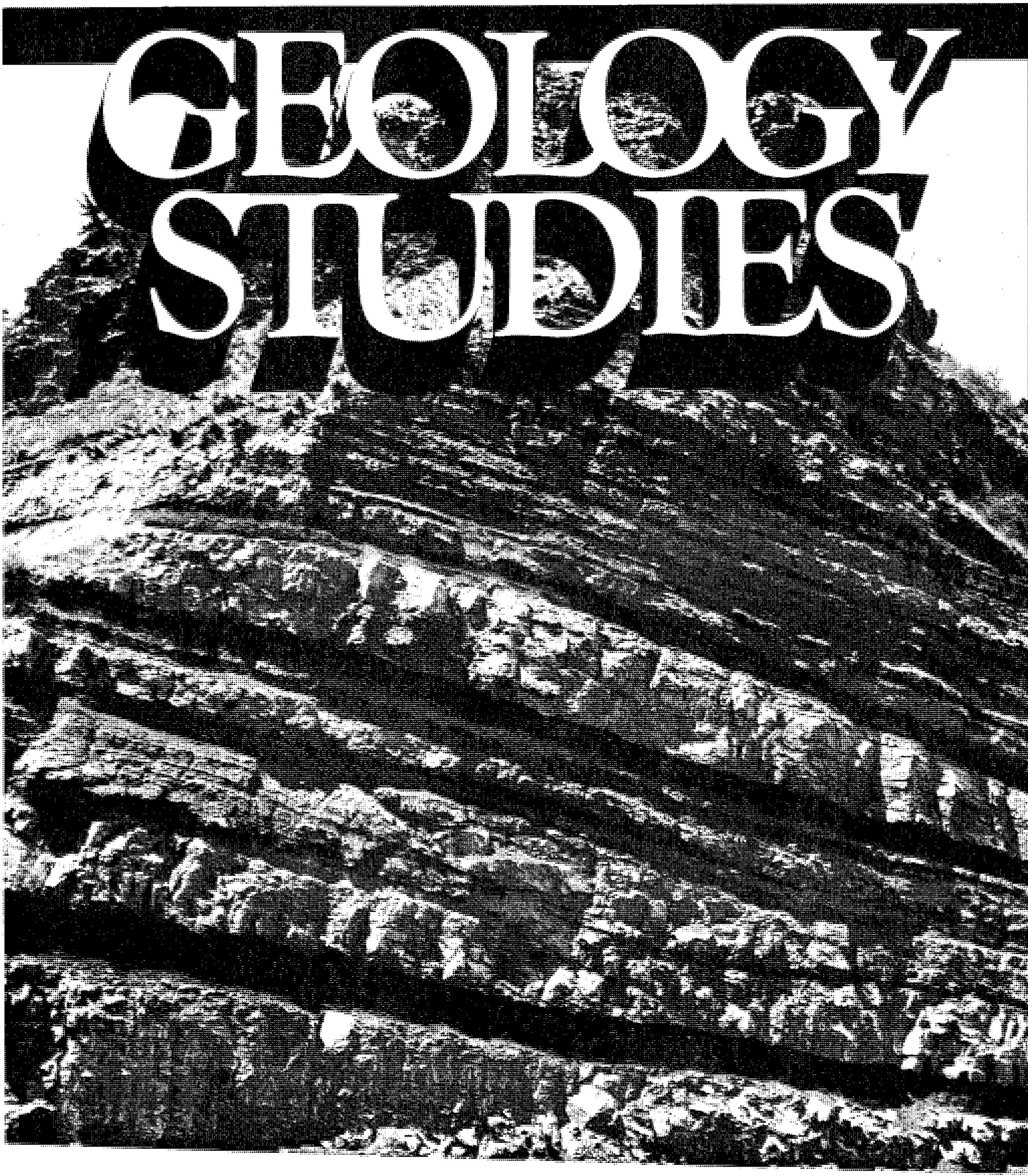
BRIGHAM YOUNG UNIVERSITY

# GEOLOGY STUDIES



VOLUME 26, PART 2 JULY 1979

# Brigham Young University Geology Studies

## Volume 26, Part 2

## CONTENTS



*Cover: Cretaceous coals near Castle Gate, Utah.*

A publication of the

Department of Geology

Brigham Young University

Provo, Utah 84602



*Brigham Young University Geology Studies* is published by the department. *Geology Studies* consists of graduate-student and staff research in the department and occasional papers from other contributors. *Studies for Students* supplements the regular issues and is intended as a series of short papers of general interest which may serve as guides to the geology of Utah for beginning students and laymen.

ISSN 0068-1016

Distributed July 1979

7-79 525 38477

CONTENTS

# Stratigraphy and Archaeocyathans of Lower Cambrian Strata of Old Douglas Mountain, Stevens County, Washington*

GEORGE L. HAMPTON III
*Amoco Production Company, Denver, Colorado 80202*

ABSTRACT.—An abundant fauna of archaeocyathans occurs in Lower Cambrian strata exposed near Douglas Lake, on the south end of Old Douglas Mountain, Stevens County, Washington. The outcrops are located about 6.5 km north-northeast of Colville, Washington, and consist of the Gypsy Quartzite and the Maitlen Formation. At this location, the lower Maitlen Formation contains two carbonate units, the lowermost Reeves Limestone Member and another dolomite and limestone unit referred to as the dolomite of Douglas Lake. In the past, the Reeves Limestone has been correlated with the "Old Dominion Limestone." This correlation is incorrect, and rocks early referred to as "Old Dominion Limestone" correlate with the Metaline Formation of Middle and ?Upper Cambrian age. The structure of the area is complex, and the strata are folded and cut by numerous faults.

Carbonate units of the lower Maitlen Formation contain a diverse Lower Cambrian fauna. Trilobites, echinoderms, sponges, hyolithids, and bryozoans(?) are reported for the first time. Archaeocyathans are the most abundant and varied faunal elements. Seven families are presented by seven or eight genera. The following species are described: *Loculicyathus* (*Loculicyathus*) cf. *L. canadensis* Handfield, 1971; *Diplocyathellus* aff. *D. princetonensis* Handfield, 1971; *Ethmophyllum whitneyi* Meek, 1868; Genus A sp. of Handfield, 1971; *Protopharetra* cf. *P. raymondi*, Okulitch, 1935; Genus? sp. A; Genus? sp. B; and *Pseudosyringocnema* cf. *P. uniporous* Handfield, 1971.

## INTRODUCTION

An abundant and diverse fauna of archaeocyathans and other Lower Cambrian fossils occurs in strata on the south end of Old Douglas Mountain, Stevens County, Washington. The fauna is found in the Reeves Limestone Member and associated carbonates within the lower Maitlen Formation.

The purpose of this paper is to describe the archaeocyathans which occur in the carbonate units of the Maitlen Formation that crop out around Douglas Lake at the south end of Old Douglas Mountain. The stratigraphy of the Lower Cambrian strata in the area is discussed, and these formations are compared and correlated with those of northeastern Washington and southeastern British Columbia. The structure is discussed briefly, but no detailed structural study of the surrounding area was conducted. The paleontology of the carbonate units in the Maitlen Formation is reported, as well as the systematic paleontology of the archaeocyathans that occur within the units.

### Location

Archaeocyathan-bearing limestones occur on the south end of Old Douglas Mountain, near Douglas Lake, in the NE 1/4 of section 22, T. 36 N, R. 39 E, Stevens County, approximately 6.5 km north-northeast of Colville, Washington. Paved county roads and unimproved dirt roads provide access to the study area (figs. 1 and 2).

### Previous Work

Archaeocyathans were first collected by W. A. G. Bennett from limestones of the Colville area and were briefly noted half a century ago (Ressor 1934, p. 7; Bennett 1937, p. 316). In 1948, H. W. Little (1950) collected specimens of archaeocyathans from limestone units in the same belt, but approximately 100 km to the north, near Salmo, British Columbia. Little collected archaeocyathan specimens the following year, from the Colville area (Greggs 1959, p. 63). Okulitch (1951, p. 405) also collected archaeocyathans from limestones near Colville.

Archaeocyathan occurrences in Washington and British Columbia were reported by Okulitch and Greggs (1958), and Greggs (1959) gave the first detailed paleontological report of Archaeocyatha from the Colville area. He described the fossils which Little and Okulitch had previously collected from a "west-facing bluff of 'Old Dominion Limestone' about one mile north of Colville, Washington" (Greggs 1959, p. 63). The "Old Dominion Limestone" mentioned by Greggs is the Reeves Limestone Member of the Maitlen Formation or its age equivalent (Okulitch 1951, p. 405). Other workers also mentioned archaeocyathan-bearing limestones in northeast Washington, including Mills (1962, 1977), Fyles (1970), and Yates (1976).

Archaeocyatha have long been known from western North America. Specimens from Nevada were first discussed by Meek (1868), who described *Ethmophyllum whitneyi* as a coral. *Ethmophyllum whitneyi* Meek, *Protopharetra* sp., *Coscinocyathus* sp., and *Archaeocyathus* sp. were the first archaeocyathans reported from the White Mountains of Inyo County, California (Walcott 1886). Although some preliminary taxonomic studies of the

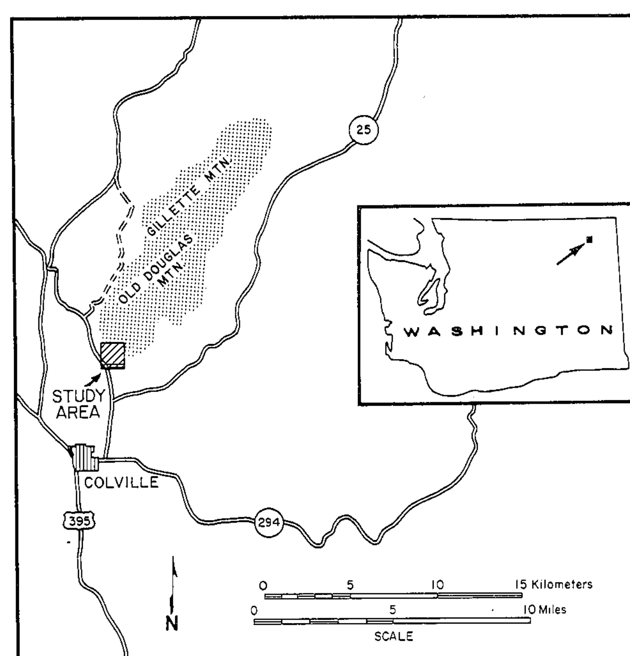



FIGURE 1.—Index map.

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, April 1979. Thesis committee chairman: J. Keith Rigby.

California and Nevada faunas have been made (Raymond 1931, Okulitch 1954), the first detailed studies of the collections were by Gangloff (1963, 1975). He reported that archaeocyathans have been collected and identified from 15 widely separated localities in California and Nevada (Gangloff 1976, p. 19).

McKee and Gangloff (1969) reported on the stratigraphic distribution of archaeocyathans in the Silver Peak Range and the White and Inyo mountains, western Nevada, and eastern California. The paleoecology of archaeocyathan bioherms in the White and Inyo mountains was discussed by Morgan (1976). Gangloff (1975, 1976) gave an excellent summary of the geographic and stratigraphic distribution of Archaeocyatha from the White-Inyo Range, along with interesting paleoecological aspects recognized there. Okulitch (1952, p. 27) described a fauna of archaeocyathans from Sonora, Mexico, that shows remarkable similarities to the California and Nevada faunas.

Archaeocyatha studies in western Canada have been principally carried out by Okulitch (1935, 1943, 1948, 1955; Okulitch and Roots 1947). Other taxonomic studies of western Canadian archaeocyathans include those of Kawase and Okulitch (1957) and Handfield (1971). Handfield described many new taxa and, for the first time in the northern Cordillera, placed collections of archaeocyathans in their stratigraphic framework. Their usefulness as regional correlation tools was demonstrated, and attempts at international and intercontinental correlation were discussed. Stelck and Hedinger (1975) reported on archaeocyathans and the Lower Cambrian continental shelf of the Canadian Cordillera.

### Methods

Fieldwork consisted of mapping and collecting specimens in May of 1978. Geologic data were recorded directly on aerial photographs in the field and were later transferred to a topographic base map. Bedding was often difficult to determine, and the most reliable attitudes were taken at contacts of contrasting lithologies. No stratigraphic sections were measured, but some samples were collected across strike at intervals of 3 or 4 m. In areas 1–9, 12, 13, 16a, 17–20, 3A, and 4A–D (fig. 3), samples were collected at irregularly spaced localities over an area of several square meters. Most samples collected were from the outcrop; float samples were usually avoided. Collecting sites are designated on the geologic map (fig. 3).

More than 130 thin sections were prepared. Most individual archaeocyathans were cut transversely or obliquely, but some longitudinal and tangential thin sections were also made. Samples that contained silicified archaeocyathans or sponge spicules were etched in 10 percent glacial acetic acid to remove the calcareous matrix.

