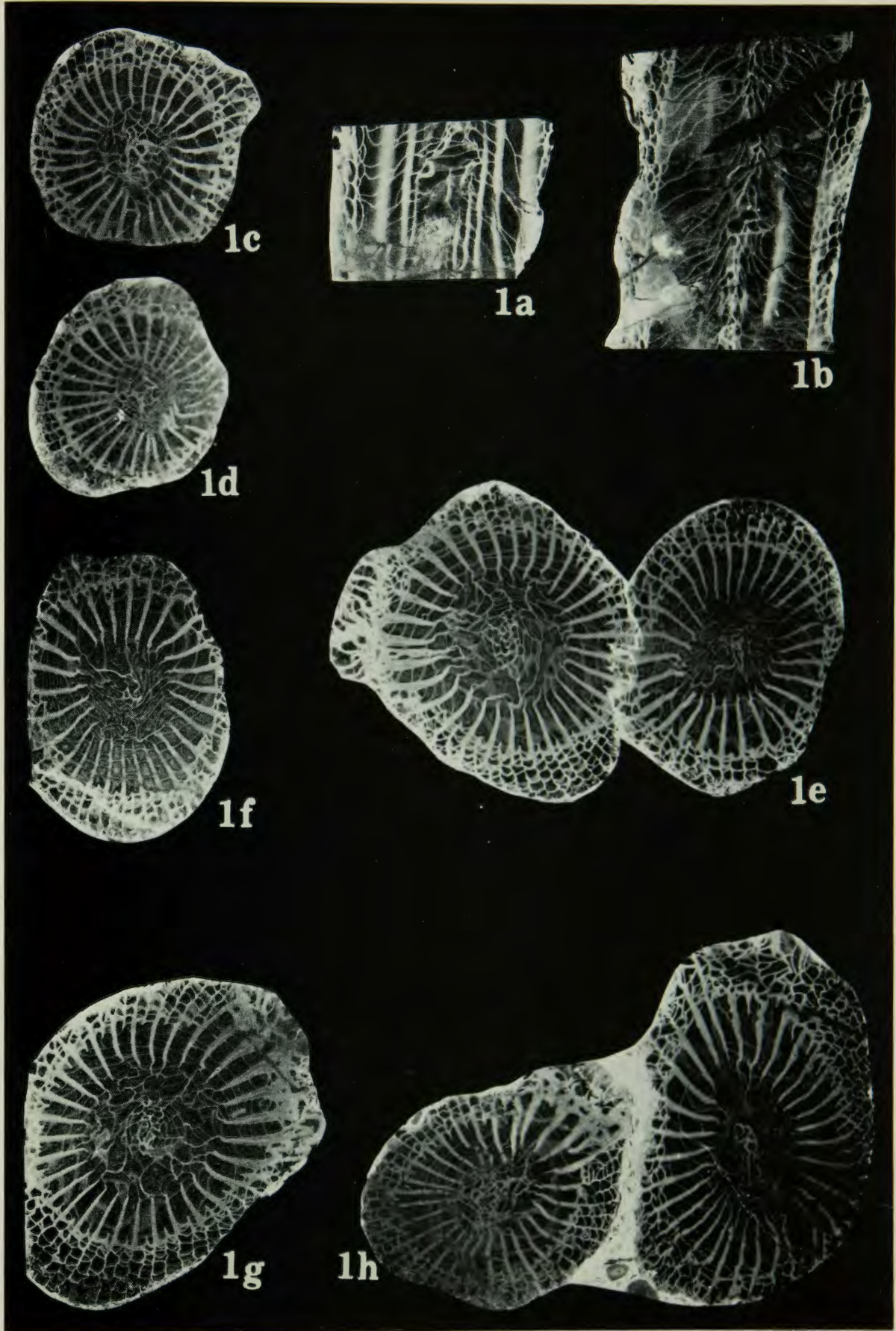


PLATE 4

All illustrations negative prints except 3h, x2; orientation of cardinal septum variable in 3a, 3d, and 3e

Figure 1

Heritschioides summitensis new species. Paratype corallum, UA 1031, locality MC-6.

- a. Longitudinal section; note "tented" axial tabellae, small clinotabellae adjacent to dissepimentarium.

Figure 2

Heritschioides summitensis new species. Paratype corallum, UA 1027, locality MC-6.

- a. Transverse section, ephebic stage.
- b. Transverse section, ephebic stage: note compact axial structure in these and other transverse sections.
- c. Longitudinal sections of two corallites showing strongly differentiated axial and periaxial tabellae and continuous axial structure.
- d. Transverse section, ephebic stage.

Figure 3

Heritschioides summitensis new species. Holotype corallum, UA 1025, locality MC-6.

- a-e. Transverse sections of corallites in holotype corallum, neanic through late ephebic growth stages.
- f. Inked and bleached duplicate of 3b.
- g. Inked and bleached duplicate of 3c.
- h. Longitudinal section (recrystallized) ephebic stage.

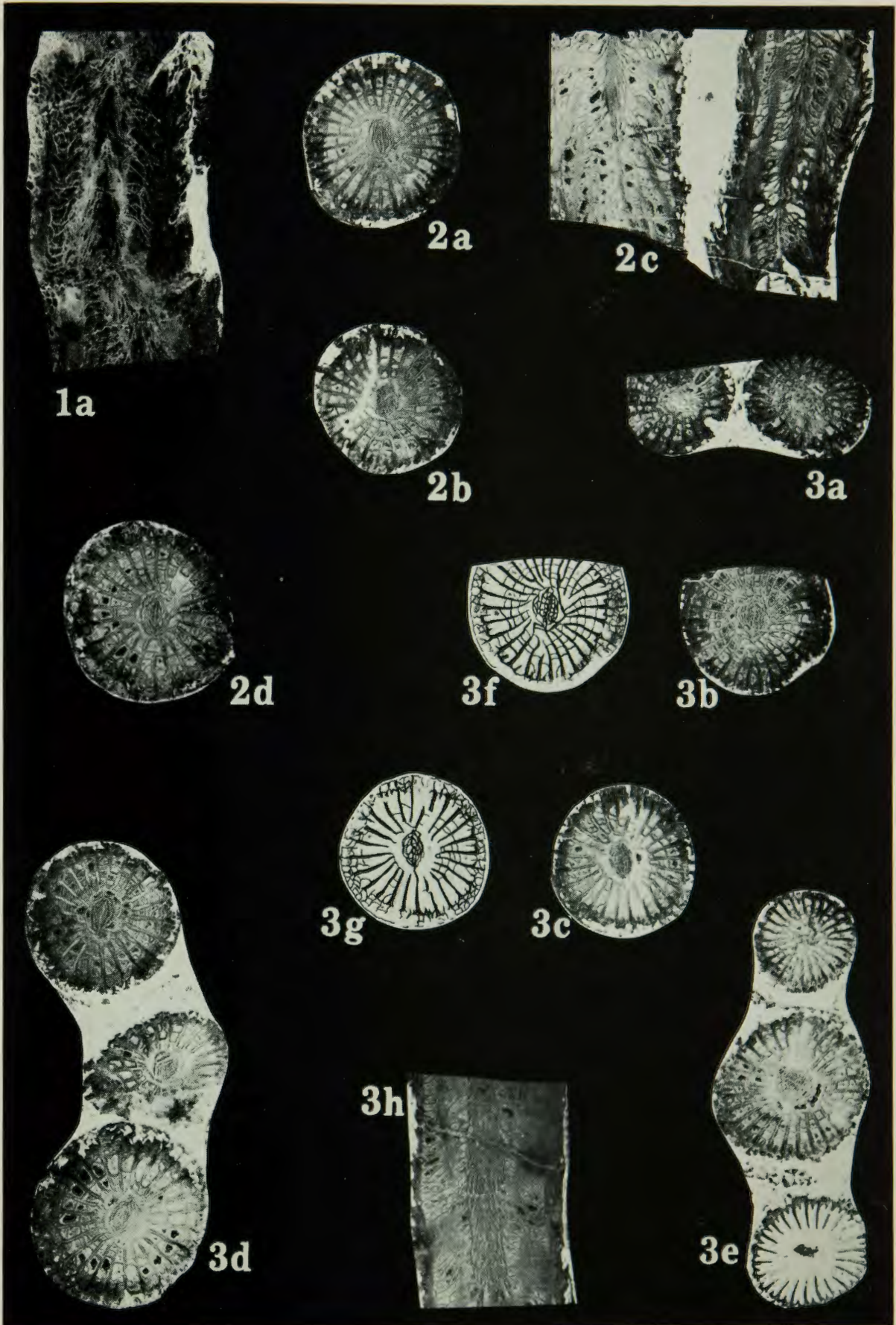


PLATE 5

All illustrations negative prints, x2

Figure 1

Auloclisia deltense new species. Holotype UA 1007, locality DR-16.

- a. Transverse section, late ephebic stage; cardinal septum at top of plate.
- b. Transverse section, ephebic stage; cardinal septum at right. Note aulophylloid axial structure, pseudoherringbone dissepiments.
- c. Transverse section, ephebic stage.
- d. Transverse section, early ephebic stage (cardinal septum lowermost in 1c, 1d).
- e. Transverse section, late neanic stage; corallite is distorted and open axial structure is displaced to upper right quadrant.

