Corals From Well Cores of Madison Group, Williston Basin

By WILLIAM J. SANDO

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1071-F

A description of Early Mississippian corals from three wells in northeastern Montana with special reference to their value as facies and time indicators

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1960

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price $1 (paper cover)

CONTENTS

ILLUSTRATIONS

[Plates 16–20 follow index]

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By WILLIAM J. SANDO

ABSTRACT

Mississippian corals from three wells in the Madison group in northeastern Montana are divided into three groups for facies analysis: nondissepimented solitary corals, dissepimented solitary corals, and colonial corals. Lateral changes in abundance, diversification, and vertical limits of the coral fauna seem to be directly related to changes in lithic facies within the Madison group. Northward impoverishment of the fauna of the Lodgepole limestone seems to be correlated with increase in clay content and decrease in grain size of the limestone toward the center of a basin characterized by poor circulation of the sea water. The fauna of the overlying Mission Canyon limestone is more uniformly distributed, suggesting a widespread, generally well-aerated environment. The distribution of corals in the Charles formation appears to be related to northward increase in evaporites, which indicate extreme restriction of the late Early Mississippian sea in this region.

The corals of the Madison group hold little promise as horizon markers for detailed local correlation within the Williston basin because of strong facies control and the long stratigraphic range of common genera. They offer greater potential for regional correlation because of the wide distribution of distinctive associations of genera and species in rocks of Early Mississippian age.

The 24 species that are described and illustrated are distributed among the following genera: *Amplexocarinia*, *Amplexus*, *Cyathaxonia*, *Homalophyllites*, *Menophyllum?*, *Rotiphyllum*, *Rylstonia*, *Zaphrentites*, *Caninia*, *Caninophyllum*, *Enygmophyllum*, *Vesiculophyllum*, *Zaphriphyllum*, *Aulopora*, *Cladochonus*, *Cleistopora*, *Lithostrotion*, and *Syringopora*.

INTRODUCTION

Recent discovery and development of petroleum resources in the Madison group of carbonate rocks of the Williston basin area have stimulated study of the Mississippian system in the Northern Rocky Mountains and Great Plains provinces. Although much has been written about the stratigraphy and sedimentation of the Madison, very few paleontologic data have been published. This study deals with the nature and distribution of corals from the Madison in cores from three wells drilled in northeastern Montana. Because corals are abundant in the rocks of Madison age and seem to be rather sensitive to changes in environment, they offer good possibilities for analyzing Madison sedimentation.

In July 1952, cores from three discovery wells in northeastern Montana (fig. 16) were made available to members of the U.S. Geological Survey at Billings, Mont. These wells are—

Shell Oil Co., Pine Unit, No. 1, SW¼SW¼NE¼ sec. 30, T. 12 N., R. 57 E., Wibaux County, Mont.

Shell Oil Co., Richey area, Northern Pacific Railroad, No. 1, SW¼NW¼NW¼ sec. 19, T. 23 N., R. 50 E., Dawson County, Mont.

C. H. Murphy Corp., East Poplar Unit, No. 1, center, SW¼ NE¼ sec. 2, T. 28 N., R. 51 E., Roosevelt County, Mont.

The stratigraphy of these wells was discussed previously by Barnes (1952) and Nordquist (1953). A large fauna, consisting mainly of brachiopods, corals, gastropods, pelecypods, trilobites, bryozoans, crinoids, and ostracodes, was collected from the cores by J. E. Smedley and R. P. Kunkel. The corals were subsequently assigned to the writer for study; work on the remainder of the fauna is still in progress.

The writer is indebted to Helen Duncan for initial orientation and guidance in all phases of the work and to J. E. Smedley for stratigraphic and faunal data and preliminary preparation of most of the coral specimens.

STRATIGRAPHIC SUMMARY

The Madison group of the Williston basin subsurface includes three formations, which are, in ascending order, Lodgepole limestone, Mission Canyon limestone, and Charles formation (pl. 13.) The Geological Survey considers all formations of the Madison group to be of Early Mississipian age.

The Lodgepole limestone consists mainly of cherty, argillaceous limestone with thin shale interbeds. Dark fine-grained argillaceous limestone with thin lenses of bioclastic calcarenite dominates the lower half of the formation. In the upper half the limestone is generally coarser grained and less argillaceous. Within the area studied, the amount of argillaceous material increases northward, particularly in the lower half of the formation. The formation thickens northward from 525 feet in the Shell Pine well to 680 feet in the Murphy East Poplar well; further thickening takes place eastward into North Dakota (Nordquist, 1953, fig. 6). The Lodgepole fauna consists largely of brachiopods and corals; less common elements are bryozoans, crinoids, blastoids, trilobites, pelecypods, gastropods, ostracodes, cephalopods, and conodonts. The Lodgepole conformably overlies the Bakken formation (Nordquist, 1953) of Devonian(?) and Mississippian age.