## STRATIGRAPHY

Cambrian strata were first reported in northeastern Washington in 1931 by Ressor (1934, p. 7), who also noted that archaeocyathans and other Cambrian fossils had been collected from limestones near Colville by W. A. G. Bennett. Although a Paleozoic age had been indicated for the Addy Quartzite and Old Dominion Limestone (Weaver 1920), these units were not


FIGURE 2.–View of Douglas Lake, southwest end of Old Douglas Mountain, looking south. Areas 7 and 8 in foreground, areas 17, 19, and 20 in background (fig. 3).

assigned a definite Cambrian age until this paleontological evidence (Ressor 1934) was presented. Near Colville, three formations of Cambrian age have been recognized (fig. 4). The Gypsy Quartzite and overlying Maitlen Formation are Lower Cambrian (Yates 1976, p. 207), and the younger Metaline Formation is Middle to ? Upper Cambrian (Repetski 1978, p. 531). These are the only Upper Cambrian rocks reported from near Colville.

The base of the Cambrian System was tentatively placed at "the hiatus below the Monk Formation" by Park and Cannon (1943, p. 15). Little (1960, p. 14, 24), however, included the Monk Formation in the Windermere Series of Precambrian age. He concluded that the base of the Canadian Quartzite Range Formation (equivalent to part of the Gypsy Quartzite) therefore represented the Precambrian-Cambrian boundary. Yates (1964; 1970, p. 26, 27) also placed the lower boundary of the Cambrian at the base of the Gypsy Quartzite.

### Gypsy Quartzite

The Gypsy Quartzite (figs. 3, 4, 5) was named by Park (1938, p. 713, 714) and was later described in more detail by Park and Cannon (1943, p. 13–15). They characterized it as having a basal sequence of schist, conglomerate, quartzite, and grit, as much as 1,925 m thick. This sequence is overlain by 245 to 495 m of white to pink, clean, cliff-forming quartzite. The upper 15 to 90 m of the unit is composed of "alternating beds of quartzite and phyllite in nearly equal parts." Yates (1976, p. 19, 20) reported a similar sequence from the Deep Creek area to the west, and noted that the Gypsy Quartzite becomes progressively less siliceous upward. Quartzites in the lower unit are light gray to white, and the upper strata are "darker in color, ranging from dark-gray to dark-greenish gray."

The Gypsy Quartzite grades downward into the Monk Formation. The upper boundary was placed at a horizon of "fucoids" by Park and Cannon (1943, p. 13, 14). Since this fucoidal horizon is not always present, it has been suggested (Schuster pers. comm. 1978) that the top of the Gypsy Quartzite be placed at the base of the Reeves Limestone. Yates (1976, p. 17) also defined the top of the Gypsy Quartzite at the base of the Reeves Limestone, for it is "an easily recognized horizon and an abrupt change from the interbedded phyllite and quartzite to the limestone beds of the Reeves."

Bennett (Campbell 1947, p. 609) considered the Gypsy Quartzite to be correlative with the Addy Quartzite (Weaver 1920) of the Chewelah and Addy districts, south of Colville. This view was also supported by Okulitch (1951, p. 405) and Yates (1976, p. 348). Little (1960, correlation chart) correlated the Gypsy Quartzite with the Reno, Quartzite Range, and Three Sisters formations; the Hamill Group; and the uppermost part of the Horsethief Creek Group where they are exposed in southern British Columbia (fig. 4).

The upper and middle part of the Gypsy Quartzite were observed as part of this study in the Colville area. The quartzite in the southwest corner of the area (fig. 3) is clean, white to light pink quartzite with some conglomerate of angular quartzite pebbles, and is approximately 300 to 350 m thick. It is probably the massive white quartzite of Park and Cannon (1943, p. 14). Outcrops of Gypsy Quartzite in the north part of the map area (fig. 3) are grayish green, dirty to clean, medium- to fine-grained quartzite, often with rusty orange specks. These specks may be weathered magnetite crystals like those reported by Yates (1976, p. 21). The quartzite is locally interbedded with argillite, slate, and phyllite. The argillaceous material increases in proportion toward the top of the unit. These rocks are in the upper Gypsy Quartzite of Park and Cannon (1943, p. 13, 14) and Yates (1976, p. 20, 21), and may be up to 90 m thick.

Fossils in the Gypsy Quartzite are rare. Park and Cannon (1943, p. 15) reported Cambrian trilobite fragments. Okulitch (1951, p. 405) reported *Nevadia addyensis* Okulitch, *Hyolithellus* sp., and several species of brachiopods. The Gypsy Quartzite was therefore given an Early Cambrian age. The author did not find any fossils in the Gypsy Quartzite during the present field study.

### Maitlen Formation

The Maitlen Formation (figs. 3, 4, 5) was named the Maitlen Phyllite by Park (1938, p. 13, 14) and first described by Park and Cannon (1943, p. 15–17) in the Metaline Quadrangle. Lithology of the Maitlen beds is extremely diverse (Park and Cannon 1943, p. 15; Campbell 1947, p. 608) and justifies a name change to Maitlen Formation. The main body of the formation is made up of greenish gray, fine-grained and banded phyllite (Park and Cannon 1943, p. 16). Park and Cannon (1943, p. 15) and Campbell (1947, p. 608) described a gray white limestone band (Reeves Limestone) 60 to 90 m thick near the base of the formation. However, they did not report archaeocyathans from this unit. A variety of schist, slate, argillite, quartzite, and limestone layers have been reported within the unit.

The Maitlen Formation correlates with the Laib Formation (Yates 1970, p. 26; 1976, p. 208), lower Lardeau Group and, in part, with the Badshot Formation, all of British Columbia (Little 1960, correlation chart).

The Reeves Limestone Member was named for the lowermost limestone exposures near the Reeves MacDonald mine in the Salmo Mining District of southwestern British Columbia (Fyles and Hewlett 1959, p. 25, 26). They described what are possibly archaeocyathans: "In places it contains rounded dark-grey coarsely crystalline spots one-quarter to three-quarters of an inch in diameter resembling remnants of fossils."

The name Reeves Limestone Member was applied to the lowest of several limestone units (Park and Cannon 1943, p. 15) of the Maitlen Formation in the Deep Creek area of northeastern Washington by Yates (1964) in order to "avoid duplicate names for an identical unit." Yates (1976, p. 23) described the Reeves Limestone as a

> cream white, medium- to coarse-grained rock from 90 m to 120 m thick that has fair to poor bedding and a pronounced shear cleavage. It is banded white and gray, but the banding is continuous for only short distances. In places it is faintly mottled with pinkish buff mottles in a white background. The mottles consist of light tan dolomite crystals set in a calcite matrix.

Other descriptions of the Reeves Limestone, both in Canada and in northeastern Washington, have been given by Yates (1970, p. 27), Fyles and Hewlett (1959, p. 25, 32), and Fyles (1970, p. 46).

The Reeves Limestone Member of the Maitlen Formation correlates with the Reeves Limestone of the Laib Formation. Farther to the north, in the Lardeau map-area of British Columbia, the Reeves Limestone is equated with the Badshot (limestone) Formation (Walker, Bancroft, and Gunning 1929, p. 10). The Badshot Formation contains Lower Cambrian archaeocyathans and can be traced as far as 210 km north of the international border to the Rogers Pass map-area (Wheeler 1963, p. 6, 7). The Reeves Limestone Member also correlates

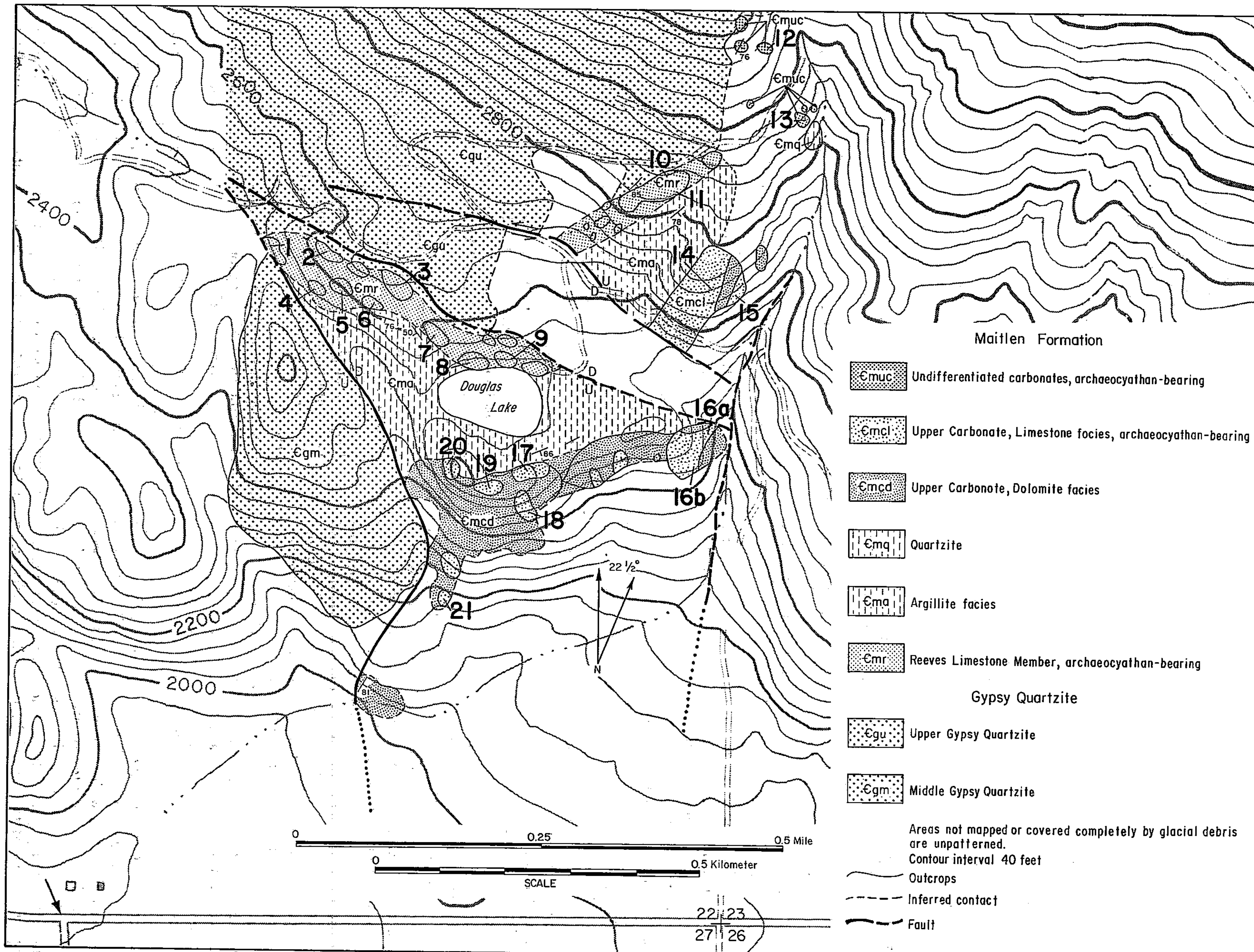



FIGURE 3.–Geologic map of study area. Numbers correspond to fossil collecting sites. Arrow in lower left corner corresponds to intersection of roads indicated by arrow above words *study area* in figure 1. Upper limestone and dolomite combined are referred to in text as "dolomite of Douglas Lake."

with the Poleta Formation of Inyo County, California, since *Nevadella* sp. is found in both units (Palmer written comm. 1978).

A controversy has arisen regarding correlation of the Reeves Limestone with the "Old Dominion Limestone" of Weaver (1920, p. 66). Campbell and Bennett (Campbell 1947, p. 606) believed that the "Old Dominion Limestone" in the Colville area was partly equivalent to the Metaline Formation. But they also stated that the base of the "Old Dominion Limestone" is Lower Cambrian. Bennett (1941, p. 9) had reported that brachiopods identified as *Kutorgina cingulata* (Billings), of Early Cambrian age, had been found in limestones in section 22, T. 33 N, R. 40 E, south of Colville. He referred to these limestones as "Old Dominion Limestone" of Weaver. The base of the Metaline Formation is Middle Cambrian (Park and Cannon 1943, p. 19). Yates (1976, p. 208) said, "The Metaline Formation, as the Old Dominion Limestone of Weaver (1920), however, extends as far south as the Spokane River." Some limestone units in the Hunters Quadrangle (37 km southwest of Colville) were mapped by Campbell and Raup (1964) as "Old Dominion Limestone of Weaver 1920)." Even though these limestones overlie the Addy (Gypsy) Quartzite (Campbell and Raup 1964), Mills (1977, p. 20) felt that they are Metaline Limestone since they are overlain by the Ordovician Ledbetter Slate.