Figure 2

Auloclisia deltense new species. Paratype UA 1011, locality DR-16.

- a. Longitudinal section, late neanic and ephebic stages.

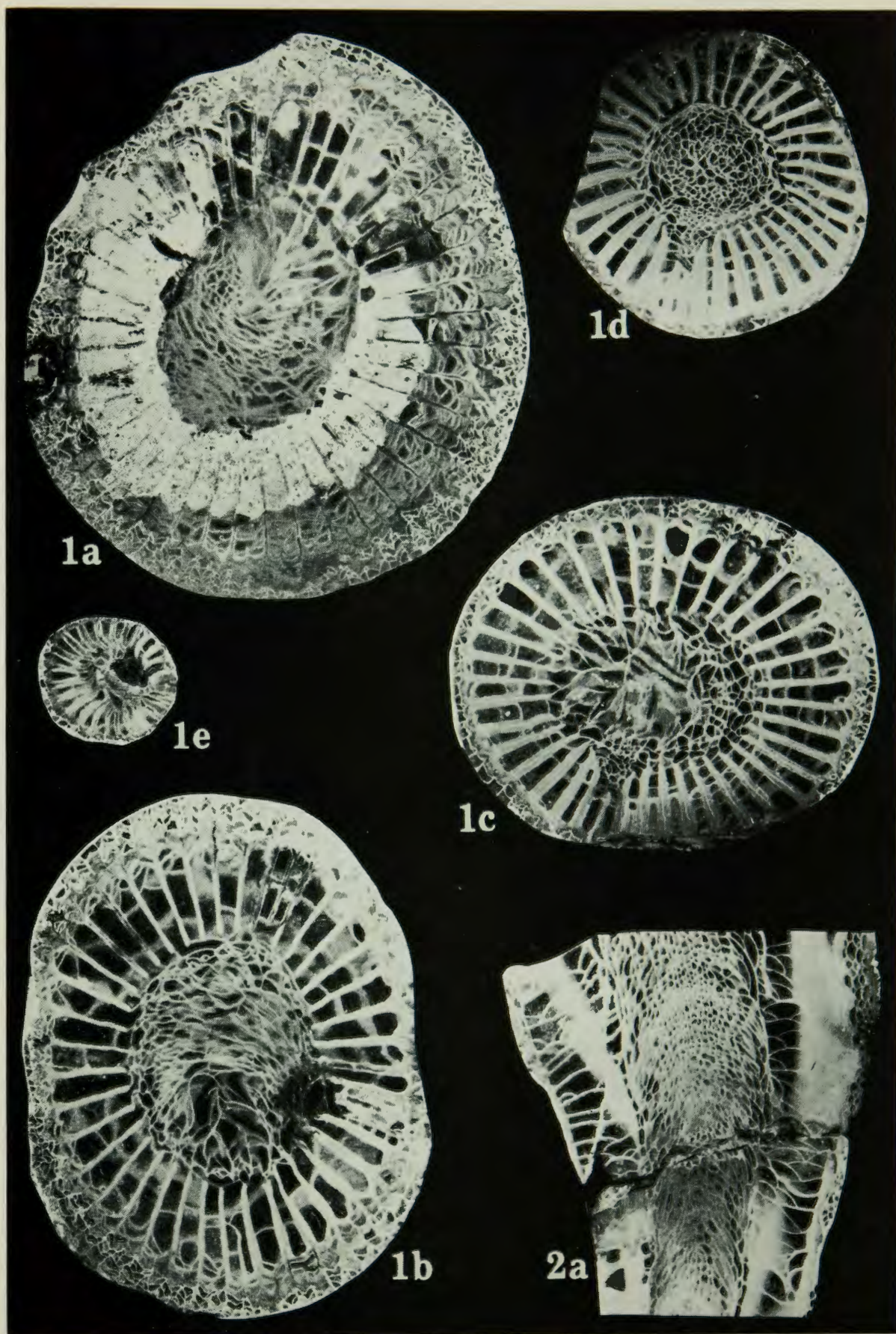


PLATE 6

All illustrations negative prints, x2

Figure 1

Auloclisia deltense new species. Paratype UA 1011, locality DR-16.

- a. Longitudinal section illustrating abundant axial tabellae.
- b. Longitudinal section, ephebic stage only.

Figure 2

Auloclisia deltense new species. Paratype UA 1015, locality DR-16.

- a. Transverse section, early neanic stage; note lathlike axial column.
- b. Transverse section, neanic stage; incipient septal lamellae are visible in column. Note sharply reflected septa in counter quadrants.

Figure 3

Auloclisia deltense new species. Paratype UA 1016, locality DR-16.

- a. Transverse section, late neanic or early ephebic stage, showing short septal lamellae.
- b. Transverse section, early neanic stage.

Figure 4

Auloclisia deltense new species. Paratype UA 1009, locality DR-16.

- a. Transverse section, late neanic stage.

Figure 5

Auloclisia deltense new species. Paratype UA 1008, locality DR-16.

- a. Transverse section, early ephebic stage.
- b. Transverse section, early ephebic stage.
- c. Transverse section, early ephebic stage; note distinctly clisiophylloid column in 5c, trending toward an aulophylloid condition in 5a (compare also with Pl. 5, figs. 1a, b).

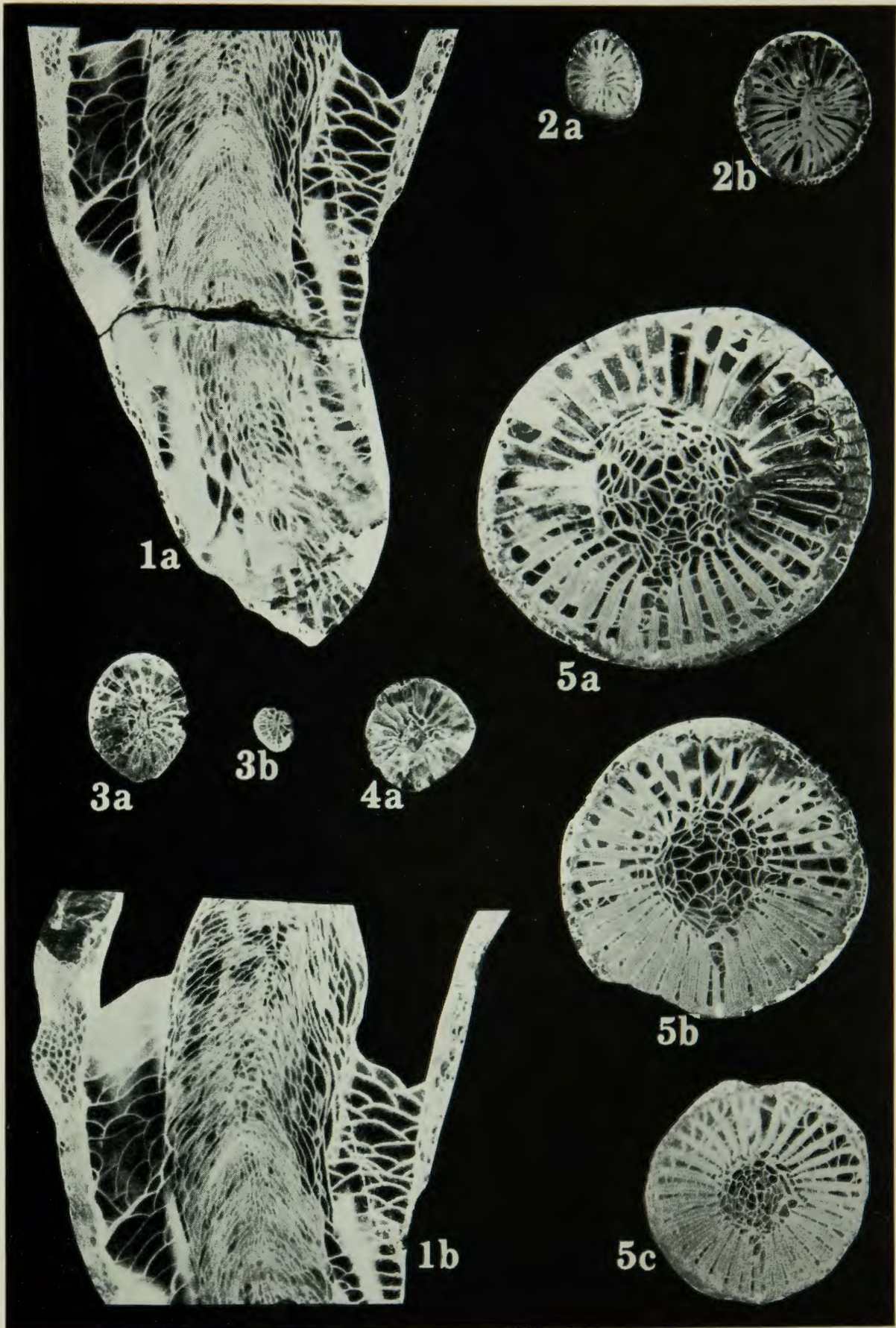


PLATE 7

All illustrations negative prints, x2

Figure 1

Clisiophyllum sp. A. UA 1021, locality DR-16.