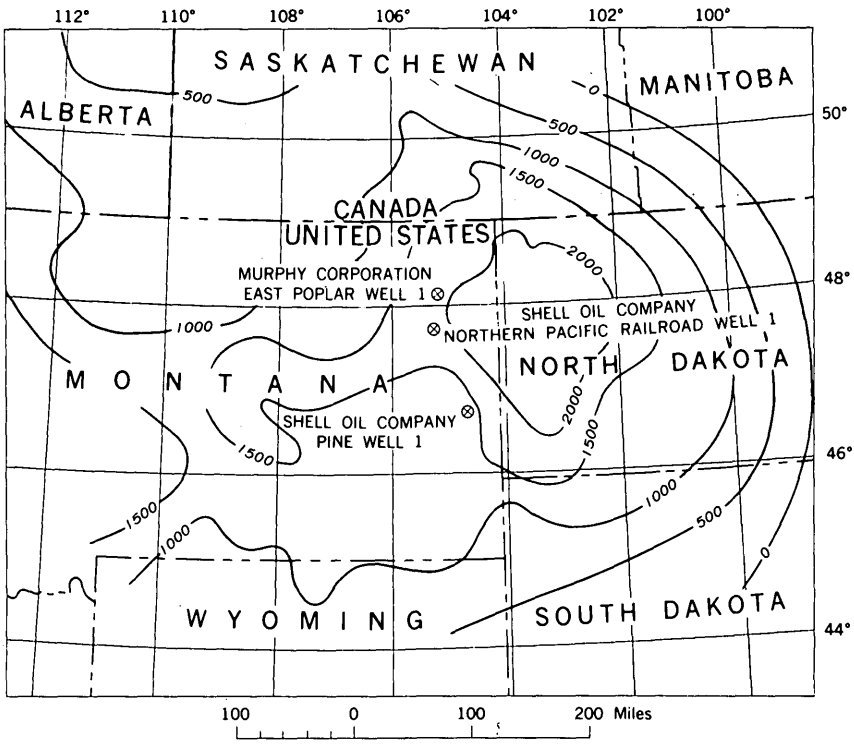

FIGURE 16.—Index map showing location of wells and thickness of Madison group by isopach lines (after Barnes, 1952).

The Mission Canyon limestone conformably and transitionally overlies the Lodgepole limestone. The Mission Canyon consists mainly of clean light-colored bioclastic calcarenite, like that in the upper Lodgepole. Fine-grained argillaceous limestone is much less abundant than in the Lodgepole, but as in the Lodgepole, the proportion of argillaceous material increases northward. Some of the limestone near the top of the formation contains anhydrite. The Mission Canyon limestone thickens northward from 415 feet in the Shell Pine well to 690 feet in the Murphy East Poplar well. Nordquist (1953, p. 77, fig. 7) interprets this thickening to indicate the presence of a negative tectonic center in northeastern Montana during Mission Canyon time. The Mission Canyon fauna is not so large or diversified as that of the Lodgepole limestone. Crinoidal debris, brachiopods, and corals are the most abundant fossils; gastropods and bryozoans are rare.

The Mission Canyon limestone is conformably and transitionally overlain by the Charles formation. The Charles formation is characterized by Mission Canyon-type calcarenite interbedded with considerable anhydrite, gypsum, salt, and argillaceous dolomite. The evaporite content increases eastward toward the center of the Williston basin. The formation is 455 feet thick in the Shell Pine well, 395 feet in the Shell Northern Pacific Railroad well, and 390 feet in the Murphy East Poplar well. According to Nordquist (1953, p. 79–80, fig. 8), the Shell Northern Pacific and Murphy East Poplar wells are in two anomalous isopach "lows" that modify the general pattern of eastward thickening of the Charles formation. These areas of reduced thickness may reflect the positions of islands in the Charles sea or may be due to removal of salt from the section by leaching. The Charles fauna is like that of the Mission Canyon, differing mainly by having fewer individuals. Within the area studied, the Charles is conformably overlain by terrigenous sedimentary rocks of the Big Snowy group of Late Mississippian and Early Pennsylvanian age.

BIOLOGIC ANALYSIS

The corals of the Madison are grouped in three main categories for purposes of discussion in this paper: nondissepimented solitary corals, dissepimented solitary corals, and colonial corals. This grouping has the advantage of objectivity and is useful for environmental analysis.

All the genera of solitary corals described herein are commonly referred to the Order Rugosa of the Class Anthozoa. The nondissepimented group includes 8 genera and makes up about 70 percent of the coral fauna. Morphologically, these corals are the simplest of the

solitary forms, although some genera are closely related to the more complex dissepimented corals and several families are represented in the group. The dissepimented solitary corals include 5 genera and make up about 17 percent of the coral fauna. These complex forms are generally believed to have evolved from nondissepimented ancestors. The genera here included in this category are probably more closely interrelated than the genera included in the nondissepimented group. The colonial corals are represented by 5 genera, which constitute about 13 percent of the coral fauna. Of the colonial genera, *Lithostrotion* is a member of the Rugosa, whereas the others are generally placed in the Order Tabulata. Plate 14 shows the frequency distribution of specimens of coral genera in the Madison collections.

Most of the genera are represented by one species. The apparent lack of diversification at the species level is undoubtedly attributable in part to the generally poor quality of preservation and small number of specimens available. However, regional studies of the Early Mississippian coral faunas suggest that many species were remarkably persistent geographically and stratigraphically. Hence, the low degree of specific diversity in the limited samples from the cores probably reflects also a general tendancy toward uniformity.

A detailed statement concerning the stratigraphic range and world distribution of genera is inadvisable at this time because the literature contains many erroneous identifications and much study remains to be done. A few generic names used in this paper have not previously been applied in North American systematic studies probably because of difficulty in evaluating foreign literature and the fact that some genera are relatively uncommon. Almost all solitary corals here described are restricted to Carboniferous and Permian rocks; and, strictly interpreted, many of these seem to be confined to the lower Carboniferous or Mississippian. *Amplexus*, *Cyathaxonia*, *Homalophyllites*, *Rotiphyllum*, *Rylstonia*, *Zaphrentites*, *Caninia*, and *Caninophyllum* are abundant in lower Carboniferous rocks througout the world. The colonial rugose coral *Lithostrotion* likewise is known only in post-Devonian rocks and is especially characteristic of the lower Carboniferous. The other colonial genera (tabulates) are generally longer ranging forms which originated in the Silurian and Devonian and ranged into the Permian. All colonial genera here described are abundant and widespread in lower Carboniferous rocks.

CORAL DISTRIBUTION IN THE MADISON GROUP

There is a striking, apparent relationship between the distribution of corals and lithic facies in the Madison group. The spatial distribution of each of the three types of corals has the general form of a

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wedge thinning northward from the Shell Pine well (fig. 17). Each wedge is constricted at the Shell Northern Pacific well, then enlarges slightly or continues with less reduction to the Murphy East Poplar well. The relative abundance of specimens of each coral type follows the same pattern (fig. 17). The fauna also becomes less diverse northward; 17 genera are present in the Shell Pine fauna, whereas the Shell Northern Pacific and Murphy East Poplar faunas contain 9 genera each (pl. 13). Differences in vertical distribution and abundance between the Shell Northern Pacific and Murphy East Poplar faunas are not large enough to seem significant; they may be due to collecting factors inasmuch as the Shell Northern Pacific fauna was not collected by the same person who collected the Shell Pine and Murphy East Poplar material. However, differences between the Shell Pine fauna and the combined Shell Northern Pacific and Murphy East Poplar faunas warrant further examination. The reality of the northward inpoverishment of the coral fauna is supported by the fact that the Shell Pine core was the least complete of the three when the fossils were collected (pl. 13).