Okulitch (1951, p. 405) reported Lower Cambrian archaeocyathans from an outcrop he called "Old Dominion Limestone" near Colville. From this observation he also gave the "Old Dominion Limestone" a Lower Cambrian age but correlated it with the lower limestone beds of the Maitlen Formation. Greggs (1959, p. 63) reported that some of the archaeocyathans described in his paper were collected by H. W. Little and V. J. Okulitch from a "west-facing bluff of 'Old Dominion Limestone' about one mile north of Colville, Washington." This archaeocyathan-bearing limestone has been mapped by Schuster (pers. comm. 1978) as Reeves Limestone. The outcrop occurs in the NW ¼ of section 4, T. 36 N, R. 39 E, Stevens County, Washington. Weaver (1920) mapped it as Colville Quartzite. These rocks were later identified as Gypsy Quartzite and Maitlen Formation (Bennett, geologic map, in Mills 1962; and Schuster 1978 pers. comm.). It now appears that a Lower Cambrian age for the "Old Dominion Limestone" is incorrect because of errors in correlation. Outcrops from which Okulitch collected the Lower Cambrian archaeocyathans are actually the Reeves Limestone, not the "Old Dominion Limestone."

Further geologic mapping and paleontological study of the area are needed to completely resolve the controversy. Most of what has been earlier mapped as "Old Dominion Limestone" (Weaver 1920) is probably equivalent to the Metaline Formation. The "basal" archaeocyathan-bearing limestone mentioned by Okulitch (1951) and Greggs (1959) overlies the Addy (Gypsy) Quartzite and is the Reeves Limestone Member of the Maitlen Formation.

A 50-to-60-m-thick semicontinuous band of archaeocyathan-bearing Reeves Limestone has been mapped by J. Eric Schuster of the Washington State Department of Natural Re-

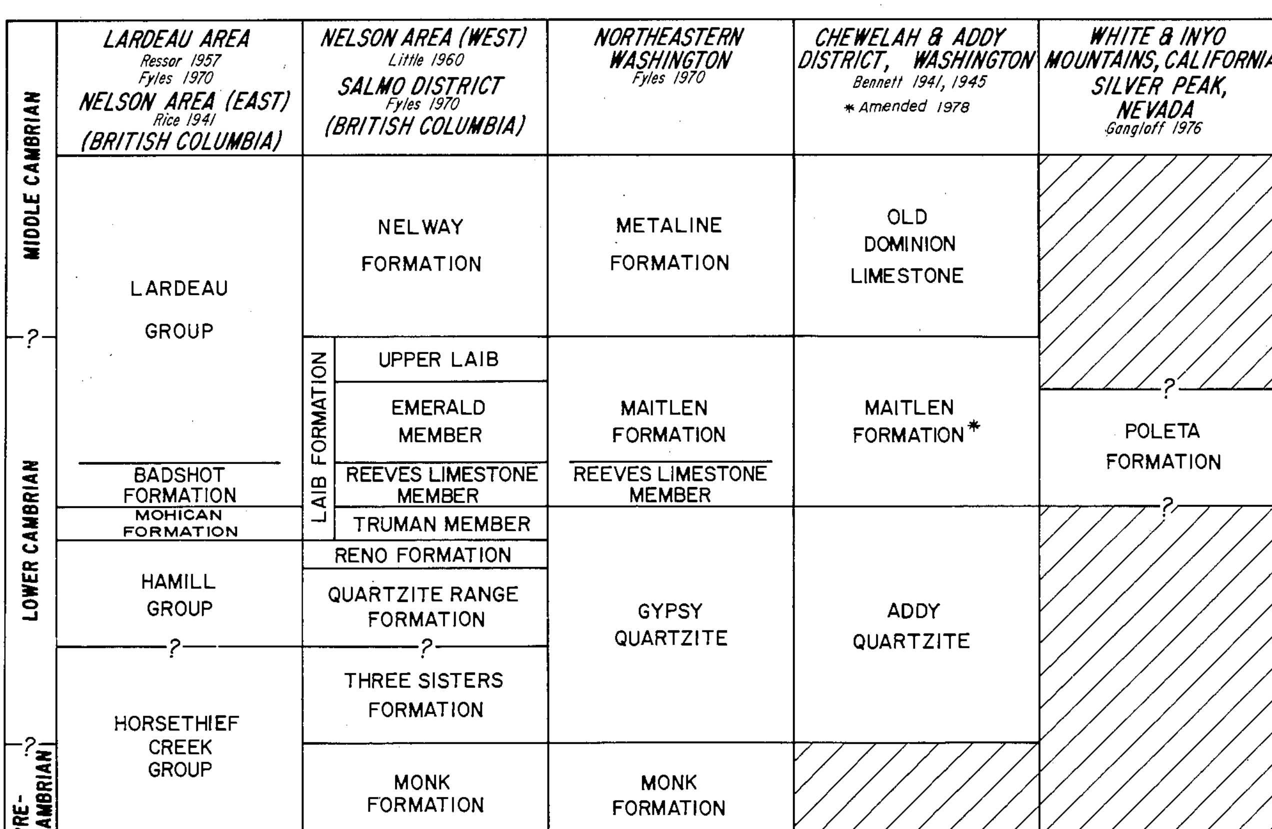



FIGURE 4.—Generalized correlation chart of Precambrian and Lower and Middle Cambrian stratigraphic units in northeastern Washington, southern British Columbia, and White and Inyo mountains, California and Nevada.

sources (pers. comm. 1978) over a distance of 18 km to the northeast of the study area in the Gillette Mountain and Aladdin quadrangles. Complex structure and cover of glacial debris often make precise correlation difficult. As the limestone unit is traced into the Douglas Lake area (fig. 3), it appears to be split into two units. Prior to detailed geologic mapping of the Douglas Lake area (fig. 3), it was not known whether these two outcrop belts were a structural repetition of a single unit or two stratigraphically distinct units. The two outcrop belts are separated by a jointed argillite which is overlain by a band of interbedded argillite, phyllite, and quartzite.

The 50-m-thick lower limestone unit varies from very light gray to dark gray, to occasionally gray green, sometimes with light pink stringers or mottles. It locally contains argillaceous stringers or some orange brown specks. Occasionally pods or lenses of medium- to fine-grained very light gray to medium gray dolomite also occur. The dolomite weathers to a reddish brown and has a characteristic sucrosic texture. The unit locally contains lenses of argillite and shale.

Most of the Archaeocyatha described in this paper came from the abundant fauna of the lower limestone unit. Many lenses and discontinuous beds of a dark gray to black, coarsely crystalline fossil detritus were noted (fig. 6). This detritus consistently contains archaeocyathans and often other fossils as well. Bedding within the unit is obscure.

The two most abundant archaeocyathans in this detritus bed are *Ethmophyllum* and *Pseudosyringocnema.* This same relationship is noted by Gangloff (pers. comm. 1978) in the Lower Cambrian strata in California and Nevada. In Gangloff's material, however, the archaeocyathans are commonly silicified, but in the Reeves Limestone material silicification shows specific selectivity, for only specimens of *Pseudosyringocnema* are silicified.

The 100-to-130-m-thick middle unit between the two carbonates is predominantly gray green, fine- to coarse-grained, closely jointed argillite. It commonly weathers to a brownish orange. The argillite is sometimes interbedded with gray green, medium- to fine-grained quartzite. The percentage of quartzite beds increases upsection, but argillite remains the dominant lithology throughout the unit. The argillite is locally slaty or phyllitic. Occasional beds of shaly limestone were also noted.

The upper carbonate unit, here called the dolomite of Douglas Lake, is approximately 60 to 120 m thick and consists of essentially two lithologies: Most common is light to medium gray, fine- to coarse-grained dolomite. It weathers to a reddish brown, with a distinctly sucrosic texture. It is widely exposed in the southern part of the map area (fig. 3). The other lithology is a light or medium gray, fine-grained to micritic archaeocyathan-bearing limestone. Archaeocyathans are rare and usually preserved only as ghosts. The limestone weathers very light gray and locally contains stringers, thin beds, or layers of dolomite and argillaceous material. Limestone beds in which archaeocyathans occur usually contain few argillaceous layers or stringers. In the southern part of the map area, the limestone occurs only as pods or lenses in the more massive dolomite.

There are several differences between the lower and upper carbonate units: First, dolomite is dominant in the upper unit but relatively rare in the lower unit. Second, argillaceous and dolomitic stringers are more abundant and tend to be aligned along bedding in the upper unit. Third, archaeocyathans are rare or scarce in the upper unit but are abundant in the lower unit. Fourth, the dark gray to black fossil detritus beds of the lower unit are not found in the upper unit. Fifth, the two units contain different faunas of archaeocyathans.

These comparisons indicate that the two carbonate units near Douglas Lake are indeed stratigraphically distinct units and not a single tectonically repeated carbonate. The increase of quartzite in the top of the middle argillite unit also supports this conclusion. To avoid confusion, it has been suggested by Yates (1970, p. 27) that the name Reeves Limestone should be restricted to the lowermost limestone unit in the Maitlen Formation. Thus the lower limestone unit of the map area (figs. 3, 4) is termed the Reeves Limestone Member of the Maitlen Formation, and the upper unit is a separate, but associated, carbonate unit in the lower Maitlen beds referred to in this report as the dolomite of Douglas Lake.

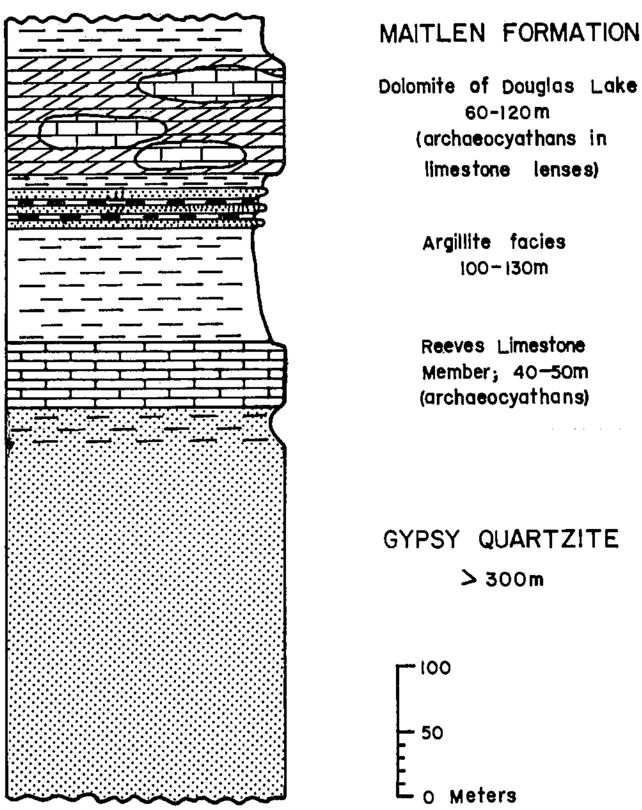



FIGURE 5.—Generalized stratigraphic column of Lower Cambrian rocks of the study area.

## STRUCTURE

The structure of the Colville area is extremely complex. Generally speaking, the south end of Old Douglas Mountain is a southwest-plunging anticline. Specifically, however, it is much more complex. It is beyond the scope of this paper to discuss the structure of the area in detail. Nevertheless, several structural interpretations were made as a result of the fieldwork (fig. 3).

The two carbonate units studied are on the southeast limb of an anticline. Beds dip very steeply, ranging from 50°S to SE or SW to vertical. Dips between 70° to 80° are most common. These steeply dipping beds are cut by several steeply(?) dipping faults (fig. 3).

Evidence for faulting includes slickensides, iron-stained gauge zones, folded beds as a result of fault drag (fig. 7), and perennial springs in the canyon west of areas 15, 16a, 16b (fig. 3). The faulting is younger than the folding.

## PALEONTOLOGY OF CARBONATE UNITS

No fossils have been reported from the phyllite and argillite of the Maitlen Formation. Archaeocyathans have been reported from the formation only from the lower limestone units. In addition to a rich fauna of archaeocyathans, fossils of several other phyla are present. The detritus beds (fig. 6) yielded many fossils other than archaeocyathans. Abundant *Chancelloria* sponge spicules (plate 1, figs. 5, 6, 7; BYU 2322–2324) (J. K. Rigby pers. comm. 1978) were found in rocks from several localities. Rocks from localities 11 and 12, containing trilobite fragments (plate 1, fig. 1; BYU 2319) were sent to Allison R. Palmer for identification. He reported (written comm. 1978) that

> each collection yielded poor but recognizable specimens of indeterminate species of *Nevadella,* so that your archaeocyathid beds are essentially synchronous with those of the Poleta Formation in California and the medial Lower Cambrian of Canada. Both collections also had rare specimens of calcareous brachiopods: in 5-19-3A (area 12) there was a ribbed form, and in 5-5P (area 11) the forms were relatively smooth. Neither collection had forms that were even generically identifiable. Collection 5-5P (area 11) also had specimens of a hypolithid with a circular cross-section.