- a. Inked and bleached print, late ephebic stage.
- b. Transverse section, ephebic stage. Cardinal septum at lower left.
- c. Transverse section, ephebic stage. Cardinal septum at lower left.
- d. Transverse section, early ephebic stage.
- e. Transverse section, late neanic or early ephebic stage.
- f. Transverse section, neanic or early ephebic stage.
- g. Inked and bleached duplicate of 1f.

Figure 2

Clisiophyllum sp. A. UA 1022, locality DR-16.

- a. Transverse section, ephebic stage. Note numerous septal lamellae.

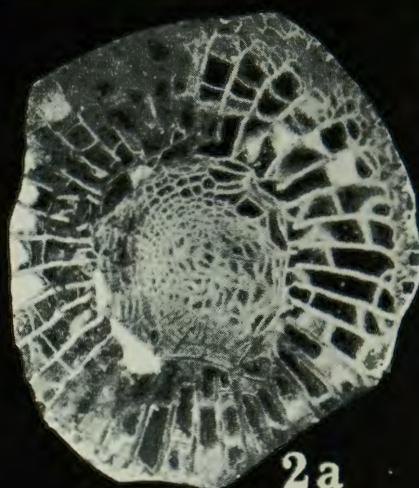
Figure 3

?*Clisiophyllum* sp. B. UA 1024, locality RC-18.

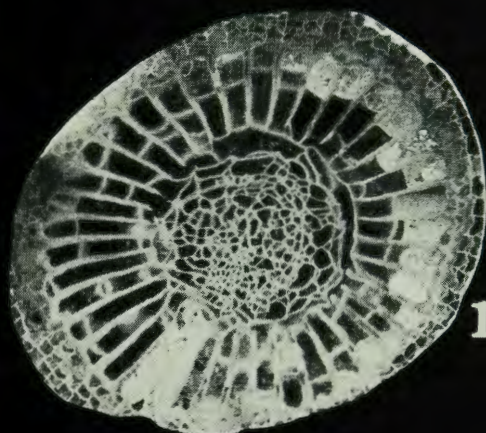
- a. Transverse section, ephebic stage.



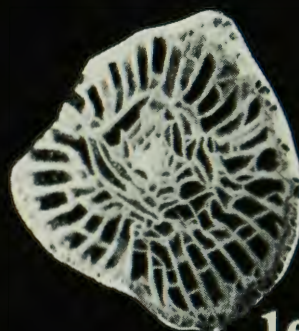
1a



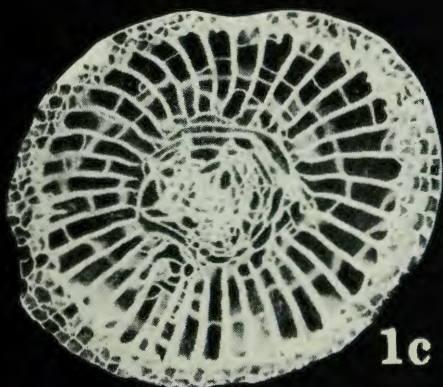
2a



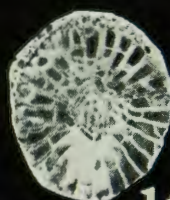
1b



1e



1c



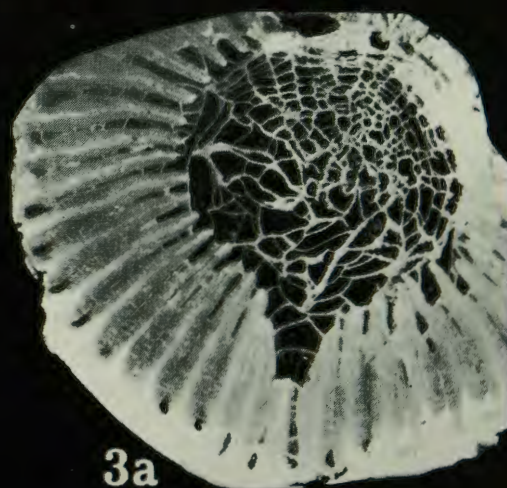
1f



1g



1d



3a

PLATE 8

All illustrations natural size except where otherwise indicated

Figure 1

Caninia petoczi new species. Holotype UA 1084, locality RC-17.

- a. Longitudinal section (recrystallized), ephebic stage.
- b. Inked and bleached duplicate of 1a; tabulae are thickened in axial region by secondary deposits of stereoplasm.
- c. Transverse section, ephebic stage.
- d. Inked and bleached duplicate of 1c; note aborted minor septa and longitudinal splitting of septal stereoplasm.

Figure 2

Caninia petoczi new species. Paratype UA 1033, locality RC-17.

- a. Transverse section, ephebic stage.

Figure 3

Caninia petoczi new species. Paratype UA 1041, locality RC-17.

- a. Transverse section, early ephebic stage.
- b. Enlargement of 3a, x2.

Figure 4

Caninia petoczi new species. Paratype UA 1038, locality RC-17.

- a. Transverse section, early neanic stage, x4. Note fusulinid (?*Parafusulina*) in matrix.
- b. Transverse section, neanic stage.
- c. Transverse section, late neanic stage. Note fusulinids in matrix.

Figure 5

Caninia petoczi new species. Paratype UA 1034, locality RC-17.

- a. Longitudinal section, early ephebic stage.

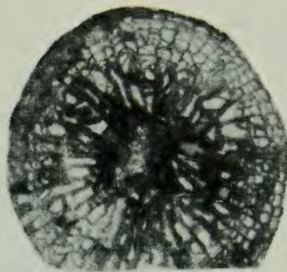
Figure 6

Caninia petoczi new species. Paratype UA 1040, locality RC-17.

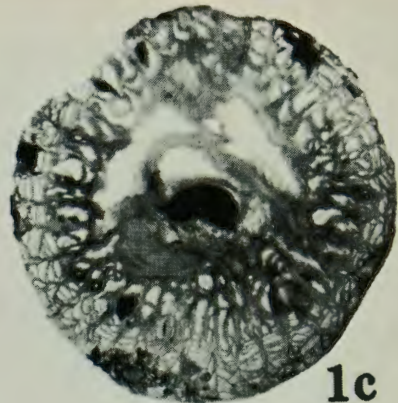
- a. Longitudinal section of specimen with atypically wide dissepimentarium.



1a



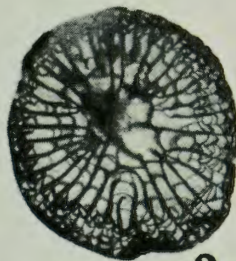
2a



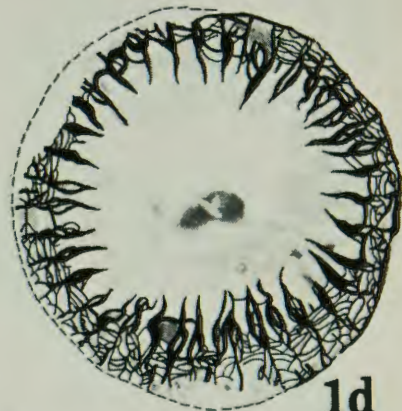
1c



1b



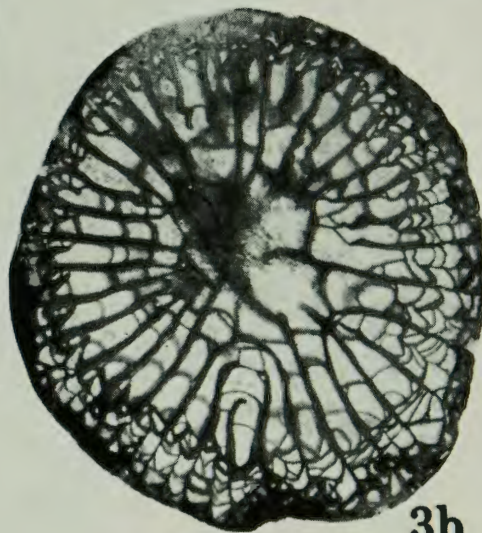
3a



1d



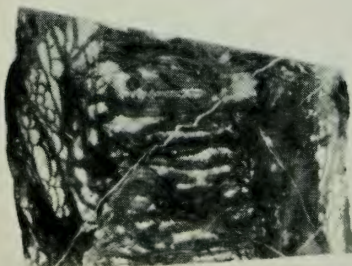
4a



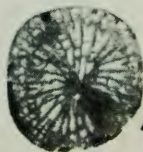
3b



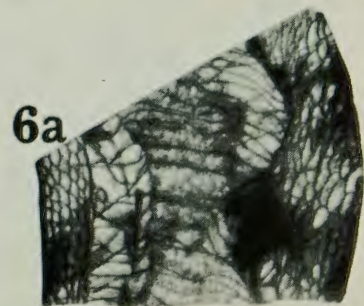
4c



5a



4b



6a

PLATE 9

All illustrations natural size

Figure 1

Timania rainbowensis new species. Paratype UA 1053, locality MC-13.

- a. Transverse section, ephebic stage.
- b. Longitudinal section (oblique in upper part), middle and late ephebic stages.

Figure 2

Timania rainbowensis new species. Holotype UA 1051, locality MC-13.

- a. Transverse section, early ephebic stage.
- b. Longitudinal section (reconstructed), ephebic stage.