The distribution patterns appear to be controlled mainly by northward reduction of favorable environments in the Lodgepole and Charles formations. Ninety percent of the Lodgepole corals and all the Charles corals come from the Shell Pine well, whereas the Mission Canyon coral fauna is distributed almost equally among the three wells (pl. 15). Examination of lithic types associated with the corals indicates that most of the solitary genera occur in relatively clean calcarenites, whereas colonial forms are not generally so restricted. Within the solitary group, dissepimented genera appear to be more sensitive to changes in environment associated with decrease in grain size and increase in argillaceous content than nondissepimented forms. *Syringopora*, which constitutes a major part of the colonial fauna, occurs mainly in fine-grained rocks.

Northward impoverishment of the coral fauna of the Lodgepole limestone appears to be related to the increase in fine-grained argillaceous limestone and shale in the lower half of the formation (pl. 13). The absence of dissepimented corals in the Lodgepole limestone of the Shell Northern Pacific and Murphy East Poplar Wells (pl. 15) may also be explained on this basis. Thus, the distribution of corals in the Lodgepole limestone supports the paleooceanographic reconstruction made by Nordquist (1953, p. 75) on the basis of isopach and lithic patterns. According to Nordquist, northeastern Montana was a basin characterized by "a reducing or stagnant environment not subjected to free circulation of the sea water" during Lodgepole time. The coral distribution pattern suggests that the Shell Pine well

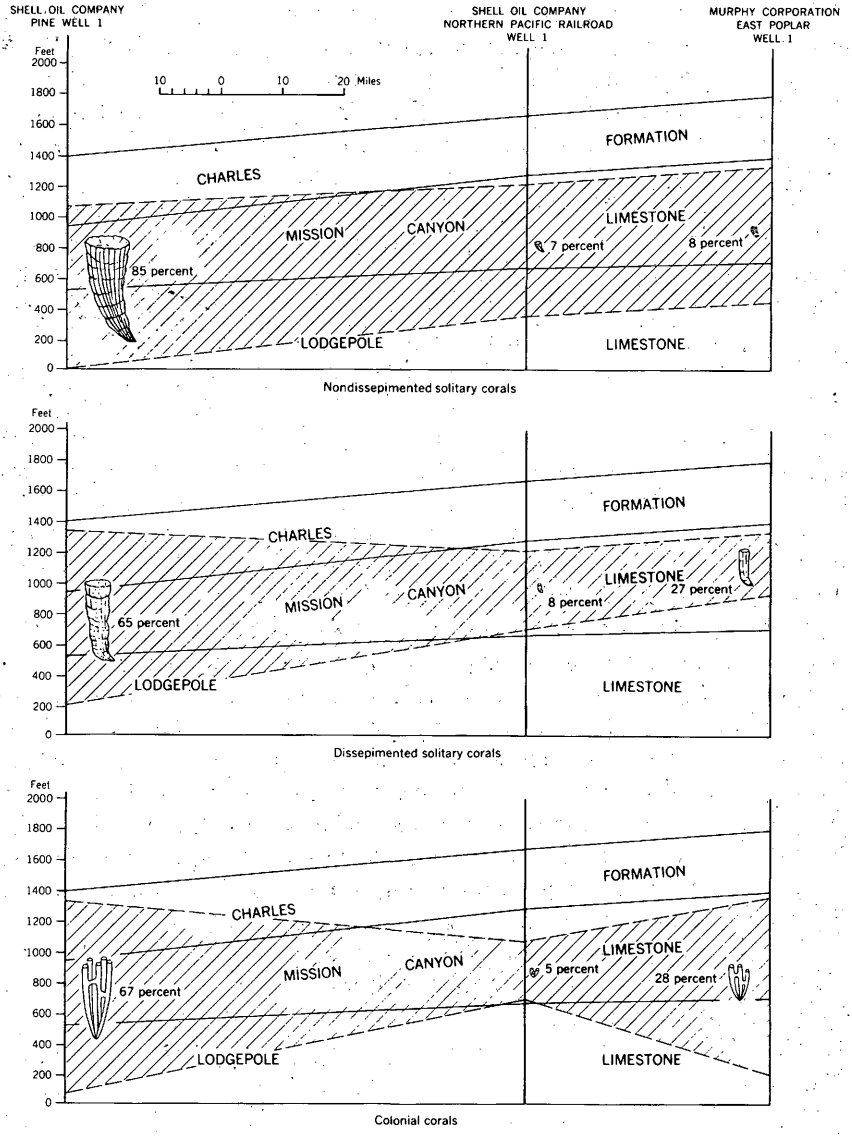

FIGURE 17.—Spatial distribution and frequency distributions of coral types in the Madison group.

lies near the margin of this basin, whereas the Shell Northern Pacific and Murphy East Poplar wells are well within its confines.

Corals are slightly less abundant in the Mission Canyon limestone than in the Lodgepole limestone (pl. 14) but are much more uniformly distributed (pl. 15). The Mission Canyon fauna consists predominantly of solitary forms, and dissepimented corals are much more abundant than in the Lodgepole. This distribution suggests widespread, generally better aerated conditions reflected in the clean, light-colored lime sands of Mission Canyon time.