Numerous echinoid plates (plate 1, figs. 2, 3, 4, 7; BYU 2320, 2321, 2324) were found in association with the archaeocyathans, as well as the alga *Renalcis* sp. (plate 3, figs. 5, 6, 9, 10). A possible trepostomate(?) bryozoan(?) (plate 1, figs. 8–10; BYU 2325–2327) was recognized in rocks from area 4 (fig. 3). This is the first time, to the author's knowledge, that trilobites, sponges, hyolithids, *Renalcis* sp., or bryozoans have been reported from the Maitlen Formation. Lower Cambrian brachiopods were reported by Bennett (1941, p. 9) from limestone then termed the "Old Dominion Limestone" of Weaver (1920). However, these limestones are probably the Reeves Limestone since they are Early Cambrian age and rest on the Addy Quartzite.

## SYSTEMATIC PALEONTOLOGY

### Introductory Remarks

Descriptions, discussion of morphology, and classification follow the nomenclature of the *Treatise on Invertebrate Paleontology,* Part E, Vol. 1 (revised) *Archaeocyatha* (Hill 1972). Numerical coefficients used are intervallum coefficient (IK), the ratio of the width of the intervallum to the central cavity diameter (width of intervallum/width of central cavity), and radial coefficient, the number of radial elements (often septa)/diameter of the cup. A new coefficient introduced by Debrenne (1974, p. 93) is the pore coefficient (PK). This is the ra-

FIGURE 6. Lens of dark gray to black, coarsely crystalline fossil detritus (hammer) between light gray limestones, area 10 (fig. 3).

tio of the pore diameter (PD) of each wall to the width of the skeletal framework or linteaux (L) which separates the pores. This coefficient may be expressed PK = PD/L.

The Archaeocyatha herein described represent most of the species found in the lower carbonate units of the Maitlen Formation. *Loculicyathus, Diplocyathellus, Pseudosyringocnema,* and Genus A Handfield are reported for the first time in northeastern Washington. Specimens of other species, not preserved well enough for identification, also are noted. Further study of the Reeves Limestone and other associated carbonates will undoubtedly result in discovery of Archaeocyatha species in addition to those included in this paper.

Classification

The following list is a summary of the taxa identified from the Reeves Limestone and associated carbonate units in the Lower Maitlen Formation on Old Douglas Mountain, Stevens County, Washington. The classification scheme of Hill (1972) is followed:

Phyllum ARCHAEOCYATHA
Class REGULARES
Order AJACICYATHIDA
Suborder AJACICYATHINA
Superfamily AJACICYATHACEA
Family AJACICYATHIDAE

*Loculicyathus* (*Loculicyathus*) cf. *L. canadensis* Handfield, 1971.
Family DIPLOCYATHIDAE
*Diplocyathellus* aff. *D. princetonensis* (Handfield, 1971)
Family ETHMOPHYLLIDAE
*Ethmophyllum whitneyi* Meek, 1968
Superfamily (?)
Family (?)
Genus A sp. Handfield, 1971

Class IRREGULARES
Order ARCHAEOCYATHIDA
Suborder ARCHAEOCYATHINA
Family PROTOPHARETREDAE
*Photopharetra* cf. *P. raymondi* Okulitch, 1935
Suborder ARCHAEOSYCONINA
Family (?)
Genus(?) sp. A
Genus(?) sp. B
Order SYRINGOCNEMIDIDA
Family SYRINGOCNEMIDIDAE
*Pseudosyringocnema* cf. *P. uniporous* Handfield, 1971

Systematics

Phylum ARCHAEOCYATHA Bornemann, 1884
Class REGULARES Vologdin, 1937

FIGURE 7. Drag folds on a fault west of area 20 (fig. 3); looking southwest, in upper carbonate unit.

Order AJACICYATHIDA R. Bedford & J. Bedford, 1939
Suborder AJACICYATHINA R. Bedford & J. Bedford, 1939
Superfamily AJACICYATHACEA R. Bedford & J. Bedford, 1939
Family AJACICYATHIDAE R. Bedford & J. Bedford, 1939
Genus LOCULICYATHUS Vologdin, 1931
Subgenus LOCULICYATHUS Hill, 1972
*Loculicyathus (Loculicyathus)*
cf. *L. canadensis* Handfield, 1971
plate 1, figs. 11–13

*Synonomy.* ?*Loculicyathus ellipticus* Kawase and Okulitch, 1957, Journal of Paleontology, v. 31, no. 5, p. 926–927, pl. 113, figs. 1–6.

*Loculicyathus canadensis* Handfield, 1971, Canadian Geological Survey Bulletin 201, p. 39, pl. 3, figs. 5a–d.

*Description.* The cup of this species is large and solitary. Early stages probably cylindro-conical followed by a rapidly expanding broadly conical stage. One cylindrical fragment and several long slender fragments were found. The cylindrical specimen is 6.6 mm in diameter. The intervallum width is 1.62 mm, central cavity diameter is 3.0 mm for an intervallum coefficient of 0.54. The long slender fragments measure 17.2 mm, 26.0 mm, and 60 mm long in transverse section. The intervallum is crossed by straight to slightly waved, close, porous septa. Dissepiments are abundant in all specimens and are 0.02 mm to 0.04 mm thick.

The intervallum of the cylindrical specimen is crossed by 45 septa, 0.26 mm to 0.34 mm apart and 0.09 mm to 0.1 mm thick. The radial coefficient is 6.8. Septa are pierced by pores, 0.1 mm wide, four or five to a horizontal row. The central cavity is round and clear of any skeletal material.

Measurements of the long slender fragments show some variability. Intervallum width varies from 1.68 mm in the 26-mm specimen to 4.1 mm in the 60-mm specimen. The intervallum is crossed by straight to slightly waved, close, porous septa. The 60-mm specimen is crossed by 43 septa, 0.21 mm to 0.24 mm thick. Pores may occur in horizontal rows, since septa appear to be either aporose or extremely porous with four to five pores per septa. Pores in the septa are 0.24 mm in diameter. Distance between septa varies between 0.8 mm and 1.0 mm. In the 26-mm and the 17.2-mm specimens septa are only 0.08 mm to 0.11 mm thick, and distance between septa averages about 0.7 mm. Pores in the septa of the 17.6-mm specimen are only 0.10 mm to 0.12 mm wide.

Walls of all specimens observed are poorly preserved or completely recrystallized. Tangential thin sections did not show any additional details. One area on the outer wall of the cylindrical specimen is approximately 0.1 mm to 0.2 mm thick and has possibly one or two pores per intersept. There are no septal furrows in the outer walls of any of the specimens. The inner wall is not well shown in the available specimens either, but is approximately 0.2 mm thick in one specimen and appears to be simply porous.

*Discussion.* The 17-mm specimen from area 16a more closely matches those described by Handfield (1971, p. 39) than do the other long fragments. The cylindrical fragments, which are presumed to be a stalk of a larger broad open cone, are similar to *Loculicyathus ellipticus* Kawase and Okulitch, 1957. However, since all the cylindrical specimens were found in the same locality with fragments from the broad open cup, it is assumed they are probably the same species. More complete specimens are needed to completely define the shape of this species. *Diplocyathellus* displays the same cup shape, beginning with a slim, cylindro-conical stalk then later expanding into a broad, open, conical shape.

Poor outer wall and inner wall preservation makes assignment of this species to a family and genus questionable. However, the presence of numerous dissepiments makes the chosen taxonomic assignment very likely. No septal furrows are present. Therefore, if the generic assignment were correct, the species would be assigned to the subgenus *Loculicyathus.*

*Material.* This taxon is represented by three long slender fragments and four cylindrical specimens. Only one of the cylindrical specimens is complete. The others are only fragments. Transverse and longitudinal sections were made. Preservation is fair to poor. The walls are especially poorly preserved. Figured specimens, BYU 2328–2330.

*Occurrence.* Lower Cambrian limestone facies of the carbonate unit above the Reeves Limestone in the Maitlen Formation, areas 15, 16a, and 17, figure 3.

Family DIPLOCYATHIDAE Debrenne, 1974
Genus DIPLOCYATHELLUS Debrenne, 1974
*Diplocyathellus* aff. *D. princetonensis*
(Handfield, 1971)
plate 2, figs. 1–7

*Synonomy.* *Zonacyathus princetonensis* Handfield, 1971, Canadian Geological Survey Bulletin 201, p. 48, pl. 6, figs. 3–6.

*Description.* The cup is large, solitary; early stage is conical and narrow followed by a rapidly expanding, broadly conical later stage. The intervallum is relatively narrow, 0.58 mm to 1.2 mm wide. The central cavity varies greatly from 2.12 up to approximately 29.0 mm in the later stages. Hence intervallum coefficients range from 0.36 in the early stages, to 0.02 in the 30-mm-diameter cup.

The intervallum is crossed by numerous, straight, aporose septa. They are 0.04 mm to 0.07 mm thick and an average of 0.42 mm apart. The radial coefficient ranges from 5.86 to approximately 10 for the large, broad conical stage.

The outer wall is retiform and 0.06 mm to 0.1 mm thick. It is pierced by simple pores, three to five per intersept, usually arranged in alternating vertical rows. The pores are 0.10 mm in diameter with a linteaux of 0.04 mm. The pore coefficient is 1.5. The inner wall is from 0.44 mm to 0.60 mm thick. It is composed of branching pore-canals, two per intersept. These initial pore-canals sometimes appear to bifurcate again before entering the central cavity. Therefore, the inner wall often appears very complex. The pore-canals are 0.1 mm to 0.14 mm in diameter with a linteaux of 0.06 mm to 0.10 mm, for a pore coefficient of 1.1 to 1.6.

*Discussion.* This species differs slightly from *D. princetonensis* Handfield in several aspects. First of all, Handfield (1971, p. 48) did not mention an early conical stage; however, he had only two large fragments. Secondly, details of outer and inner walls differ slightly, and the intervallum of the Colville specimens is narrower. These specimens have an affinity with *Diplocyathellus princetonensis* (Handfield, 1971), but they may be a separate species. However, Handfield's original description was based upon only two fragments, which does not permit much range of variation. Gangloff (pers. comm. 1978) also found *Diplocyathellus* in California and Nevada. His specimens are closely related to both the Canadian and northeast Washington species.

*Material.* This taxon is represented by 45 specimens. Several whole specimens were broken loose from the matrix, thus allowing a three-dimensional view of the species. Many specimens occur in each thin section. Numerous transverse cross sections were obtained as well as oblique longitudinal sections. Preservation is generally good. Figured specimens, BYU 2331–2337.

*Occurrence.* Lower Cambrian, Reeves Limestone Member of the Maitlen Formation, area 1, figure 3.

Family ETHMOPHYLLIDAE, Okulitch, 1943
Genus ETHMOPHYLLUM Meek, 1868
*Ethmophyllum whitneyi* Meek, 1868
plate 2, figs. 8–12, plate 3, figs. 1–3

*Synonomy. Ethmophyllum whitneyi* Meek, F.B., 1868, American Journal of Science, 2nd Series, v. 45, p. 62.

*Ethmophyllum whitneyi* Walcott, C.D., 1886, U.S. Geological Survey Bulletin 30, pp. 81–84, pl. 4, figs. 1, 1(a–c), 1g.

*Ethmophyllum whitneyi* Okulitch, V.J., 1943, Geological Society of American Special Paper 48, p. 65–67, pl. 3, figs. 15(a–c), pl. 4, figs. 1, 3, 4, 8.

*Ethmophyllum whitneyi* Greggs, R. G., 1959, Journal of Paleontology, v. 33, p. 66, pl. 13, figs. 7, 8;

*Ethmophyllum whitneyi* McKee, E.H., 1963, Journal of Paleontology, v. 37, p. 288, figs. 2–4.

*Ethmophyllum whitneyi* Hill, D. 1965, Trans-Arctic Expedition 1955–1958, Scientific Reports, No. 10, (Geology: 3), p. 72–73, pl. 4, figs. 1(a–c).

*Description.* The cup is solitary and cylindro-conical and is irregularly round in transverse cross section. Diameter of the cup ranges from 1.12 mm to 5.8 mm. The intervallum is from 0.32 mm to 1.02 mm wide, and the central cavity is 0.72 mm to 2.9 mm in diameter, for an intervallum coefficient ranging from 0.28 to 0.50.

The intervallum is crossed by straight, aporose septa which become wavy near the inner wall. The number of septa varies from 16 at the diameter of 1.12 mm, to 40 at 5.8 mm diameter. Radial coefficient ranges from 5.8 to 14.3. Septa are, for the most part, 0.04 mm to 0.06 mm thick at the outer wall.