Figure 3

Timania rainbowensis new species. Paratype UA 1054a, b, locality MC-13.

- a. Transverse section, ephebic stage; note lateral increase of new corallites.
- b. Inked and bleached duplicate of neanic corallite (UA 1054b) in 3a.

Figure 4

Timania rainbowensis new species. Paratype UA 1052, locality MC-13.

- a. Transverse section, neanic stage.

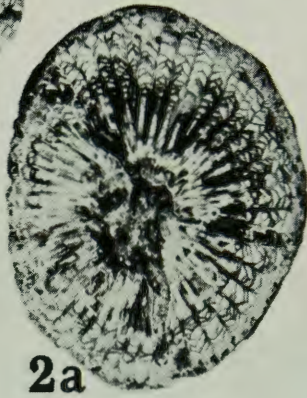
Figure 5

Timania cf. *T. schmidtii* Stuckenberg. UA 1058, locality VV-21a.

- a. Transverse section, early ephebic stage. Note long counter septum.
- b. Longitudinal section, ephebic stage.



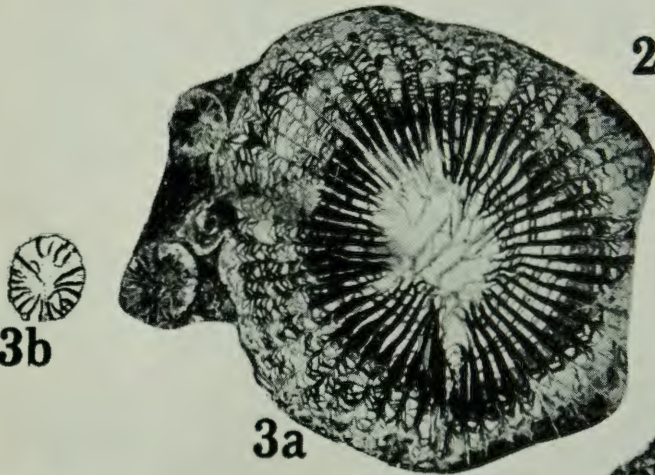
1a



2a



2b



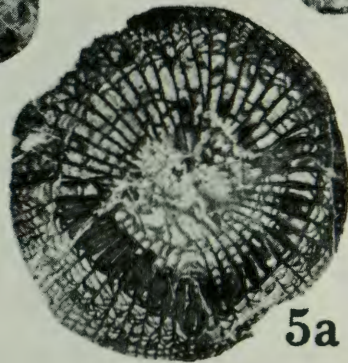
3a



3b



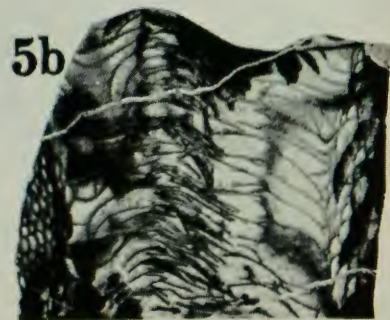
4a



5a



1b



5b

PLATE 10

All illustrations natural size except where otherwise indicated

Figure 1

Timania sp. A. UA 1063, locality MC-0.

- a. Transverse section, ephebic stage.

Figure 2

Timania sp. A. UA 1060, locality MC-0.

- a. Transverse section, ephebic stage (negative print).
- b. Transverse section, early ephebic stage; note long counter septum
- c. Transverse section, late neanic stage.
- d. Transverse section, neanic stage.
- e. Inked and bleached duplicate of 2d.

Figure 3

Timania cf. *T. schmidtii* Stuckenberg. UA 1056, locality VV-21a.

- a. Transverse section, ephebic stage.
- b. Transverse section, ephebic stage, showing rejuvenescence(?).

Figure 4

Bothrophyllum sp. A. UA 1071, locality MC-1.

- a. Transverse section, early ephebic stage.
- b. Transverse section, ephebic stage.
- c. Transverse section, ephebic stage.
- d. Inked and bleached duplicate of 4c; note short cardinal septum and open fossula.

Figure 5

Bothrophyllum sp. A. UA 1072, locality MC-1.

- a. Inked and bleached photograph of ephebic stage; note strongly lanceolate major septa

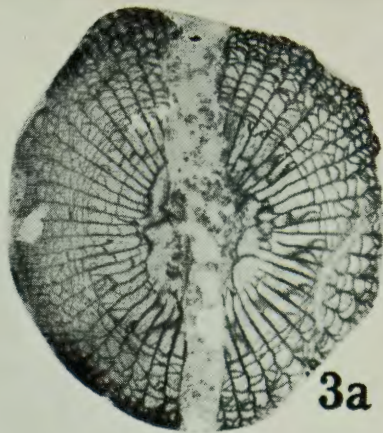
Figure 6

Bothrophyllum cf. *B. pseudoconicum* Dobrolyubova. UA 1068, locality MC-7.

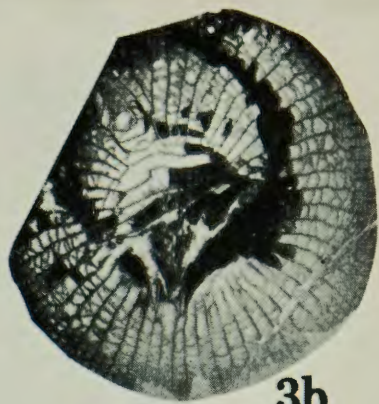
- a. Longitudinal section, ephebic stage.
- b. Inked and bleached duplicate of 6a.
- c. Transverse section, ephebic stage, x2.



1a



3a



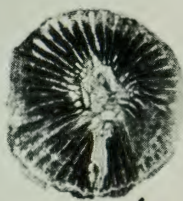
3b



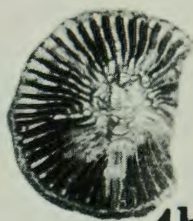
2a



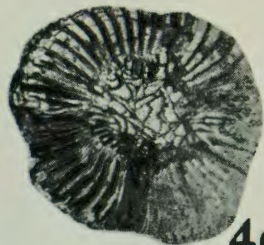
2b



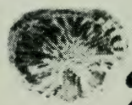
4a



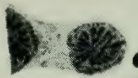
4b



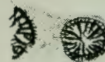
4c



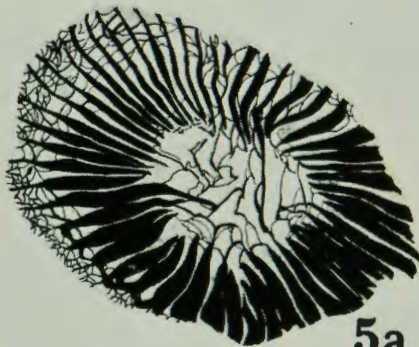
2c



2d



2e



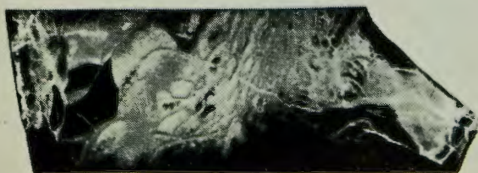
5a



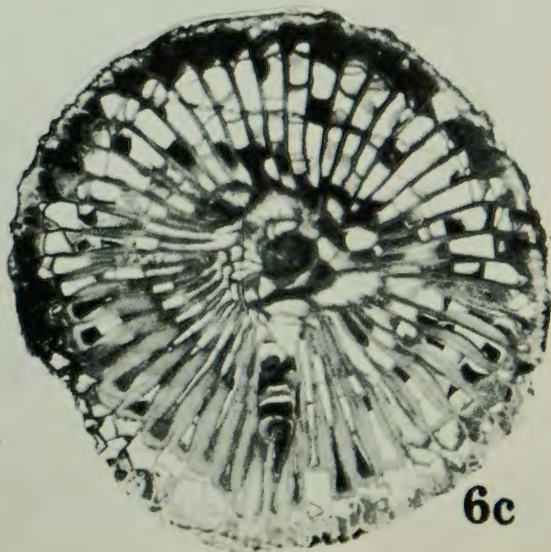
4d



6b



6a



6c

PLATE 11

Enlargements as indicated

Figure 1

Bothrophyllum cf. *B. pseudoconicum* Dobrolyubova. UA 1067, locality MC-7.

- a. Transverse section, ephebic stage, natural size.
- b. Enlargement (negative print) of 1a, x2, showing details of dissepimental zone.
- c. Inked and bleached print of neanic stage; note short septal lamellae(?); natural size.

Figure 2

Bothrophyllum cf. *B. pseudoconicum* Dobrolyubova. UA 1069, locality MC-7.

- a. Inked and bleached print of longitudinal section, ephebic stage, x2.

Figure 3

Syringopora katoi new species. Holotype corallum, UA 1081, locality MC-5.

- a. Transverse section of part of corallum (negative print), x1.5.
- b. Enlargement of a part of 3a, x5; note chain of 12 or more corallites connected by short "stolons". Concentrically lamellar wall structure is simulated in corallite in lower centre (arrow) by upturned edges of distally concave tabulae.