The coral fauna of the Charles formation is known only from the Shell Pine well. The total number of individuals is about as large as that found in the Mission Canyon limestone in all three wells (pl. 14), and the composition of the fauna is very similar (pl. 15). Here again, the Shell Pine well appears to lie just outside an area unfavorable for coral growth. No corals were collected from the Shell Northern Pacific Railroad and Murphy East Poplar wells. The center of the Charles basin of deposition is characterized by an increase in dolomite, anhydrite, gypsum, and salt, which are considered products of extreme restriction of the sea. The Shell Northern Pacific and Murphy East Poplar wells lie on peculiar isopach "lows," which Nordquist (1953, p. 79–80) interprets as areas of intermittent islands in the Charles sea or sections of partial removal of salt by leaching. Either extensive subaerial exposure or a highly saline environment might explain the absence of corals in these areas.

STRATIGRAPHIC VALUE OF CORALS OF MADISON GROUP

The corals of the Madison group offer little promise as zonal indices for detailed local correlation within the Williston basin. The strong facies control of the corals has been demonstrated. The more common genera—*Homalophyllites*, *Rylstonia*, *Zaphrentites*, *Vesiculophyllum*, and *Syringopora*—have long stratigraphic ranges within the Madison group (pl. 13). *Menophyllum?*, *Rotiphyllum*, *Cleistopora*, and *Cladochonus* also have long ranges. *Amplexocarinia*, *Amplexus*, *Aulopora*, *Enygmophyllum*, and *Cyathaxonia* are known only from the lower 300 feet of the group but were found only in the Shell Pine well. *Caninia*, *Caninophyllum*, *Zaphriphyllum*, and phaceloid *Lithostrotion* occur in a zone between 400 and 850 feet below the top, but all except *Caninophyllum* were found in only 1 or 2 wells. Studies of faunas from other well cores in the Williston basin might reveal associations of genera or individual species useful as time markers; the present data are insufficient for such a delineation.

The Madison corals have greater potential value in regional correlations, although exact statements are inadvisable until more is

known about the distribution of genera and species in other areas. Many of the following comparisons are based on unpublished studies of U.S. Geological Survey collections. The Williston basin fauna contains many elements of the fauna of the Madison group in northwestern Wyoming. *Syringopora aculeata*, *S. surcularia*, *Cleistopora placenta*, *Aulopora geometrica*, *Zaphrentites excavatus*, and *Rylstonia teres* were originally described from this area by Girty (1899). Collections from the type section of the Madison group in southwestern Montana and from the type sections of the Lodgepole and Mission Canyon formations in central Montana made by J. E. Smedley contain species of *Amplexus*, *Homalophyllites*, *Menophyllum?*, *Rylstonia*, *Zaphrentites*, *Vesiculophyllum*, *Caninia*, *Cladochonus*, *Cleistopora*, *Aulopora*, and *Syringopora* identical with or similar to the Williston basin forms.

The Madison corals closely resemble those occurring in formations of Kinderhook and early Osage age in the Mississippi Valley region. (See Easton, 1944b.) *Amplexus*, *Homalophyllites*, *Rotiphyllum*, *Cyathaxonia*, *Zaphrentites*, *Caninia*, *Vesiculophyllum*, *Cleistopora*, *Cladochonus*, and *Syringopora* are represented by species similar to or identical with those of the Madison group.

Collections from the Joana limestone of the Ely district, Nevada, contain the following Madison forms (Duncan, *in* Nolan, Merriam, and Williams, 1956, p. 55–56): *Homalophyllites*, *Zaphrentites* (identified as *Amplexi-Zaphrentis*), *Rylstonia* aff. *R. teres*, *Cyathaxonia*, *Caninophyllum*, *Vesiculophyllum*, *Enygmophyllum* (included in *Vesiculophyllum?*), *Syringopora aculeata*, and *S. surcularia*. The Lake Valley limestone of New Mexico has yielded *Cyathaxonia*, *Homalophyllites*, *Rylstonia*, *Zaphrentites*, *Menophyllum?*, and *Caninia arcuata*. Species of *Zaphrentites* (identified as *Triplophyllites*), *Homalophyllites*, and *Vesiculophyllum* (identified as *Caninophyllum*) similar to the Madison species, as well as *Syringopora aculeata* and *S. surcularia*, have been described from the Redwall limestone of Arizona (Easton and Gutschick, 1953).

Elements of the Madison fauna have also been found in other formations of Early Mississippian age throughout the Great Basin and Rocky Mountain region. *Homalophyllites*, *Rylstonia*, and *Vesiculophyllum* hold great promise as guides to rocks of Madison age in this area. Other common genera, such as *Cyathaxonia*, *Menophyllum?*, *Zaphrentites*, and *Caninia*, should prove very useful when more is known about their component species.

SYSTEMATIC DESCRIPTIONS

Taxonomic revisions are avoided in the following systematic treatment. The generic concepts are based on those established in the

literature pertaining to Paleozoic corals. Provisional generic diagnoses are given for many of the genera for the convenience of readers not possessing specialized knowledge of corals. Although generic concepts are not emended, many of the diagnoses have been reworded in the interest of clarity and consistency of terminology. Detailed synonymies for most of the genera may be found in Hill (1938–41) and Easton (1944b). Other basic information concerning genera is given by Lang, Smith, and Thomas (1940).

Although the fauna contains some species that appear to differ significantly from described species, no new names are proposed for them. Much of the material from the cores is fragmentary or otherwise unsuitable for primary types. Interpretation of the material from the cores depended heavily on knowledge obtained through preliminary study of collections from the type sections of the Madison group, Lodgepole limestone, and Mission Canyon limestone. Because these collections from surface exposures contain many elements in common with the core material, the naming of new species is deferred until the surface collections are studied in detail.

The morphologic terminology used in the following descriptions is that of Easton (1944b, p. 15–25).

A register of U.S. Geological Survey collections follows the systematic descriptions. All illustrated specimens have been deposited in the U.S. National Museum.

NONDISSEPIMENTED SOLITARY CORALS

Genus AMPLEXOCARINIA Soshkina, 1928

Diagnosis.—"Cylindrical or sub-cylindrical rugose corals typically simple in which a wide aulos formed by the downwardly bent edges of the axial tabulae, divides the lumen into an axial and periaxial region. The short major septa abut against the aulos, and minor septa are either absent or only feebly developed. Within the aulos the tabulae are horizontal, those outside it usually slope down towards the periphery. Dissepiments are typically absent but are present in some species." (Smith, 1955, p. 86.)