The outer wall exhibits strong transverse annulations. These annulations are also noted in the inner wall but are less prominent. The outer wall is pierced by geniculate pore-tubes. In longitudinal section the pore-tubes are shaped like an inverted V with a crest at its apex. They are arranged in three to six alternating vertical rows per intersept, four to five rows per intersept being most common. The pore-tubes are round to oval in tangential cross section and range from 0.04 mm to 0.09 mm in diameter, 0.06 mm to 0.08 mm being most common. Thickness of the walls of the pores varies from 0.02 mm to 0.04 mm, for a pore coefficient from 2 through 3.4. The inner wall is 0.22 mm to 0.80 mm thick and is a complex system of intercommunicating pore-tubes and pore-canals. Two alternating vertical rows of pore-canals occur per intersept on the intervallum side of the inner wall. The pore-canals are directed behind the septa and connect to a larger, upward directed pore-tube. Each pore-tube is joined by two pore-canals, one from each intersept on either side of the pore-tube. The pore-canals are 0.06 mm to 0.14 mm in diameter and 0.42 mm to 0.46 mm long. The walls are 0.04 mm and 0.08 mm thick, for an average pore coefficient of 1.7. The pore-tubes range from 0.10 mm to 0.22 mm in diameter and are 0.54 mm to 0.62 mm long, with walls 0.08 mm to 0.20 mm thick. Average pore coefficient for the pore-tube is 1.14. The pore-canals and pore-tubes are round to oval in cross section.

*Discussion.* In the original description of *Ethmophyllum whitneyi* Meek (1868, p. 62), geniculate pore-tubes are not described in the outer wall. However, in plate IV, fig. 1d (Hill 1965), which is a X30 enlargement of the lectotype of Walcott (1886, fig. 1c), the outer wall appears to be pierced by geniculate or V-shaped pore-canals with a "spine" or crest at the apex of the V. Hill (1972, p. E72) also mentions that *Ethmophyllum* has "curved (or ? geniculate) pore-canals in quincunx" in the outer wall. Gangloff (pers. comm. 1978) feels that the geniculate appearance is the result of a downward-directed external bract.

Hill (1972, p. E72) defined *Ethmophyllum* as possessing porous septa. However, Handfield (1971, p. 42) and Gangloff (pers. comm. 1978) reported that *Ethmophyllum* has aporose septa. These specimens from Washington also possess aporose septa; therefore, this part of the definition of the genus should be amended.

Except for the above differences, the Colville specimens compare well with previously described *Ethmophyllum whitneyi* Meek and are included in that species.

*Material.* Twenty-two specimens in the collection are assigned to this species. Preservation ranges from fair to good. No silicified specimens were observed. Oblique longitudinal, as well as normal and oblique transverse thin sections were prepared. Approximately twenty additional specimens which resemble *E. whitney* were found but cannot be confidently assigned to this species. Figured specimens, BYU 2319, 2338–2343.

*Occurrence.* Lower Cambrian, Reeves Limestone Member of the Maitlen Formation, areas 1, 4, 6, 10, and 11, figure 3.

Superfamily ?
Family ?
Genus A Handfield, 1971
Genus A sp. Handfield, 1971
plate 3, fig. 4

*Synonomy.* Genus A sp. Handfield, 1971, Canadian Geological Survey Bulletin 201, p. 56, pl. 10, figs. 4a, b.

*Description.* The cup is catenulate colonial and is irregularly shaped. The diameter of a single specimen varies from 8.3 mm to 10.0 mm, with a central cavity approximately 2.76 mm wide and an intervallum which varies from 1.3 mm to 1.5 mm wide. The average intervallum coefficient is 0.5.

The intervallum is crossed by 25 porous septa. The radial coefficient is approximately 2.7. Septae range in thickness from 0.08 mm to 0.1 mm, are secondarily thickened, and are dark in the center and lighter near the edges. One of the septa appears to bifurcate before reaching the outer wall. Septal pores are irregularly arranged and are approximately 0.07 mm to 0.14 mm in diameter.

The single described specimen has one large central cavity and two smaller ones. The smaller central cavities are apparently early stages of a catenulate colony. The inner wall is 0.2 mm to 0.3 mm thick and is pierced by two branching pore-canals per intersept. The pore-canals branch to join one pore-canal, opposite the septa. This single pore-canal enters the central cavity. The outer wall is 0.18 mm to 2.0 mm thick with 2 to 4 irregularly spaced pore-canals per intersept.

*Discussion.* This single specimen resembles what Handfield (1971, p. 56) called Genus A sp. Handfield reported that his specimen is solitary rather than colonial and has complex inner walls 1.1 mm thick. It also has a thicker intervallum than does the Colville specimen. These differences are not of generic significance but may differentiate two species. The Colville specimen also closely resembles a new genus in Gangloff's 1975 Ph.D. dissertation. Gangloff's specimen exhibits catenulate colonialism also. Because of poor preservation of the Colville specimen, a closer taxonomic assignment is not possible.

*Material.* Only one transverse thin section of a single specimen was studied. Preservation is fair, and some details are difficult to see. Figured specimen, BYU 2344.

*Occurrence.* Lower Cambrian, Reeves Limestone Member of the Maitlen Formation, area 1, figure 3.

Class IRREGULARES Vologdin, 1937
Order ARCHAEOCYATHIDA Okulitch, 1935
Suborder ARCHAEOCYATHINA, Okulitch, 1935
Family PROTOPHARETRIDAE Vologdin, 1957
Genus PROTOPHARETRA Bornemann, 1884
*Protopharetra* cf. *P. raymondi* Okulitch, 1935
plate 3, figs. 5–11; plate 4, fig. 1

*Synonomy. Protopharetra raymondia* Okulitch, 1935, Transactions of the Royal Society of Canada, series 3, 29, section 4, p. 103, pl. 2, fig. 2.

*Protopharetra raymondi* Okulitch, 1943, Geological Society of America Special Paper 48, p. 71, pl. 4, fig. 8; pl. 6, figs. 3, 4.

*Protopharetra raymondi* Zhuravleva, 1960, Arkheotsiaty Sibirskoi platformy, p. 295.

*Description.* The cup is small to medium sized and cylindrical, and the species generally maintains a dendritic colonial habit. Two incomplete specimens measure 14 mm and 26 mm long. Slight transverse annulations were noted in the outer wall, but they do not appear to greatly affect the inner wall or the central cavity. The cup is between 2.4 mm and 4.0 mm in diameter, less than 2.8 mm in diameter being most common. The intervallum is from 0.6 mm to 1.6 mm wide. Central cavity widths vary from 0.4 mm to 0.84 mm. The intervallum coefficient ranges from 1.0 to 1.7.

The intervallum is characteristically filled by irregularly waved taeniae, joined with synapticulae. Taeniae are 0.06 mm to 0.28 mm thick and are often joined to form polygonal or round spaces, as viewed in transverse section. In longitudinal section the taeniae are arranged in semiparallel rows that curve upward and outward giving the intervallum a latticelike appearance. The taeniae are irregularly porous, with pores varying in size from 0.08 to 0.1 mm wide. Dissepiments are present but not abundant in any of the specimens studied. They are 0.03 mm to 0.04 mm thick.

The outer wall is 0.08 mm thick to 0.35 mm thick. Poor preservation or secondary thickening obliterates most evidence of pores in the outer wall. The few that were observed are 0.10 mm in diameter.

The inner wall is thin and porous. Thickness varies from 0.10 mm to 0.12 mm. Pores are arranged irregularly, one per intertaenial space. Pores are 0.06 mm to 0.14 mm in diameter and sometimes occur as pore-canals produced by secondary thickening of the inner wall.

*Discussion. Protopharetra raymondi* Okulitch (1935, p. 103) and *Protopharetra dunbari* Okulitch (1943, p. 71) appear to be similar. As originally discussed by Okulitch (1943, p. 71), *P. dunbari* differs from *P. raymondi* by having a thicker outer wall, lacking numerous pores, and having much more dense intervallum tissue. However, he also described *P. raymondi* as having "very dense" intervallum tissue (Okulitch 1935, p. 103). Original descriptions of both *P. raymondi* and *P. dunbari* lack measurements of the thickness of the outer and inner walls and thickness of intervallum tissue (taeniae). Gangloff (pers. comm. 1978) suggested that secondary thickening of skeletal elements of archaeocyathans, especially in irregular forms, is an environmental response to the presence of algae. Thirteen of the specimens studied from the Colville area resembled *P. dunbari* Okulitch in that they have very thick outer walls and taeniae. However, the specimens are also in close association with the alga *Renalcis* sp. It is likely that *P. dunbari* is conspecific with *P. raymondi* and that the differences noted by Okulitch are environmental rather than genetic.

In a Ph.D. dissertation, Gangloff (1975), described a new species of *Protopharetra.* Measurements of the Colville specimens agree closely with those of Gangloff's species. One morphological difference exists, however, for the outer wall of Gangloff's new species is sometimes screened by a microporous sheath, and a pellis can be present. These features are strikingly absent from the Colville material. However, this absence may be a result of poor preservation since the microporous sheath is delicate. Okulitch (1943) did not mention a double outer wall when he described *P. raymondi,* but in plate 6, figure 3, a double outer wall appears to be present.

Since Gangloff's species is unpublished and data included in the original description of *P. raymondi* is lacking important measurements, the specimens from Colville are assigned as *Protopharetra* cf. *P. raymondi* Okulitch, 1935.

*Material.* Fifty specimens were identified as *Protopharetra* cf. *P. raymondi.* Six other specimens were noted that may be *Protopharetra* cf. *P. raymondi* Okulitch but are too poorly preserved for positive identification. Preservation of specimens is fair to poor. Details of the outer wall are especially difficult to resolve. Longitudinal and transverse thin sections were prepared. Figured specimens, BYU 2345–2351.

*Occurrence.* Lower Cambrian Reeves Limestone Member and undifferentiated carbonate unit in north of study area, areas 2, 3 and 12, figure 3. Specimens of archaeocyathans resembling the genus *Protopharetra* were observed in the carbonate unit above the Reeves Limestone but were too poorly preserved to identify positively.

Suborder ARCHAEOSYCONINA Zhuravleva, 1950
Family ?
Genus ?
Sp. A
plate 4, figs. 2–7

*Description.* The cup is solitary, large, and conical(?). One fragment measures 20.0 mm in an oblique longitudinal section. The intervallum ranges from 3.0 mm to 3.2 mm wide. Central cavity diameter varies from approximately 3 mm to 4.2 mm. Intervallum coefficient is approximately 0.76 to 1.0. The intervallum is crossed by septa (or taeniae) 0.2 to 0.4 mm thick. The septa are often irregular in outline, appear to be slightly curved, and may be irregularly porous. Approximately 36 septa occur in one specimen roughly 6.7 mm in diameter for a radial coefficient of 5.4. The cup also has rare dissepiments.

The skeletal elements of the specimen contain what are possibly monactin sponge (?) spicules. The spicules(?) are irregularly placed and oriented and are concentrated in some areas and absent in others.

One of the walls, probably the inner wall, is pierced by large (0.30 mm to 0.32 mm), round pores. They are arranged, one per intersept, in horizontal rows and are 0.62 mm and 0.76 mm apart. The pore coefficient is approximately 0.46. The outer wall is not well understood but appears to be porous.

*Discussion.* This species is not well enough preserved to be taxonomically assigned past suborder level. There are also not enough specimens in the collection to provide a good overall view of the species. The spongelike spicules(?) were more than likely not produced by the organism, but were probably incorporated from the surrounding area as the skeleton developed. This hypothesis is supported by the fact that the spicules(?) are irregularly distributed within the skeleton, and some are found in matrix surrounding the organism. However, spicules(?) within the fossil are incorporated into the skeleton and do not occur in the matrix.

*Material.* Two specimens represent this species. Oblique transverse and longitudinal thin spections were prepared. Preserva-

tion is fair. Figured specimens, BYU 2352, 2353.
*Occurrence.* Lower Cambrian limestone facies of the carbonate unit above the Reeves Limestone in the Maitlen Formation, area 21, figure 3.

Family ?
Genus ?
sp. B
plate 4, fig. 8

*Description.* This species is medium sized; the cup is 6.5 mm in diameter. There is no apparent central cavity. The intervallum appears to possess horizontal rods connected by thin dissepiments. The outer wall appears to be porous and is 0.08 mm to 0.10 mm thick.
*Discussion.* This species is probably what Greggs (1959, p. 71; pl. 11, figs. 8, 9, 11, 12) called *Claruscyathus solidus.* However, what Greggs (pl. 11, fig. 6) identified as tabulae look more like curved dissepiments. Therefore, Greggs's specimens are probably not *C. solidus.* Without his original material or more specimens from the Colville area, a more precise taxonomic assignment is not possible at this time.
*Material.* Only one specimen was recognized as this species; a single transverse thin section was prepared. Preservation is fair. Figured specimen, BYU 2354.
*Occurrence.* Lower Cambrian Reeves Limestone Member of the Maitlen Formation, area 3, figure 3.