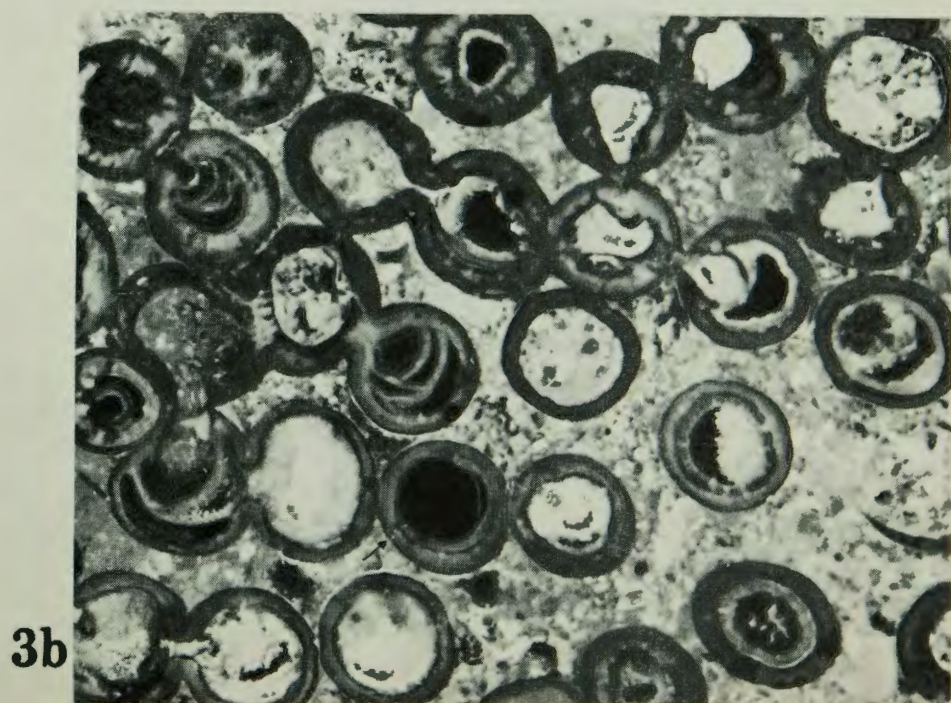
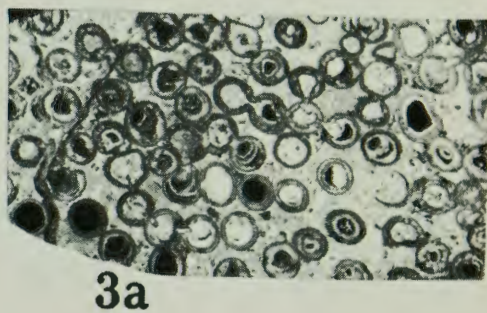
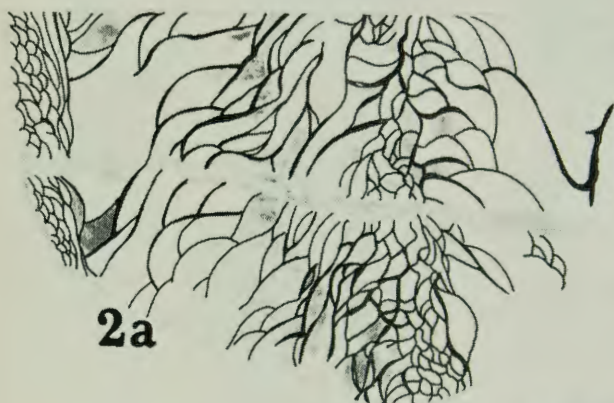
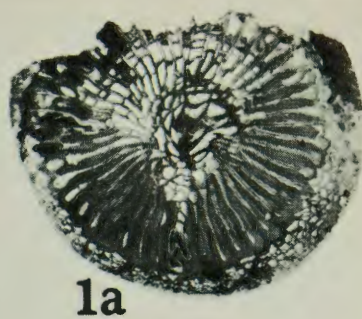
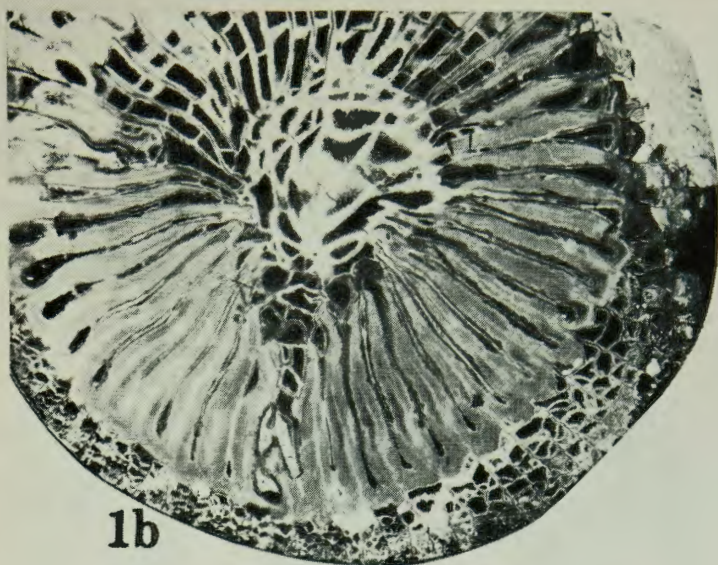


PLATE 12

All illustrations negative prints; enlargements as indicated

Figure 1

Syringopora katoi new species. Holotype corallum, UA 1081, locality MC-5.

- a. Longitudinal section of single corallite, x5.
- b. Inked and bleached duplicate of 1a.

Figure 2

Syringopora katoi new species. Paratype corallum, UA 1082, locality MC-5.

- a. Longitudinal sections of four corallites, x5.
- b. Inked and bleached duplicate of 2a.

Figure 3

Syringopora katoi new species. Holotype corallum, UA 1081, locality MC-5.

- a. Transverse section of holotype corallum, x1.5.
- b. Enlargement of part of 3a; note connecting tube (stolon) joining two corallites at left.



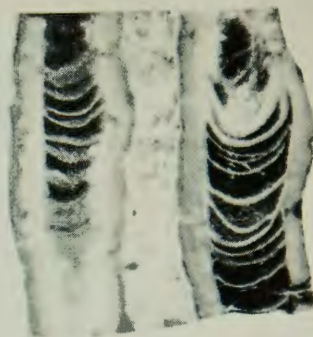
1a



1b



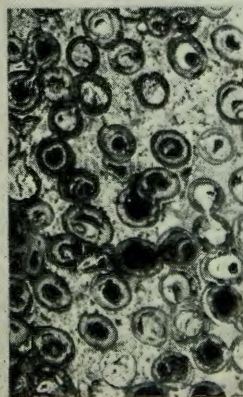
2a



2b



3b



3a

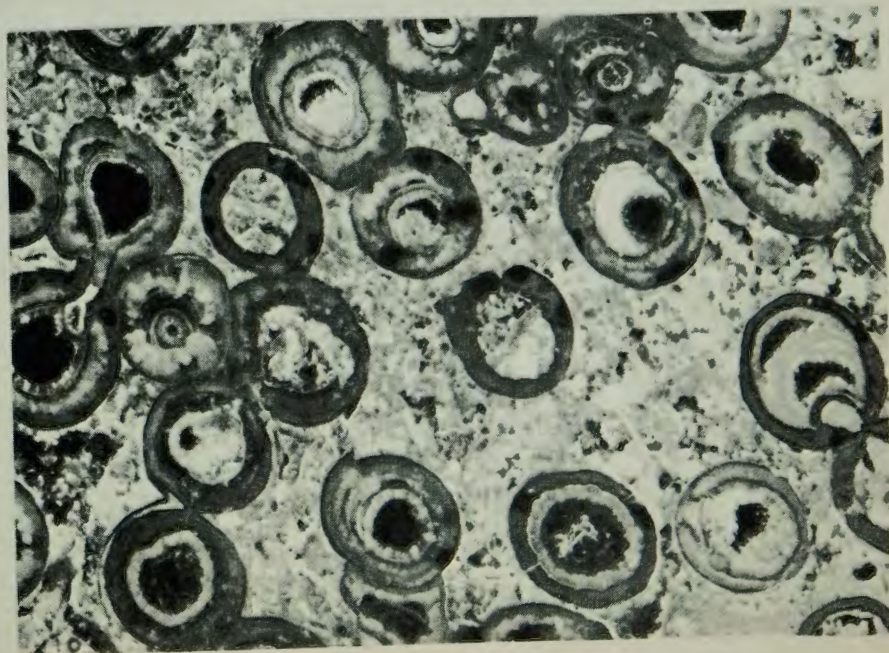


PLATE 13

All illustrations negative prints; enlargements as indicated

Figure 1

Sinopora minatoi new species. Holotype corallum, UA 1078, locality VV-21b.

- a. Longitudinal and oblique sections of several corallites, x5.
- b. Inked and bleached duplicate of 1a. Note numerous septal spines along corallite walls.