Type species.—*Amplexocarinia muralis* Soshkina, 1928.

Amplexocarinia aff. A. heimoi Heritsch

Plate 16, figures 13–22

In the Williston basin collections there are 14 specimens of a species similar to *Amplexocarinia heimoi* Heritsch (1936, p. 106–107; pl. 17, figs. 11–14; text fig. 7), which occurs in the Permian of the Carnic Alps and the Ural Mountains. The Williston basin material is silicified, and most of the specimens have been etched from limestone.

Apically the corallum is erectly turbinate to trochoid, becoming cylindrical in later growth stages. The largest specimen in the collections, one that has attained the cylindrical stage, is about 17 mm long and has a maximum diameter of about 8 mm. Judging from other specimens, the maximum diameter probably was not greater than 9 or 10 mm. The exterior is marked by low rugae. Many of the smaller specimens show indentations in the epitheca and short rootlets, by means of which the coral was attached to other objects. Rejuvenation is common.

The interior of the corallum is characterized by development of a central aulos occupying a little more than half the total diameter and formed by the downbent edges of the tabulae. Tabulae are numerous (about 18 in 17mm) and thin. They occur mostly within the aulos, where they are generally complete and horizontal, but some appear to continue to the theca, being slightly deflected downward between aulos and theca.

Major septa are radially arranged and very short; their axial ends appear to be confluent with the wall of the aulos. There are about 16 major septa at 3 mm diameter, 18 at 4 mm, 19–20 at 5 mm, 21 at 7 mm, 22 at 8 mm, and 23 at 9 mm. Minor septa are absent.

According to Smith (1955, p. 85) species of *Amplexocarinia* are known from Devonian, Mississippian, Pennsylvanian, and Permian strata of North America, the British Isles, Europe, Asia, and Australia. Its long geologic range and simple morphology suggest that it may be a form genus. Possibly the Mississippian forms represent a homeomorphic development in the cystelasmoid stock that finds a counterpart in the Permian faunas.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13869, 13872, 13874.

Genus AMPLEXUS Sowerby, 1814

Amplexus sp.

Plate 16, figures 23, 24

Amplexus is represented by two specimens from the same collection; possibly these specimens belong to the same species. One specimen, thought to be a neanic form, is attached to a fenestrate bryozoan. The free, silicified corallum is 9 mm long and 5 mm in maximum diameter. The corallum is ceratoid, and one side is flattened where the coral is attached to the bryozoan. Small rootlets were developed to strengthen this attachment. Short amplexoid septa run out on the slightly convex tabula that forms the calyx floor. Eighteen major septa and no minor septa are developed in the calyx. The four primary septa are about equal in length, although the counter septum may be a little shorter than the alar and cardinal septa.

The other specimen is a partly silicified free cylindrical fragment about 70 mm long and 25 mm in maximum diameter. The calyx is preserved but crushed. There are 37 thin major septa 2–3 mm long at a diameter of 19 mm (just below base of calyx). The cardinal septum is short but could not be distinguished from the other major septa except for the development of a siphonofossula around it. Tabulae are thin, flat, and generally horizontal but deflected downward at the margins and in the vicinity of the cardinal septum, where a siphonofossula is formed. The tabulae are about 2 mm apart.

Comparison with described species cannot be made owing to the incomplete nature of the material.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13872.

Genus CYATHAXONIA Michelin, 1847

Cyathaxonia arcuata Weller?

Plate 16, figures 25–27

Sixteen partly decorticated silicified specimens etched from limestone are placed in this category. The corallum had a maximum length of more than 10 mm and a maximum diameter of at least 4 mm (the calyx is incomplete in the largest specimen measured). The basal third of the corallum is trochoid; the upper two-thirds is nearly cylindrical. The exterior is moderately wrinkled and costate. The cardinal side of the corallum is convex. Two specimens have 32 and 34 septa at a diameter of 3.5 mm. Minor septa are long and contratingent. The septa are without spines. The columella is about 0.5 mm in diameter in a corallum of 3.5 mm diameter.

These specimens compare favorably with descriptions and illustrations of *Cyathaxonia arcuata* Weller (1909, p. 269–270, pl. 10, figs. 12, 13; *see also* Conkin and Conkin, 1954, p. 215, fig. 1E–K). However, they appear to be smaller than the type lot, hence the identification is queried. *Cyathaxonia tantilla* (Miller) (*See* Conkin and Conkin, 1954, p. 214–215, fig. 1A–D) has fewer septa and belongs to the category *Cyathocarinia* Soshkina (1928, p. 376), which is distinguished by its tuberculated septa.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13869, 13873.

Genus HOMALOPHYLLITES Easton, 1944

Diagnosis.—Small solitary ceratoid or trochoid corals with a prominent cardinal fossula on convex side of corallum; commonly flattened on convex side; cardinal fossula typically narrow with parallel sides, bounded laterally by cardinal lateral septa and axially by fused axial ends of major septa; septal plan radial in ephebic stage; major septa long, thin, straight; minor septa ordinarily well developed and later-

ally fused to adjacent major septa forming a peripheral stereozone in subcalicular stages; tabulae upwardly arched; dissepiments absent.

Type species.—*Lophophyllum calceola* White and Whitfield, 1862.

Homalophyllites cf. H. subcrassus Easton and Gutschick

Plate 16, figures 6–12

The material referred here consists of about 100 specimens, most of which are free of matrix. All but 6 of the ephebic coralla are 20–30 mm long (average about 25 mm) and have a maximum diameter of 9–13 mm (average about 10 mm). The epitheca is relatively smooth, with few strong constrictions. The degree and persistence of flattening of the convex side of the corallum is variable, but all have a circular cross section beyond the earliest quarter of their length and most show little or no flattening. The corallum commonly tapers very rapidly, so that the tip is sharply pointed. The maximum number of major septa in these specimens is 30–35. The major septa of the cardinal quadrants are commonly dilated in subcalicular stages. Minor septa are generally a fifth to a quarter as long as the major septa. These specimens are similar to *Homalophyllites subcrassus* Easton and Gutschick (1953, p. 16; pl. 1, fig. 4; pl. 2, figs. 1–4) in external form but differ by being smaller (average) and having fewer septa at maturity.