Order SYRINGOCNEMIDIDA Okulitch, 1935
Family SYRINGOCNEMIDIDAE Taylor, 1910
Genus PSEUDOSYRINGOCNEMA Handfield, 1971
*Pseudosyringocnema* cf. *P. uniporous* Handfield, 1971
plate 4, figs. 9, 10; plate 5, figs. 1–10

*Synonomy. Pseudosyringocnema uniporous* Handfield, 1971, Canadian Geological Survey Bulletin 201, p. 76, 77, pl. 15, figs. 3a–c, 4, 5.
*Description.* The cup is cylindro-conical and of moderate size, and some are solitary and others colonial. The diameter varies greatly from 3.25 mm to 6.4 mm and intervallum widths range from 0.96 mm to 2.0 mm. The central cavity diameter varies from 1.24 mm to 2.0 mm, resulting in intervallum coefficients of 0.77 to 0.95. The intervallum is filled with hexagonally shaped tubules, 0.26 mm to 0.34 mm wide, which begin parallel to the inner wall and curve upward at a high angle and outward toward the outer wall. The distal or outer part of the tubule is at a high angle near the inner wall then flattens out to become nearly normal to the outer wall. Walls of the tubules are porous, being pierced by a single row of pores per wall. The pores are irregularly round to oval and 0.08 mm to 0.18 mm in diameter. Skeletal elements between pores are 0.14 mm to 0.70 mm thick.

The inner wall is made up of S-shaped pore-tubes, 0.3 mm to 0.4 mm long. Lips of the pore-tubes develop into thin (0.02 mm to 0.04 mm) annuli around the central cavity. The pore-tubes originate as pores in the tubule wall closest to the central cavity, three or four pore-tubes to a vertical row. The outer wall is not well preserved in any of the specimens studied. It is approximately 0.04 mm to 0.16 mm thick, appears to be made up of the end of the outwardly inclined tubules, and is pierced by one, sometimes two, pores per tubule. One pore per tubule is most common. The outer wall is irregular in outline when viewed in transverse section.
*Discussion.* The dimensions of *Pseudosyringocnema* cf. *P. uniporous* agree closely with those of *Pseudosyringocnema uniporous* Handfield, 1971. The only major difference is that Handfield does not mention the presence of annuli on his specimens. However, plate XV, figure 3a (Handfield 1971) appears to show bracts or annuli. If these structures are indeed present, the Colville species would be conspecific with *P. uniporous.*

Gangloff (1975) proposed a new genus which is nearly identical to *Pseudosyringocnema* Handfield except that the former possesses annuli. The Colville specimens are possibly conspecific with Gangloff's new genus. However, Gangloff also mentions the presence of a double outer wall in his species. The double outer wall is apparently absent in the Colville specimens. The Colville specimens are not especially well preserved, however, which may explain the absence of the delicate, secondary outer wall. Handfield (1971, p. 76,77) mentioned that the outer wall is "irregular" and "poorly understood" in his material. Since the outer wall is not well understood and annuli are present in the Colville specimens, they are designated *Pseudosyringocnema* cf. *P. uniporous* Handfield, 1971.
*Material.* Eighty specimens of this species were identified from the Colville material. Preservation ranges from poor to good. Most specimens are only fairly well preserved, however. Numerous transverse and several longitudinal thin sections were obtained, as well as several well-preserved, acid-etched silica-replaced specimens. Calcareous skeletons of the acid-etched specimens were coated by a thin silica layer sometime after deposition. The actual skeleton was not replaced by silica. When the specimens were etched in a dilute HCl solution, the calcareous skeleton dissolved, leaving a delicate, hollow, outer mold of the skeleton. Figured specimens, BYU 2355–2364.
*Occurrence.* Lower Cambrian, Reeves Limestone member of the Maitlen Formation, areas 2–4, 6–12, figure 3.

## CONCLUSIONS

The two limestone units of the Maitlen Formation near Douglas Lake are definitely stratigraphically distinct units and are not a single, tectonically repeated carbonate bed. The lowermost unit is the Reeves Limestone Member. Archaeocyathan-bearing carbonates near Colville at one time were mistakenly called the "Old Dominion Limestone." The "Old Dominion Limestone," as now understood, is correlative with the Middle and(?) Upper Cambrian Metaline Formation. The Reeves Limestone and other carbonates in the lower Maitlen Formation are the only archaeocyathan-bearing rocks in the area and are Early Cambrian in age. This is the first time that archaeocyathans from northeastern Washington have been described in their proper stratigraphic framework.

Both carbonate units in the Lower Maitlen Formation contain archaeocyathans, but the Reeves Limestone contains a richer and more diverse fauna, especially the dark, detrital lenses. The detrital lenses almost invariably contain *Ethmophyllum* and *Pseudosyringocnema.* Silicification was generally selective and affected only specimens of *Pseudosyringocnema* and sponges. Sponges, trilobites, hyolithids, *Renalcis,* and a possible early bryozoan are reported for the first time from the Maitlen Formation.

## ACKNOWLEDGMENTS

Sincere thanks are expressed to Dr. J. Keith Rigby, who served as my thesis chairman and gave freely of his time throughout the study. Dr. Lehi Hintze also offered helpful suggestions. I also thank the following people who helped considerably during the study: J. Eric Schuster, Roland Gangloff, Allison R. Palmer, and Chris Hude. Thanks are also extended to the property owners who allowed me access to the study area, especially John Dawson and Harold Larsen. Financial assistance was provided by the Washington State Department of Natural Resources, Brigham Young University Geology Department, and Amoco Production Company.

Especially appreciated are the efforts of my wife, Lydia, who helped prepare the thin sections and constantly encouraged me.

## REFERENCES CITED

Bennett, W. A. G., 1937, Archaeocyathids from Stevens County, Washington (abstr.): Geological Society of America Proceedings, p. 316.

———, 1941, Preliminary report on magnesite deposits of Stevens County, Washington: Washington Bureau of Conservation and Development, Report of Investigations No. 5, 25p.

Campbell, C. D., 1947, Cambrian rocks of northeastern Stevens County, Washington: Geological Society of America Bulletin, v. 58, p. 597–612.

Campbell, A. B., and Raup, O. B., 1964, Preliminary geologic map of the Hunters Quadrangle, Stevens and Ferry Counties, Washington: U.S. Geological Survey Mineralogical Investigations. Field Studies Map MF-276, Scale 1:48,000.

Debrenne, F., 1974, Anatomy and systematics of the regular archaeocyathids without tabulae from the Ajax Mine (Lower Cambrian, South Australia): Geobios., No. 1, pt. 2, p. 91–138.

Dings, M. G., and Whitebread, D. H., 1965, Geology and ore deposits of the Metaline zinc-lead district, Pend Oreille County, Washington: U.S. Geological Survey Professional Paper 489, 109p.

Fyles, J. T., 1970, Geological settings of the lead-zinc deposits in the Kootenay Lake and Salmo areas of British Columbia: In Weissenborn, A. E., Armstrong, F. C., and Fyles, J. T. (eds.), Lead-zinc deposits in the Kootenay Arc, northeastern Washington and adjacent British Columbia: Washington Division of Mines and Geology Bulletin 61, p. 41–53.

Fyles, J. T., and Hewlett, C. G., 1959, Stratigraphy and structure of the Salmo lead-zinc area: British Columbia Department of Mines Bulletin 41, 162p.

Gangloff, R. A., 1963. Archaeocyatha from the Westgard Pass area, Inyo-White Mountains, California: Master's thesis, University of California–Berkeley, 127p.

———, 1975, The Archaeocyatha of the central and southwestern Great Basin, California and Nevada: Ph.D. dissertation, University of California–Berkeley, 302p.

———, 1976, Archaeocyatha of eastern California and western Nevada: In Moore, J. N., and Fritsche, A. E. (eds.), Depositional environments of Lower Paleozoic rocks in the White and Inyo mountains, Inyo County, California: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Field Guide I, 75p.

Greggs, R. G., 1959, Archaeocyatha from the Colville and Salmo areas of Washington and British Columbia: Journal of Paleontology, v. 33, p. 63–75.

Handfield, R. C., 1971, Archaeocyatha from the Mackenzie Mountains and Cassiar Mountains, Northwest Territories, Yukon Territory and British Columbia: Canadian Geological Survey Bulletin 201, 119p.

Hill, D., 1955, Archaeocyatha from Antarctica and a review of the phylum: Trans-Arctic Expedition 1955–1958, Scientific Reports, no. 10 (Geology:3), 151p.

———, 1972, Archaeocyatha: In Teichert, C. (ed.), Treatise on invertebrate paleontology, Part E, (revised), v. 1, Geological Society of America and University of Kansas Press, Lawrence, 158p.

Kawase, Y., and Okulitch, V. J., 1957, Archaeocyatha from the Lower Cambrian of the Yukon Territory: Journal of Paleontology, v. 31, p. 913–30.

Little, H. W., 1950, Salmo map-area, British Columbia: Geological Survey of Canada Paper 50-19, 43p.

———, 1960, Nelson map-area, west half, British Columbia (82 FW1/2): Geological Survey of Canada Memoir 308, 295p.

McKee, E. H., and Gangloff, R. A., 1969, Stratigraphic distribution of archaeocyathids in the Silver Peak Range and the White and Inyo mountains, western Nevada and eastern California: Journal of Paleontology, v. 43, p. 716–26.

McKee, E. H., and Gangloff, R. A., 1969, Distribution of archaeocyathids in the Lower Cambrian of southeastern California and southwestern Nevada: Geological Society of America Abstracts with Programs, part 5 (Rocky Mountain Section), p. 52–53.

Meek, F. B., 1868, Preliminary notice of remarkable new genus of corals, probably typical of a new family: American Journal of Science, series 2, v. 45, p. 62–64.

Mills, J. W., 1962, High-calcium limestones of eastern Washington: Washington Division of Mines and Geology Bulletin 48, 268p.

———, 1977, Zinc and lead ore deposits in carbonate rocks, Steven County, Washington: Washington Division of Geology and Earth Resources Bulletin 70, 171p.

Morgan, N., 1976, The Montenegro bioherms: Their paleoecology, relation to other archaeocyathid bioherms and to Early Cambrian sedimentation: In Moore, J. N., and Fritsche, A. E. (eds.), Depositional environments of Lower Paleozoic rocks in the White-Inyo Mountains, Inyo County, California: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Field Guide I, 75p.

Okulitch, V. J., 1935, Cyathospongia: A new class of Porifera to include Archaeocyathinae: Royal Society of Canada, Proceedings and Transactions, v. 29, series 3, section 4, p. 75–106.

———, 1943, North American Pleospongia: Geological Society of America Special Paper 48, 107p.

———, 1948, Lower Cambrian Pleospongia from the Purcell Range of British Columbia, Canada: Journal of Paleontology, v. 22, p. 340–49.

———, 1951, A Lower Cambrian fossil locality near Addy, Washington: Journal of Paleontology, v. 25, p. 405–7.

———, 1952, Pleospongia. In Cooper, C. A. et al., Cambrian stratigraphy and paleontology near Caborca, northwestern Sonora, Mexico: Smithsonian Miscellaneous Collections, v. 119, p. 27–35.

———, 1954, Archaeocyatha from the Lower Cambrian of Inyo County, California: Journal of Paleontology, v. 28, p. 293–96.

———, 1955, Archaeocyatha from the McDame area of northern British Columbia: Royal Society of Canada, Proceedings and Transactions, v. 49, series 3, section 4, p. 47–64.

Okulitch, V. J., and Greggs, R. G., 1958, Archaeocyathid localities in Washington, British Columbia, and the Yukon: Journal of Paleontology, v. 32, p. 617–23.

Okulitch, V. J., and Roots, E. F., 1947, Lower Cambrian fossils from the Aiken Lake area, British Columbia. Royal Society of Canada, Proceedings and Transactions, v. 41, series 3, section 4, p. 37–46.

Park, C. F., Jr., 1938, Dolomite and jasperoid in the Metaline district, northeastern Washington: Economic Geology, v. 33, no. 7, p. 709–29.

Park, C. F., Jr., and Cannon, R. S., Jr., 1943, Geology and ore deposits of the Metaline Quadrangle, Washington: U.S. Geological Survey Professional Paper 202, 81p.

Raymond, P. E., 1931, The systematic position of the Archaeocyathinae: Harvard University Museum of Comparative Zoology Bulletin, v. 55, p. 172–77.

Repetski, J. E., 1978, A fish from the Upper Cambrian of North America: Science, v. 200, no. 4341, p. 529–31.

Ressor, J. E., 1934, Recent discoveries of Cambrian beds in the northwestern United States: Smithsonian Miscellaneous Collections, v. 92, no. 10, 10p.

———, 1957, Lardeau (east half), British Columbia: Geological Survey of Canada Map 12.

Rice, H. M. A., 1941, Nelson map-area, east half, British Columbia: Geological Survey of Canada Memoir 228, 86p.