Figure 2

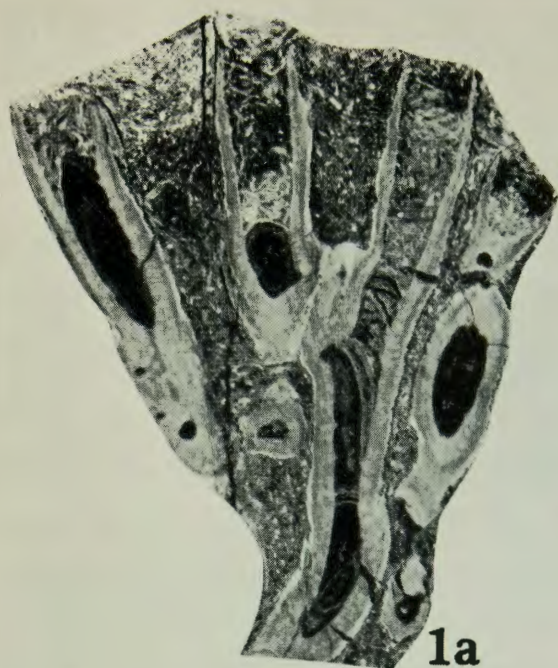
Sinopora minatoi new species. Holotype corallum, UA 1078, locality VV-21b.

- a. Longitudinal section, x5.
- b. Inked and bleached duplicate of 2a.

Figure 3

Sinopora minatoi new species. Holotype corallum, UA 1078, locality VV-21b.

- a. Transverse section of part of corallum, x1.5.
- b. Enlargement of part of 3a, x5; note septal spines in many corallites and (vestigial) concentric lamellar layering of walls.



1a



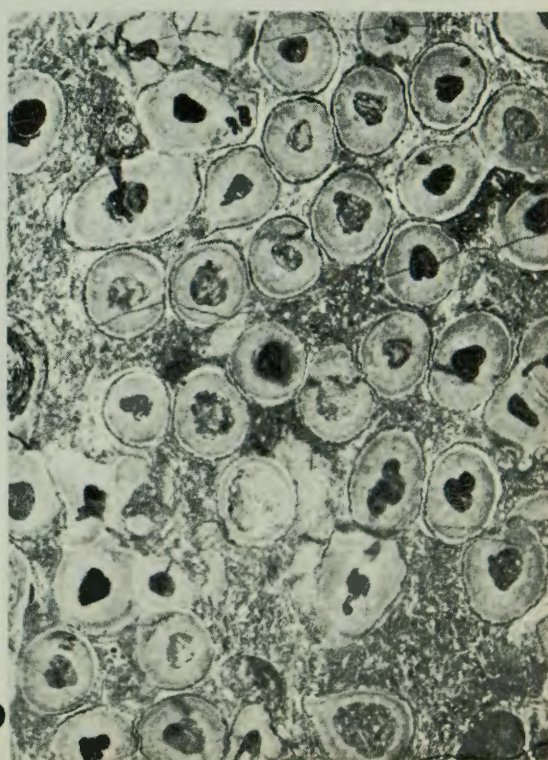
2a



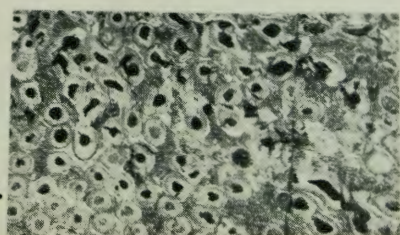
2b



1b



3b



3a

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APPENDIX I. Tabulation of Data: Rugosa

Data shown below include corallite diameter (d), number of major septa (n), and, where available, height (h) and diameter of the dissepimentarium (d^a). Septal ratios (number of major septa per one millimetre diameter, n/d) were computed to the nearest one-tenth. All measurements are in millimetres. The symbol $\pm$ is used throughout these data to indicate approximate counts, measurements, or calculated values. Crushed or otherwise unusable specimens are not included.

Locality numbers correspond to those described and located in the text and on accompanying maps. All specimens, both figured and unfigured, have been assigned University of Alaska catalogue numbers (UA). These data also are shown in graphical form in the text-figures.

Locality	Number	d	n	n/d	h
<i>?Bradyphyllum</i> sp. A					
MC-1	UA 1001	2.5	16	6.4	
		6.0	20	3.3	
		10.0	27	2.7	
		12.0	29	2.4	
		12.5	30±	2.4±	
<i>?Pseudobradiphyllum</i> sp. A					
MC-1	UA 1002	12.0	33	2.8	
		13.0	36	2.8	
		16.0	37	2.3	
		20.0	38	1.9	
		26.0	46	1.8	
<i>Cryptophyllum striatum</i> n. sp.					
RM-8	UA 1003	6.5	22	3.4	
		7.3	24	3.3	
		9.0	23	2.6	
		10.0	28	2.8	
<i>Durhamina alaskaensis</i> n. sp.*					
VV-21b	UA 1004-1	8.0	20	2.5	28
VV-21b	UA 1004-2	9.2	21±	2.3±	31
		9.6	21	2.2	41
		10.4	21	2.0	44
		12.0	21	1.8	51
VV-21b	UA 1004-3	9.0	20	2.2	41
		10.0	20	2.0	44
		11.0	20	1.8	51
		10.2	21	2.1	54
		10.8	21	1.9	59

*Individual corallites comprising corallum UA 1004 (holotype)

Locality	Number	d	n	n/d	h
<i>Durhamina alaskaensis</i> n. sp. (cont'd.)					
VV-21b	UA 1004-4	12.0 $\pm$	24 $\pm$	2.0 $\pm$	51
		12.6 $\pm$	25	2.0	54
		13.2	25	1.9	59
		13.4	25	1.9	62
		14.2	25	1.8	68
VV-21b	UA 1004-5	11.0	23	2.1	25
		12.0	23	1.9	28
		13.2	24	1.8	31
		13.0	26	2.0	41
		13.0	25	1.9	44
		13.6	25	1.8	51
		13.8	25	1.8	54
		13.8	25	1.8	59
		14.1	25	1.8	62
		12.0	25	2.1	68
VV-21b	UA 1004-6	8.0 $\pm$	21 $\pm$	2.6 $\pm$	28
VV-21b	UA 1004-7	11.2	25	2.2	25
		11.4	25	2.2	28
		11.0	25	2.3	31
		12.2	24	2.0	41
		12.5	25	2.0	44
		14.5	25	1.8	51
		13.2	26	2.0	54
		13.4	26	1.9	59
VV-21b	UA 1004-8	8.8	20	2.3	25
		9.2	20	2.2	28
		9.5	20	2.1	31
		9.6	20	2.1	41
		9.8	21	2.1	44
		10.0	21	2.1	51
		10.5	21	2.0	54
		11.0	22	2.0	59
		11.4	22	1.9	62
VV-21b	UA 1004-9	10.6	25	2.4	25
		11.0	26	2.4	28
		10.5	25	2.4	31
		11.6	25	2.2	41
		12.5	25	2.1	44
		12.2	25	2.0	51
		12.2	25	2.0	54
		12.4	26	2.1	59
VV-21b	UA 1004-10	14.0	24	1.7	25
		13.6	24	1.8	28
		13.0	24	1.8	31
		12.6	24	1.9	41
		12.5	24	1.9	44
		12.4	24	1.9	51
		12.7	24	1.9	54
		13.4	24	1.8	59
		11.0	24	2.2	59
VV-21b	UA 1004-14	7.0 $\pm$	16 $\pm$	2.3 $\pm$	28
		8.0	19	2.4	41
		8.2	20	2.4	44
		14.0	23 $\pm$	2.6	51
VV-21b	UA 1004-15	8.5	20	2.4	28
		9.0	21	2.3	31
		9.4	20	2.1	41
		10.0	22	2.2	44

Locality	Number	<i>d</i>	<i>n</i>	<i>n/d</i>	<i>d</i> ^{d*}
<i>Durhamina sutherlandi</i> n. sp.†					
DR-15	UA 1006-2	15.0	28	1.9	
		14.0	29	2.1	
		17.0	29	1.7	
DR-15	UA 1006-3	13.0	29	2.2	
		15.0±	29	1.9±	
DR-15	UA 1006-4	11.0	25	2.3	
		14.5	29	2.0	
		17.0	30	1.8	
DR-15	UA 1006-5	20.0	29	1.5	
		19.0	31	1.6	
		18.0	32	1.8	
DR-15	UA 1006-6	18.0	31	1.7	
DR-15	UA 1006-7	15.0	32	2.1	
		21.0	33	1.6	
		23.0	33	1.4	
DR-15	UA 1006-8	17.0	28	1.8	
		18.0	28	1.6	
		22.0	31	1.4	
<i>Heritschioides summitensis</i> n. sp.					
MC-6	UA 1025 (holotype)	7.0	21	3.0	0.3
		8.5	24	2.8	0.3
		8.0	24	3.0	0.3
		8.2	24	2.9	0.4
		7.5	23	3.1	0.3
		9.5	25	2.6	0.5
		6.5	21	3.2	0.2
		9.9	25	2.5	0.9
		7.5	25	3.3	0.5
		10.5	28	2.7	1.0
		7.0	22	3.1	0.7
		11.0	28	3.3	0.5
		8.5	28	3.3	0.5
		8.0	23	2.9	1.0
MC-6	UA 1026	8.5	24	2.8	0.5
		6.1	16	2.6	0.0
		6.5	19	2.9	0.1
		11.2	28	2.5	1.0
		6.5	21	3.2	0.3
		9.0	26	2.9	0.5
		6.5	22	3.4	0.2
		8.0	24	3.0	0.5
		6.0	22	3.7	0.3
MC-6	UA 1027	9.0	24	2.7	0.5
		10.3	23	2.2	1.3
		6.5	20	3.1	0.3
		11.2	24	2.1	1.6
		9.0	22	2.4	0.6
		12.3	24	2.0	1.7
		6.0	21	3.5	0.5
		6.2	23	3.7	0.3
		9.6	24	2.5	1.0
		7.6	23	3.0	0.5
	10.2	28	2.7	1.2	