The 6 additional specimens are between 23 and 35 mm long and attain a maximum diameter of about 15 mm. At 14 mm diameter (just below base of calyx) they have 41 major septa. They are similar to the other specimens in other details. These specimens are more closely comparable to the types of *H. subcrassus* in size and number of septa.

The two variants discussed above have about the same stratigraphic range and occur together in one of the collections. Probably the larger forms are late ephebic specimens and the smaller, more common forms early ephebic. Further study may prove that all the Williston basin forms are conspecific with *H. subcrassus* Easton and Gutschick.

Occurrence.—Lodgepole limestone, USGS colln. 13883, 13886. Mission Canyon limestone, USGS colln. 13895, 13899. Charles formation, USGS colln. 13902, 13903, 13904, 13905. All from Shell Pine well.

Homalophyllites sp.

This category includes about 30 specimens too poorly preserved and incomplete for specific assignment.

Occurrence.—Lodgepole limestone, USGS colln. 13879, 13881, 13887 (Shell Pine well); 15750 (Shell Northern Pacific Railroad well). Mission Canyon limestone, USGS colln. 13891, 13892, 13893, 13894,

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13896, 13898 (Shell Pine well); 13932, 13933, 13949 (Murphy East Poplar well); 15766, 15769 (Shell Northern Pacific Railroad well).

Genus MENOPHYLLUM Milne-Edwards and Haime, 1850

Provisional diagnosis.—Small solitary ceratoid or trochoid corals with a conspicuous cardinal fossula on convex side of corallum; cardinal fossula bounded laterally by cardinal lateral septa and axially by downturned edges of tabulae and confluent axial ends of major septa; alar pseudofossulae poorly to moderately well developed; septal plan ordinarily pinnate; major septa long, thick, wedge shaped, their axial ends twisted and intertwined in later stages; minor septa absent or poorly developed; tabulae arched at axis of corallum and depressed in cardinal fossula; dissepiments absent.

Type species.—*Menophyllum tenuimarginatum* Milne-Edwards and Haime, 1850.

Discussion.—Although the internal features of the type specimens of the genotype of *Menophyllum* are unknown, the description and illustrations of the original material (Milne-Edwards and Haime, 1851, p. 348; pl. 3, figs. 1, 1a) suggest that the name can be applied to certain corals that are common in rocks of Mississippian age in North America. These corals appear to be related to *Zaphrentites* Hudson (1941, p. 309–310) but differ mainly by having the cardinal fossula on the convex side of the corallum rather than on the concave side. Unfortunately, the name was once used for North American Mississippian corals now known to belong to *Zaphrentites* (see discussion of *Zaphrentites excavatus*). In spite of the difficulties presently inherent in the use of the name *Menophyllum*, it is here applied provisionally to some of the Williston basin corals because it appears to fill an important gap in generic classification. The generic diagnosis is based on the original description and illustrations of the genotype and Williston basin specimens that probably belong to the taxon.

Menophyllum differs from *Zaphriphyllum* Sutherland (1954, p. 363–364) by lacking a dissepimentarium and well-developed minor septa—features that link *Zaphriphyllum* with the caninoid corals. The short cardinal septum, pinnate septal plan, and absence of a rhopaloid counter septum and counter pseudofossula differentiate *Menophyllum* from *Fasciculophyllum* Thompson (1883, p. 448; see also Hudson, 1942).

Menophyllum? sp.

Plate 16, figures 28–30

The material consists of one nearly complete specimen and three incomplete specimens in limestone matrix, and one fragmentary silicified specimen that was etched free. The largest specimen has

a length of over 50 mm and a maximum diameter of about 25 mm. This specimen has 21 major septa at 10 mm diameter, 33 at 12 mm, 35 at 15 mm, and 36 at 18 mm (just below base of calyx). The calyx appears to have been quite deep. The late ephebic (subcalicular) stage of this species is characterized by a short cardinal septum lying in a large, axially expanded cardinal fossula, a lack of pronounced alar pseudofossulae, and complex intermingling of the axial ends of the major septa. It appears to differ from *Menophyllum tenuimarginatum* by its larger size, greater number of septa, and less pronounced alar pseudofossulae.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13872. Mission Canyon limestone, Shell Northern Pacific well, USGS colln. 15766, 15774.

Genus ROTIPHYLLUM Hudson, 1942

Diagnosis.—Small solitary ceratoid or trochoid corals with a poorly developed cardinal fossula on convex side of corallum and an axial stereocolumn formed by fusion of axial ends of rhopaloid major septa; cardinal fossula axially constricted, bounded laterally by cardinal lateral septa and axially by stereocolumn; counter pseudofossula commonly present; septal plan radial in ephebic stage; minor septa poorly developed; tabulae conical; dissepiments absent.

Type species.—*Densiphyllum rushianum* Vaughan, 1908.

Rotiphyllum hians Easton?

Plate 17, figure 11

This species is represented by five specimens, all of which are partially silicified and imbedded in limestone matrix. The corallum attained a length of 10–15 mm and had a maximum diameter of at least 8 mm. The axial column forms a low axial boss in the calyx. There are 23 major septa at 6 mm diameter (subcalicular) and 28 at 8 mm (in calyx). The column is 1.5 mm in diameter in a transverse section measuring 6 mm and 3.0 mm in diameter in a section measuring 8 mm. Minor septa are rudimentary. The cardinal fossula is poorly defined; it contains a cardinal septum that is long and rhopaloid in the subcalicular stages but short in the calyx. Only one or two tabulae are developed.