Stelck, C. R., and Hedinger, A. A., 1975, Archaeocyathids and the Lower Cambrian continental shelf of the Canadian Cordillera: Canadian Journal of Earth Science, v. 12, p. 2014–20.

Taylor, T. G., 1910, The Archaeocyathinae from the Cambrian of South Australia with an account of the morphology and affinities of the whole class: Royal Society of South Australia Memoirs, v. 2, pt. 2, p. 55–188.

Walcott, C. D., 1886, Second contribution to the studies on the Cambrian faunas of North America: U.S. Geological Survey Bulletin 30, p. 72–89.

Walker, J. F., Bancroft, M. F., and Gunning, H. C., 1929, Lardeau map-area, British Columbia. (General geology by Walker and Bancroft, mineral deposits by Gunning.) Canadian Geological Survey Memoir 161, 142p.

Weaver, C. E., 1920, The mineral resources of Stevens County: Washington Geological Survey Bulletin 20, 350p.

Wheeler, J. O., 1963, Roger Pass map-area, British Columbia and Alberta (82NW/2), Geological Survey of Canada Paper 62-32, 32p.

Yates, R. G., 1964, Geologic map and sections of the Deep Creek area, Stevens and Pend Oreille counties, Washington. U.S. Geological Survey Miscellaneous Geological Investigations Map I-412.

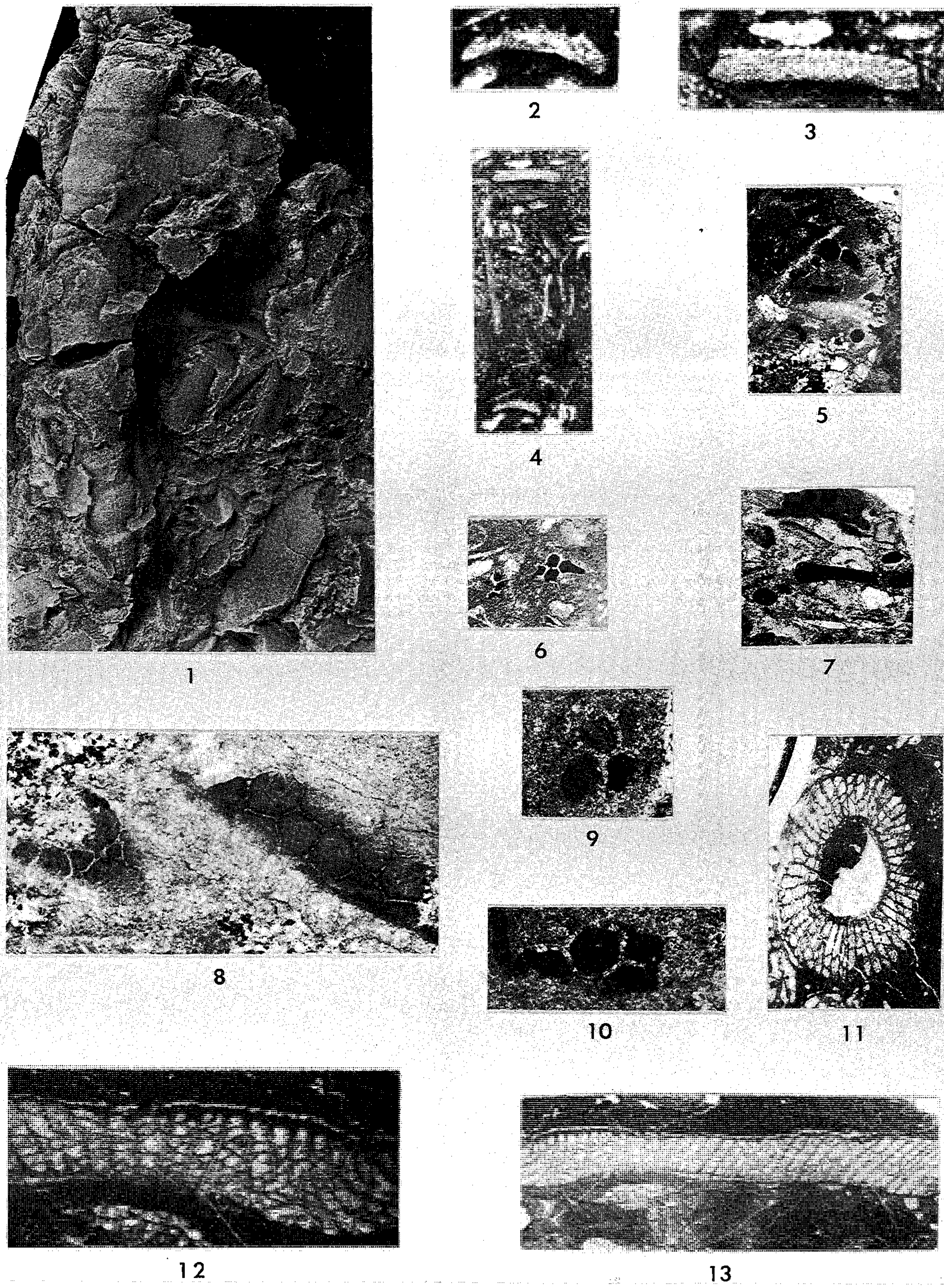
———, 1970, Geologic background of the Metaline and Northport mining districts, Washington: In Weissenborn, A. E., Armstrong, F. C., and Fyles, J. T. (eds.), Lead-zinc deposits in the Kootenay Arc, northeastern Washington and adjacent British Columbia: Washington Division of Mines and Geology Bulletin 61, p. 41–53.

———, 1971, Geologic map of the Northport Quadrangle, Washington. U.S. Geological Survey Miscellaneous Investigations Map I-603.

———, 1976, Geology of the Deep Creek area, Washington, and its regional significance. U.S. Geological Survey Open File Report 76-537, Spokane, Washington, 435p.

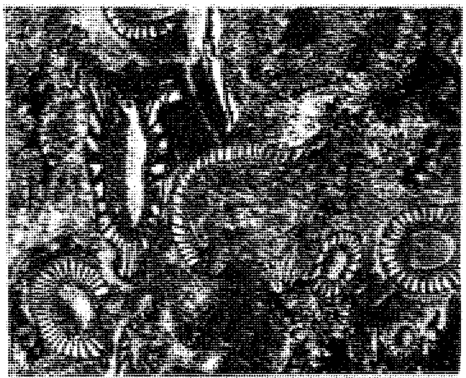
## EXPLANATION OF PLATE 1

1, *Ethmophyllum whitneyi* Meek and *Nevadella* sp. fragments; area 11, X2 (BYU 2319). 2–4, Unidentified, sculptured echinoderm plates, area 10: 2 (BYU 2320) and 3 (BYU 2321), X20; 4, X6.8. 5–7, *Chancelloria* spicules: 5, Spicule elements are attached in upper part of figure; area 4, X6 (BYU 2322); 6, Attached spicules; area 10, X6 (BYU 2323); 7, Longitudinal and transverse sections of spicules and an echinoderm plate in upper left; area 4, X6 (BYU 2324). 8–10, Possible early bryozoan. Note autopores(?) and mesopores(?) in fig. 8; area 4, X20 (BYU 2325, 2326, 2327). 11–13, *Loculicyathus* (*Loculicyathus*) cf. *L. canadensis* Handfield, area 16a: 11, Transverse section of cylindrical stalk showing dissepiments, X4 (BYU 2328); 12, Transverse section of fragment, X4 (BYU 2329); 13, Transverse section of a fragment of a large cup, X4 (BYU 2330).

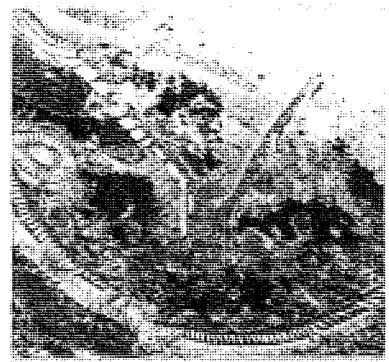

1
2
3
4
5
6
7
8
9
10
11
12
13

EXPLANATION OF PLATE 2

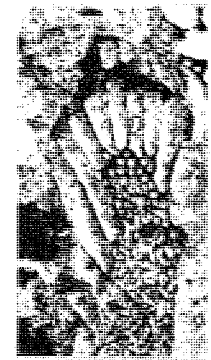
1–7, *Diplocyathellus* cf. *D. princetonensis* (Handfield) All specimens are from area 1: 1, Transverse and oblique longitudinal sections, X2 (BYU 2331); 2, Longitudinal section of a cup, showing narrow early stage and broad, open cone later stage (top of figure); transverse section of an early (left) and large open cone (bottom), X2 (BYU 2332); 3, Oblique tangential section, showing outer and inner wall pore pattern, X6.8 (BYU 2333); 4, Specimen broken free from matrix; note early and later growth stages, X2 (BYU 2334); 5, Specimen broken free from matrix, X2 (BYU 2335); 6, Transverse section, X6.8 (BYU 2336). 7, Transverse section, X6.8 (BYU 2337). 8–12, *Ethmophyllum whitneyi* Meek: 8, Transverse section; area 4, X6 (BYU 2338); 9, Oblique longitudinal section; note annulations in outer wall; area 4, X6 (BYU 2339); 10, Transverse section; note irregular outline of cup; area 11, X6 (BYU 2340); 11, Oblique transverse section, tangential to outer wall; note fluting of septa near inner wall; area 11, X6 (BYU 2341); 12, Same specimen as figure 11, enlarged to show pore pattern of outer wall, X20.