*Average; †Individual corallites comprising corallum UA 1006 (holotype)

Locality	Number	d	n	n/d	d^d
<i>Heritschoides summitensis</i> n. sp. (cont'd.)					*
MC-6	UA 1028	10.0	26	2.6	1.0
		11.0	26	2.4	0.7
		7.2	22	3.1	0.5
MC-6	UA 1029	8.6	24	2.8	0.5
		8.5	22	2.6	0.5
		10.5	22	2.1	1.2
		10.0	25	2.5	0.4
MC-6	UA 1030	11.0	27	2.5	1.2
		10.6	28	2.6	0.7
		9.2	26	2.8	0.7
		12.0	28	2.3	1.3
		11.5	28	2.4	1.0
		11.0	25	2.3	1.0
		<i>Auloclisia deltense</i> n. sp.			
DR-16	UA 1007 (holotype)	8.8	25	2.9	0.5
		17.0	33	1.9	0.7
		21.0	36	1.7	1.0
		28.0	38	1.4	2.0
		34.0	42	1.2	3.0
		35.0	42	1.2	6.5
DR-16	UA 1008	15.9	34	2.1	1.0
		20.5	36	1.8	1.7
		27.0	37	1.4	1.7
		31.0	38	1.2	3.0
DR-16	UA 1009	7.5	23	3.1	0.3
		14.3	30	2.1	—
		18.0	35	1.9	2.0
DR-16	UA 1010	21.5	38	1.8	1.5
DR-16	UA 1011	32.0	—	—	6.3
DR-16	UA 1013	9.0±	24	2.7±	—
		25.0±	38	1.5±	3.5
DR-16	UA 1014	9.0±	26	2.9±	0.5
		26.0±	39	1.5±	3.0
DR-16	UA 1015	5.0	22	4.4	0.5
		9.0	25	2.8	1.0
		16.0	29	1.8	1.5
DR-16	UA 1016	2.5	16	6.4	0.0
		7.0	23	3.3	—
DR-16	UA 1017	10.0	25	2.5	1.0
DR-16	UA 1018	29.0	35	1.2	3.0
<i>Auloclisia mutatum</i> Lewis, 1927†					
D ₁ beds, Scarlet Point, Isle of Man	R 25866 holotype	8.5	32	3.8	
		17.4	44	2.5	
		30.7	55	1.8	
		37.0	60	1.6	
		41.2	63	1.5	
	Paratypes	3.5	20	5.7	
		5.5	24	4.4	
		5.6	25	4.5	
		7.0	28	4.0	
		8.0	32	4.0	
		36.0	60	1.7	

*Average; †Included here for comparative purposes

Locality	Number	d	n	n/d	d ^a
Clisiophyllum sp. A					
DR-16	UA 1021	8.0	28	3.5	0.5
		14.5	34	2.3	1.0
		16.0	37	2.3	1.0
		16.8	37	2.2	1.5
		19.5	38	1.9	2.0
		20.0	38	1.9	2.0
		20.7	39	1.9	2.0
		22.0	39	1.8	2.0
DR-16	UA 1022	23.0	39	1.7	2.0
		25.0	39	1.6	2.0
?Clisiophyllum sp. B					
RC-18	UA 1024	11.0	33±	3.0±	
		20.0±	38±	1.9±	
		32.0±	43	1.3±	
		35.0±	46±	1.3±	
Caninia petoczi n. sp.					
DR-14	UA 1049	25.0	33	1.3	3.5
DR-14	UA 1050	32.0±	35	1.1±	4.0
RC-17	UA 1084	37.0	40	0.9	5.0
RC-17	holotype UA 1034	30.0±	37±	1.2±	—
		32.0±	37±	1.2±	3.0
		35.0	46	1.3	3.0
RC-17	UA 1033	33.0	37	1.1	3.5
RC-17	UA 1032	19.0	31	1.6	—
RC-17	UA 1035	40.0±	39±	1.0±	3.5
RC-17	UA 1036	44.0±	40±	0.9±	4.5
RC-17	UA 1037	31.0	37±	1.2±	3.0
RC-17	UA 1038	15.0	26	1.7	2.0
		17.0	30	1.8	2.0
		20.0	30	1.5	1.5
RC-17	UA 1039	9.5	24	2.5	0.0
RC-17	UA 1040	—	—	—	9.0
RC-17	UA 1041	27.0	36	1.3	3.0
RC-17	UA 1042	28.0	26	0.9	3.0
RC-17	UA 1043	21.0	32	1.5	1.5
RC-17	UA 1044	19.0	32	1.7	2.5
RC-17	UA 1045	22.0	31	1.4	2.5
RC-17	UA 1047	30.0±	34±	1.1±	3.5
RC-17	UA 1048	28.0	38	1.4	5.0
		29.0	37	1.3	3.5
Timania rainbowensis n. sp.					
*					
MC-13	holotype	37.0±	44±	1.2±	9.0
		40.0±	52	1.3±	8.0
		42.0±	54	1.3±	7.0
		42.0±	55	1.3±	7.0
MC-13	UA 1053	55.0±	60	1.1±	15.0
		53.0	—	—	16.0
		61.0	—	—	14.0
MC-13	UA 1052	24.0	39±	1.6±	1.0
		25.0	—	—	3.0
		35.0	—	—	5.0
		48.0	50	1.0	7.0

*Maximum

Locality	Number	d	n	n/d	d^d
<i>Timania rainbowensis</i> n. sp. (cont'd.)					*
MC-13	UA 1054a	50.0	53	1.1	14.0
	UA 1054b	8.0	22	2.8	0.0
MC-13	UA 1055	55.0±	55	1.0±	14.0
<i>Timania</i> cf. <i>T. schmidtii</i> Stuckenberg					
VV-21a	UA 1058	39.0	51	1.3	7.0
		42.0	—	—	7.0
VV-21a	UA 1059	50.0±	—	—	11.0
VV-21a	UA 1057	43.0±	—	—	7.0
VV-21a	UA 1056	50.0±	52	1.0±	7.0±
		50.0±	55±	1.1±	5.0±
<i>Timania</i> sp. A					
MC-0	UA 1060	9.0	29	3.2	0.2
		15.0	38	2.5	0.5
		16.0	40	2.5	1.0
MC-0	UA 1061	4.5	19	4.2	0.0
MC-0	UA 1062	28.0±	49	1.8±	5.0
		30.0±	50	1.7±	6.0
MC-0	UA 1063	20.0	36	1.8	2.0
		26.0	41	1.6	2.5
<i>Bothrophyllum</i> cf. <i>B. pseudoconicum</i> Dobrolyubova					
MC-7	UA 1070	27.0	41	1.5	—
MC-7	UA 1068	30.0	49	1.6	3.0
		32.0	50	1.7	3.5
		32.0	51	1.6	2.0
MC-7	UA 1069	33.0	52	1.6	2.5
		41.0	48	1.2	4.0
		13.0	34	2.6	0.7
MC-3	UA 1065	10.5	30	2.9	0.5
		23.0	45	2.0	1.0
		28.0	47	1.7	2.0
		30.0	51	1.7	1.5
MC-3	UA 1066	40.0±	59±	1.5±	—
		21.0	37	1.8	1.5
MC-3	UA 1064	37.0	48	1.3	3.0
<i>Bothrophyllum</i> sp. A					
MC-1	UA 1072	45.0±	55±	1.2±	5.0
MC-1	UA 1071	20.0	44	2.2	1.5
		25.0	46	1.8	1.5
		32.0	53	1.7	1.5
MC-1	UA 1073	45.0±	60±	1.3±	4.5
<i>Bothrophyllum pseudoconicum</i> Dobrolyubova, 1937†					
C ³ II horizon, Moscow Basin	469 holotype	3.0	17	5.7	
		5.0	25	5.0	
		7.5	32	4.3	
		9.0	34	3.8	
		18.0	35	1.9	
		19.0	41	2.2	
		29.0	45	1.6	
		33.0	48	1.5	

*Maximum; †Measurements of holotype included here for comparative purposes.

APPENDIX II. Fossil Localities

Fossil localities are listed stratigraphically, beginning with the oldest. A brief description of principal rock types is followed by the structural attitude, approximate elevation, location, and fauna for each locality. The identification of fossil invertebrates other than rugose and tabulate corals is preliminary and doubtless will require modifications as these groups are studied in more detail; tentative identifications of these fossils are included here primarily to indicate the variety of the fauna at the various localities.

RM-8

Limestone, medium crystalline, grey to black, silty; bedding thin to medium, regular, with thin interbeds of calcareous shale; strike N70°W, dip 65–70°, overturned toward the southeast; elevation approximately 2,750 feet; exposures along east side of Richardson Highway near mile post 212, Northern Rainbow Mountain area (Text-fig. 3).