The Williston basin specimens are very similar to *Rotiphyllum hians* Easton (1944b, p. 33–34; pl. 3, figs. 4–6; pl. 16, figs. 6–8). The presence of an axial boss suggests this species rather than *R. calyculus* (Miller). (See Easton, 1944b, p. 32–33; pl. 3, figs. 7–10; pl. 16, figs. 32, 33.) However, lack of sufficient material leaves some of the specific criteria in doubt.

Occurrence.—Lodgepole limestone, USGS colln. 13926, 13928. Mission Canyon limestone, USGS colln. 13950; all from Murphy East Poplar well.

Genus RYLSTONIA Hudson and Platt, 1927

Diagnosis.—Small solitary ceratoid or trochoid, rarely cylindrical, corals with cardinal fossula on convex side of corallum and a pronounced axial column formed by dilation of a medial plate, axial ends of major septa, and tabulae; cardinal fossula bounded laterally by cardinal lateral septa and axially by tabulae or columella; axial structure initially developed by fusion of major septa with prolonged and swollen counter septum, becoming a separate structure reinforced by tabular deposits in later stages; septal plan pinnate in early growth stages, becoming radial in later stages; major septa retreat from axis in later stages; minor septa poorly developed in most species, tend to be contratingent when present; tabulae arched at axis of corallum where they contribute to formation of axial structure; a narrow regular dissepimentarium in advanced species.

Type species.—*Rylstonia benecompacta* Hudson and Platt, 1927.

Rylstonia cf. R. teres (Girty)

Plate 17, figures 1–5

Material referred here consists of 63 etched specimens showing all growth stages and 12 incomplete specimens in matrix. This species must have attained a length of about 35 mm judging from the largest specimen in the collections. This specimen has a calyx 20 mm deep, a maximum diameter of 20 mm, and an axial column 10 mm long in the calyx. Most of the ephebic specimens have a maximum diameter of 10–17 mm but have incomplete calices. The exterior of the corallum is marked by fine growth lines and numerous moderately coarse rugae; apical scars of attachment are common. Major septa number 22 at 4 mm diameter, 30–34 at 10 mm, and 43 at 20 mm. Minor septa are short and straight in all stages; some are slightly inclined, but none are definitely contratingent. The cardinal fossula is moderately deep, narrow, and ordinarily on the convex half of the corallum, where it generally lies to one side of the plane of external bilateral symmetry. The carcinophylloid axial column is bladelike and always oriented with its long dimension parallel to the length of the fossula regardless of what position the fossula assumes with respect to the plane of external bilateral symmetry. The species does not appear to have a dissepimentarium.

The Williston basin species is similar to *Clisiophyllum teres* Girty (1899, p. 514–515; pl. 67, figs. 2a–d), whose generic reference is here changed to *Rylstonia*. *Rylstonia* has a prominent, thin, relatively

solid axial structure produced by stereoplasmic deposition in and around the primary elements of the column, whereas in *Clisiophyllum* the axial structure consists of a broad weblike zone of septa and arched tabellae surrounding a thin medial plate. *Clisiophyllum* is also characterized by a broad peripheral dissepimentarium, whereas in *Rylstonia* this feature is feebly developed only in structurally advanced species. Comparison with the type specimen of *Rylstonia teres* indicates that the Williston basin specimens differ by their smaller size, smaller number of septa, and lack of dissepiments.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13872, 13873, 13875. Mission Canyon limestone, USGS colln. 13954 (Murphy East Poplar well); 15757 (Shell Northern Pacific well). Charles Formation, Shell Pine well, USGS colln. 13905.

Rylstonia sp.

Included in this category are seven specimens too incomplete for specific identification.

Occurrence.—Lodgepole limestone, USGS colln. 13870, 13874 (Shell Pine well); 13930 (Murphy East Poplar well); 15747 (Shell Northern Pacific well). Mission Canyon limestone, Murphy East Poplar well, USGS, colln. 13949.

Genus ZAPHRENTITES Hudson, 1941

Diagnosis.—Small solitary ceratoid or trochoid corals with a conspicuous cardinal fossula on concave side of corallum; cardinal fossula bounded laterally by cardinal lateral septa and axially by a wall consisting of fused axial ends of rhopaloid major septa of counter quadrants; cardinal fossula generally expanded axially but may be parallel-sided or axially constricted; alar pseudofossulae commonly well developed; septal plan ordinarily pinnate, although septal withdrawal in later growth stages may superimpose a radial plan in some species, major septa characteristically convexly curved toward cardinal septum; minor septa absent or poorly developed; tabulae arched at axis of corallum and depressed in cardinal fossula; dissepiments absent.

Type species.—*Zaphrentis parallela* Carruthers, 1910:

Zaphrentites excavatus (Girty)

Plate 16, figures 1–5

Menophyllum (?) *excavatum* Girty, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 511–512; pl. 67, figs. 1a-f.

About a dozen specimens in the Williston basin collections coincide in all important features with the type specimens of *Menophyllum* (?) *excavatum* Girty. Although the original descriptions and illus-

trations of *Menophyllum* Milne-Edwards and Haime (1850, p. lxvi; 1851, p. 348; pl. 3, figs. 1, 1a) do not provide a sound basis for a generic concept, the genus was clearly proposed for corals with the cardinal fossula on the convex side of the corallum. Because Girty's species has the fossula on the concave side of the corallum and possesses other generic characters of *Zaphrentites* Hudson, *M.? excavatum* is here assigned to *Zaphrentites*. In recent years, the name *Triplophyllites* (Eastern, 1944b, p. 35) has been applied to some Early Mississippian solitary corals, including *M.? excavatum*, that are properly assignable to *Zaphrentites*.

The Williston basin specimens of this species have a maximum length of about 35 mm or more and a maximum diameter of about 22 mm. The corallum is generally cuneate up to the late ephebic stage, becoming circular in cross section in the calyx. The calyx is very deep. The cardinal fossula commonly lies slightly to one side of the plane of external bilateral symmetry but is always on the concave side of the corallum. A typical specimen has 24 major septa at 5 by 6 mm diameter, 26 at 7 by 9 mm, 29 at 8 by 10 mm, and 30 at 12 by 15 mm (at base of calyx). Minor septa are rudimentary.