1



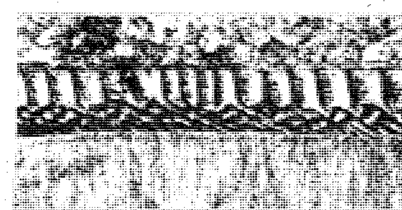
2



3

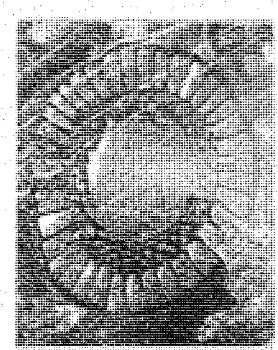
4

5

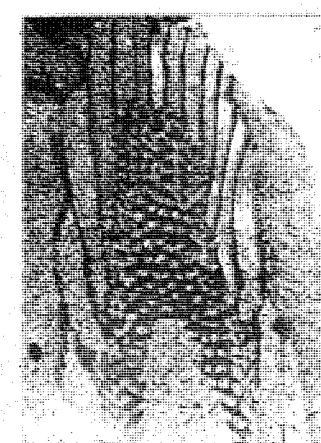


6

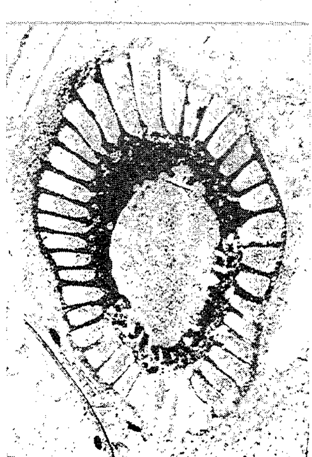
7



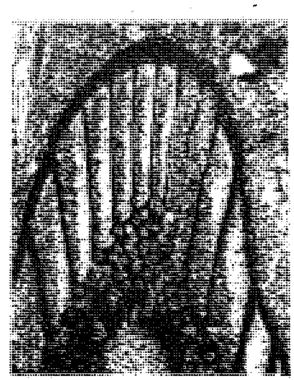
8



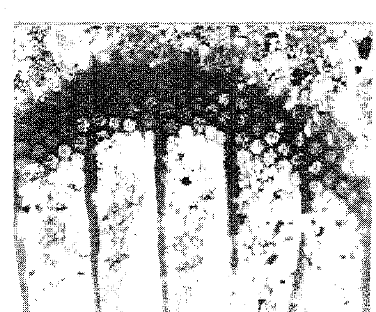
9



10



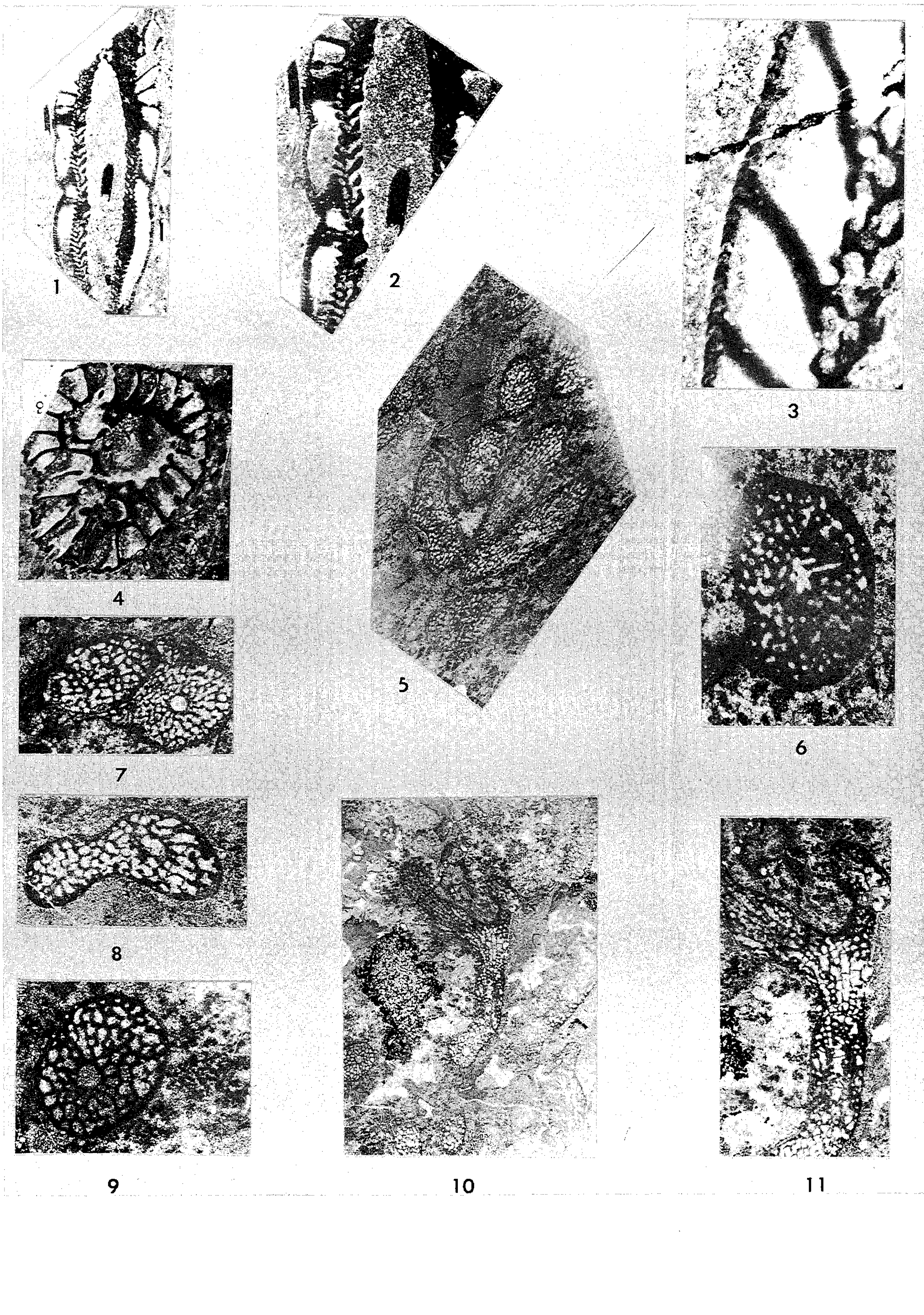
11



12

EXPLANATION OF PLATE 3

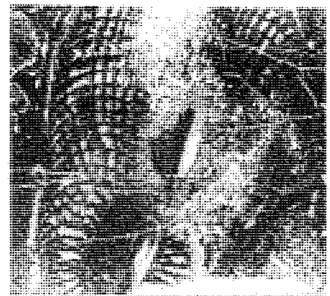
1–3, *Ethmophyllum whitneyi* Meek: 1, Oblique longitudinal section; note annulations in outer and inner wall; area 11, X4 (BYU 2342); 2, Enlargement of part of specimen in figure 1, to show pore-tube and pore-canal pattern in inner and outer wall, X7; 3, Enlargement of another specimen from area 11, to show geniculate pore-tubes in outer wall; note spike at crest of V. What appear to be pores in septa of specimens in figures 1–3 are actually clear calcite crystals. X20 (BYU 2343). 4, Genus A sp. Handfield, transverse section; note three central cavities; area 1, X4 (BYU 2344). 5–11, *Protopharetra* cf. *P. raymondi* Okulitch: 5, Dendritic colony, oblique transverse sections; note abundant *Renalcis* sp.; area 3, X2 (BYU 2345); 6, Transverse section; note irregular central cavity, thick skeletal elements, and *Renalcis* sp.; area 3, X6.8 (BYU 2346); 7, Two limbs of a dendritic colony, transverse section; area 2, X6.8 (BYU 2347); 8, Transverse section, part of dendritic colony; area 2, X6.8 (BYU 2348); 9, Transverse section; note *Renalcis* sp. to right of archaeocyathan; area 2, X6.8 (BYU 2349); 10, Oblique longitudinal and transverse sections of dendritic colonies; note *Renalcis* algae, especially near top of figure; area 12, X2 (BYU 2350); 11, Enlargement of part of specimen shown in figure 10; note rare dissepiments and pattern of taeniae, X4.


1
2
3
4
5
6
7
8
9
10
11

EXPLANATION OF PLATE 4

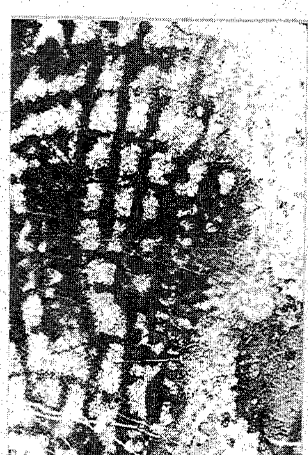
1, *Photopharetra* cf. *P. raymondi* Okulitch. Longitudinal section to show lattice-like pattern of taeniae and synapticulae; area 2, X4 (BYU 2351). 2–7, Genus ? Sp. A. All specimens are from area 21: 2, Oblique transverse section; note pore pattern in upper right, X2.24 (BYU 2352); 3, Enlargement of figure 2; note position of spicules(?), X4; 4, Enlargement of specimen shown in figure 3, X6.8; 5, Enlargement of specimen shown in figure 4, X20; 6, Oblique transverse section of another specimen, X4 (BYU 2353); 7, Enlargement of specimen shown in figure 6, X6.8. 8, Genus ? Sp. B. Transverse section; note pattern of dissepiments; area 3, X4 (BYU 2354). 9–10, *Pseudosyringocnema* cf. *P. uniporous* Handfield: 9, Transverse section; note hexagonal tubules and irregular outline of outer wall; area 12, X6 (BYU 2355). 10, Oblique longitudinal section; note S-shaped pore-tubes of inner wall and annuli at top of central cavity; area 10, X6 (BYU 2356).

1



2

3

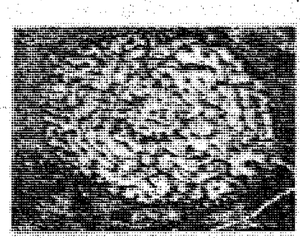


4

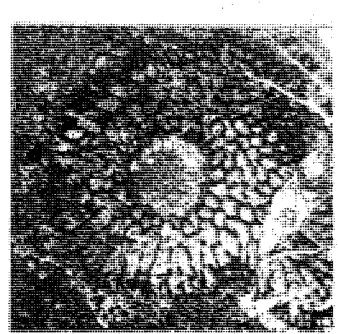
5

6

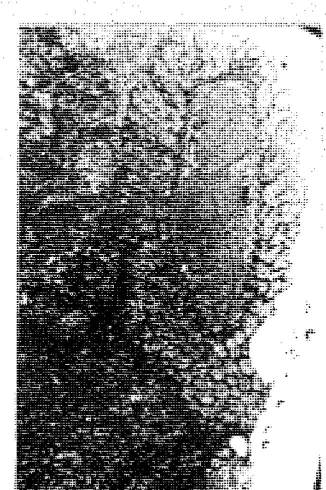
7



8



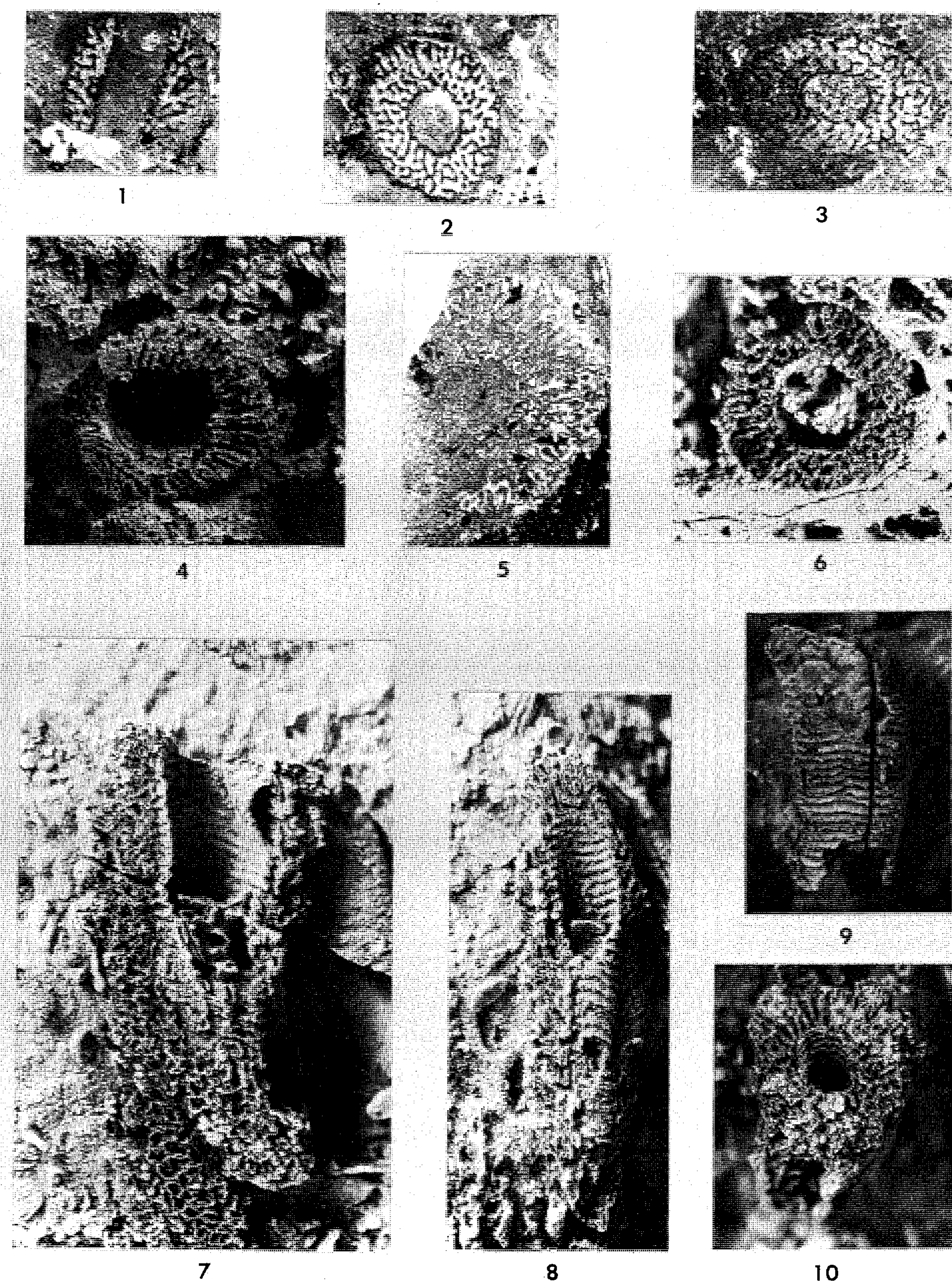
9



10

EXPLANATION OF PLATE 5

1–10, *Pseudosyringocnema* cf. *P. uniporous* Handfield; 1, Longitudinal section shows S-shaped pore-tubes of inner wall; also upward and outward pattern of tubules; area 2, X6.8 (BYU 2357); 2, Transverse section; area 2, X6.8 (BYU 2358); 3, Transverse section; note annuli of inner wall; area 2, X6.8 (BYU 2359); 4, Transverse view of acid-etched specimen; note porous tubules, sponge spicules protruding from matrix in upper right of figure; area 4, X6 (BYU 2360); 5, Transverse thin section of same specimen as figure 4; note thin black silica "rind" surrounding the calcareous skeleton, X6.8; 6, Transverse view of right side of acid-etched specimen of figures 4 and 5, X6; 7, Longitudinal view of acid-etched specimen showing well-developed annuli in central cavity along inner wall; area 4, X6 (BYU 2361); 8, Another view of the well-developed annuli, acid-etched; area 4, X6 (BYU 2362); 9, Close-up view of set of annuli, acid-etched; area 4, X6 (BYU 2363); 10, Oblique transverse view of acid-etched specimen, showing annuli and porous tubules; area 4, X6 (BYU 2364).


1
2
3
4
5
6
7
8
9
10