Fauna. Rugosa, *Cryptophyllum striatum* n. sp.; Tabulata, *Cladochonus* sp., *Michelinia* sp.; Brachiopoda, *Linoproductus* sp., *Juresania* sp., *Stenocisma* sp., ?*Institina* sp., ?*Chaoiella* sp.; Cephalopoda, *Pseudoparalegoceras hansonii*; fauna also includes unidentified pectinoid pelecypods, bryozoa, and trilobites (rare).

Age. Lower Middle Pennsylvanian (post-Morrowan, pre-Missourian).

MC-7

Mudstones, grey to red-brown, locally silty or calcareous; bedding thin, regular; strike N60°W, dip 59°SW; elevation approximately 5,850 feet, summit ridge of south end of Rainbow Mountain, there trending NNW, Southern Rainbow Mountain area (Text-fig. 3).

Fauna. Rugosa, *Bothrophyllum* cf. *B. pseudoconicum* Dobrolyubova, ?*Caninia* sp.; Tabulata, *Michelinia* sp.; fauna includes scattered poorly preserved brachiopods.

Age. Lower Permian (Wolfcampian).

MC-6

Limestones and mudstones, alternating; bedding thin to medium, regular; strike N60°W, dip 60°SW; elevation approximately 5,900 feet, summit ridge of south end of Rainbow Mountain which there trends NNW, Southern Rainbow Mountain area (Text-fig. 3).

Fauna. Rugosa, *Heritschioides summitensis* n. sp.; fauna includes a few poorly preserved brachiopods and (in limestones) unidentified marine algae and schwagerinid Fusulinidae.

Age. Lower Permian (Wolfcampian).

MC-13

Limestones, medium to coarsely crystalline, grey, in part silicified; bedding medium to thick, with irregular interbeds of silicified silts; extensively jointed; strike N45°W, variable; dip, vertical to slightly overturned, variable; elevation approximately 5,350 feet, south side of Rainbow Mountain, Southern Rainbow Mountain area (Text-fig. 3).

Fauna. Rugosa, *Timania rainbowensis* n. sp.; fauna includes large coiled gastropods (?*Omphalotrochus*), poorly preserved productid and spiriferid brachiopods and the fusulinid *Pseudofusulinella* sp.

Age. Lower Permian (Wolfcampian).

MC-5

Limestones, finely crystalline, grey to green, with large fraction of volcanic detrital grains and extensively silicified; bedding medium to thick, with lenticular interbeds of silicified green silts showing graded bedding; strike N45°W, variable; dip, vertical or near vertical; elevation 5,250 feet, south side of Rainbow Mountain, Southern Rainbow Mountain area (Text-fig. 3).

Fauna. Tabulata, *Syringopora katoi* n. sp.; Brachiopoda, *Plicatifera* sp., *Derbyia* sp.; fauna includes well-preserved fronds of fenestrate bryozoa.

Age. Lower Permian (Wolfcampian).

MC-3

Limestones, finely crystalline, grey to green, rich in volcanic material and extensively silicified; bedding medium to thick, with irregular interbeds of graded silicified silts; strike northwest, variable; dip, 35°NE; elevation approximately 5,300 feet, south side of Rainbow Mountain, Southern Rainbow Mountain area (Text-fig. 3).

Fauna. Rugosa, *Bothrophyllum* cf. *B. pseudoconicum* Dobrolyubova; Brachiopoda, *Neospirifer* sp., *Choristites* sp., ?*Unispirifer* sp., *Yakovlevia* sp., *Linoproductus* sp., ?*Calliprotonia* sp., ?*Kochiproductus* sp., *Rugosochonetes* sp., ?*Denticulophora* sp.; Fusulinidae, *Pseudofusulinella* sp., ?*Eoparafusulina* sp.

Age. Lower Permian (Wolfcampian).

MC-1

Limestones, fine to medium crystalline, grey to green, rich in volcanic material and extensively silicified; bedding medium to thick, with interbeds of silicified green graded silts; strike N62°W, dip 72°SW; elevation approximately 4,600 feet, south side of Rainbow Mountain, Southern Rainbow Mountain area (Text-fig. 3).

Fauna. Rugosa, ?*Pseudobradiphyllum* sp. A, ?*Bradyphyllum* sp. A, *Bothrophyllum* sp. A; Brachiopoda, *Spiriferella* sp., *Choristites* sp., *Reticulatia* sp., *Linoproductus* sp., *Yakovlevia* sp., ?*Kochiproductus* sp.; Fusulinidae, ?*Pseudofusulinella* sp.

Age. Lower Permian (Wolfcampian).

MC-0

Limestone, finely crystalline (micrite), grey, bedding medium to thick, commonly lenticular; strike northwest, dip 45°NE, overturned; elevation approximately 4,000 feet; strata are exposed in a large south-facing talus slope on the south side of Rainbow Mountain, Southern Rainbow Mountain area (Text-fig. 3).

Fauna. Rugosa, *Timania* sp. A; Tabulata, ?*Sinopora* sp.

Age. Lower Permian (Wolfcampian).

RC-17

Limestone and shale, interbedded; limestone tan, medium crystalline, silty, fossiliferous; bedding thin to medium, regular; intervening shales compact, dark grey, locally fossiliferous; strike N45°W, dip 20°SW in lower part of exposures, increasing to approximately 40°SW in upper part of section; elevation (unit RC-17) approximately 3,200 feet; south side of the valley of Rainy Creek near its confluence with Delta River, Upper Delta River area (Text-fig. 4).

Fauna. Rugosa, *Caninia petoczi* n. sp.; Brachiopoda, *Linoproductus* sp., *Stenosisma* sp.; Fusulinidae, *Eoparafusulina* sp., *Schwagerina* sp., *Pseudofusulinella* sp., ?*Schubertella* sp.

Age. Lower Permian (Wolfcampian or ?lower Leonardian).

DR-14

Limestone, medium crystalline, grey; bedding thick, with interbeds of calcareous shales; strike approximately N45°W, dip 55 to 70°SW, variable due to nearby minor fault; elevation 2,700 feet; bluffs on east side of Delta River, Upper Delta River area (Text-fig. 4).

Fauna. Rugosa, *Caninia petoczi* n. sp.; Fusulinidae, *Eoparafusulina* sp., ?*Schubertella* sp., *Schwagerina* sp.; fauna includes common but poorly preserved brachiopods.

Age. Lower Permian (Wolfcampian or ?lower Leonardian). These strata are believed to be lateral equivalents of the coral zone at locality RC-17.

RC-18

Limestone, medium crystalline, light coloured; bedding thin to medium, regular, with thin interbeds of argillaceous limestone, siltstone and shale; strike N45°W, dip 40°SW; elevation, approximately 3,300 feet; small knoll above the south side of Rainy Creek, Upper Delta River area (Text-fig. 4).

Fauna. Rugosa, ?*Clisiophyllum* sp. B; Brachiopoda, *Neospirifer* sp., ?*Spiriferellina*, *Spiriferella* sp., ?*Camerisma* sp., *Antiquatonia* sp.

Age. Lower Permian (Wolfcampian or lower Leonardian).

DR-16

Limestone, medium to coarsely crystalline, grey; bedding thin to medium, regular; strike northwest, dip variable due to slumping; elevation 2,700 feet; bluffs overgrown by vegetation on west side of Delta River, Upper Delta River area (Text-fig. 4).

Fauna. Rugosa, *Auloclesia deltense* n. sp., *Clisiophyllum* sp. A; Porifera, *Hindia*? sp.; fauna includes a few poorly preserved brachiopods and schwagerinid fusulinids. This horizon may be an approximate lateral equivalent of strata exposed at locality RC-18, based on the overall similarity of the clisiophyllid coral fauna and stratigraphic position.

Age. Lower Permian (Wolfcampian or lower Leonardian).

VV-21a

Limestone, grey to black, finely crystalline, silty; bedding medium to thick, regular; strike N70°W, dip 74°NE, variable due to minor faults; elevation approximately 4,150 feet; limestone outcrops in north side of "Volcanic Valley", a small tributary of McCallum Creek, McCallum Creek area (Text-fig. 4).

Fauna. *Timania* cf. *T. schmidtii* Stuckenberg.

Age. Lower Permian (Wolfcampian or lower Leonardian).

VV-21b

Limestone, grey to black, finely crystalline; bedding thin to medium, regular; strike N70°W, dip 50-70°NE, variable; elevation 4,200 feet; north side of "Volcanic Valley", McCallum Creek area (Text-fig. 4).

Fauna. Rugosa, *Durhamina alaskaensis* n. sp.; Tabulata, *Sinopora minatoi* n. sp.; Fusulinidae, *Pseudofusulinella* sp., *Schwagerina* sp.

Age. Lower Permian (Wolfcampian or lower Leonardian).

DR-15

Limestone, finely crystalline, grey to black; bedding thick, regular; strike northwest, dip 30-50°SW, variable due to slumping; elevation 2,700 feet; bluffs on west side of Delta River, Upper Delta River area (Text-fig. 4).

Fauna. Rugosa, *Durhamina sutherlandi* n. sp.; Tabulata, *Sinopora* sp.

Age. Lower Permian (Wolfcampian or lower Leonardian); this zone is thought to be an approximate lateral biostratigraphic equivalent of strata at locality VV-21b.

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