Occurrence.—Mission Canyon limestone, USGS colln. 13944 (Murphy East Poplar well); 15764, 16306 (Shell Northern Pacific well). Charles formation, Shell Pine well, USGS colln. 13904, 13905, 13906.

Zaphrentites sp.

Fourteen fragmentary specimens too poorly preserved and incomplete for specific identification are included in this category.

Occurrence.—Lodgepole limestone, USGS, colln. 13873, 13878, 13879 (Shell Pine well); 13929 (Murphy East Poplar well). Mission Canyon limestone, USGS colln. 13932 (Murphy East Poplar well); 15757 (Shell Northern Pacific well). Charles formation, Shell Pine well, USGS colln. 13902, 13903.

DISSEPIMENTED SOLITARY CORALS

Genus CANINIA Michelin, in Gervais, 1840

Diagnosis.—Solitary trochoid to scolecoid corals; major septa long in early growth stages, withdrawing from axis or becoming amplexoid in late stages; counter septum commonly rhopaloid in early stages but of normal thickness in late stages; septal plan pinnate in early stages, radial in late stages; cardinal fossula variable in position with respect to curvature of corallum, variably developed, bounded axially by downturned edges of tabulae; minor septa poorly developed or absent; tabulae well developed, ordinarily complete, flat axially, and turned down at margins; dissepimentarium vertically discontinuous in some

species, variably developed in others, composed of concentric, inosculating, or lonsdaleoid dissepiments.

Type species.—*Caninia cornucopiae* Michelin in Gervais, 1840.

Discussion.—The above diagnosis is based on the broad definition commonly given to this genus (Hill, 1939, p. 105–113; Easton, 1944a, p. 123–124). *Caninia*, as thus defined, includes many species whose essential internal features are somewhat different from those of the genotype. These species have been segregated by Hill (1939, p. 105–113) into several species groups. The Williston basin species described below belong to the *Caninia cornucopiae* group, which is characterized by short amplexoid septa and one or two nonpersistent series of dissepiments in the cylindrical phase of the corallum.

Caninia aff. C. arcuata Jeffords

Plate 17, figures 6–8

The material studied consists of 5 etched specimens and about 20 silicified specimens in matrix; only one specimen (pl. 17, fig. 7) is complete. The coralla are irregularly cylindrical and attain a length of about 50 mm and a maximum diameter of about 10 mm. The exteriors are marked by rugae spaced about 4 mm apart and finer growth lines spaced less than 1 mm apart. Longitudinal septal grooves and interseptal ridges are inconspicuous. Rejuvenation is common. The major septa are thin, amplexoid, and extend about half the distance to the axis of the corallum. There are 17 or 18 major septa at 5 mm diameter and 21–22 between 7 and 10 mm diameter. Minor septa are absent. Cardinal and counter positions are distinguished with difficulty because all the septa are of about the same length and thickness and the cardinal fossula is poorly defined. Tabulae are thin, numerous (23 in 18 mm), and essentially flat although deflected downward at the periphery of the tabularium. A single series of dissepiments is developed in the peripheral zone.

The Williston basin species differs from *Caninia arcuata* Jeffords (1943, p. 548, figs. 1–7) by its smaller size, fewer and shorter septa, less well defined fossula, lack of prominent counter septum in the cylindrical phase, and lack of minor septa.

Occurrence.—Mission Canyon limestone, Shell Northern Pacific well, USGS colln. 15774. Charles formation, Shell Pine well, USGS colln. 13905 (questionably), 13917, 13920.

Caninia sp.

Plate 17, figures 15, 16

This category includes one partly silicified specimen in limestone matrix. The corallum is greater than 50 mm long (the lower part is

broken off) and attains a maximum diameter of about 25 mm. There are 36 short dilated wedge-shaped major septa and no minor septa or dissepiments at 14–15 mm diameter. At the base of the calyx (20 mm diameter), the major septa number 40. Dilation is concentrated in the cardinal quadrants and a few rings of anguloconcentric dissepiments are developed at the periphery in the counter quadrants at this stage. Minor septa are also present as low ridges on the inner surface of the theca in the counter quadrants. The cardinal septum is short and lies in a poorly defined fossula in both stages. The counter septum is long, straight, and thin in the latest growth stage observed. Tabulae are more or less complete and abundant (7 in 5 mm); they are slightly convex upward in the septa-free axial region, continuing with a downward slant into the zone of septa where they are deflected sharply upward just before reaching the theca.

This species differs from *Caninia* aff. *C. arcuata* in its external form and by its larger size, greater number of septa, and development of tabulae and dissepiments. It does not appear to be comparable with any described North American species.

Occurrence.—Charles formation, Shell Pine well, USGS colln. 13903.

Genus CANINOPHYLLUM Lewis, 1929

Diagnosis.—Large solitary trochoid to cylindrical corals with long major septa, some of which ordinarily are axially confluent but do not form an axial structure; septal plan radial; cardinal septum ordinarily short and lying in a well-defined siphonofossula; minor septa confined to dissepimentarium; major septa commonly dilated in cardinal quadrants of tabularium; dissepimentarium broad, ordinarily composed entirely of anguloconcentric dissepiments, although a few peripheral rings of lonsdaleoid dissepiments may be developed in some species; tabulae generally continuous, horizontal in axial region and deflected downward at margin of tabularium.

Type species.—*Cyathophyllum archiaci* Milne-Edwards and Haime, 1852.

Discussion.—*Caninophyllum* differs from *Vesiculophyllum* and *Enygmophyllum* in the attitude of its tabulae and by its longer, commonly axially confluent major septa, its dilation pattern, and its more prominent cardinal fossula.

Caninophyllum sp.

Plate 17, figures 9, 10

This category includes six fragments in limestone matrix. No estimate of length can be made, but the largest corallum in the collection has a diameter of 52 mm (undecorticated). Transverse sections

show 60–70 major septa in ephebic stages. The major septa are long and relatively straight, but many of them intertwine in the axial region. The cardinal septum is short and lies in a well-defined fossula. Dilation is virtually confined to the tabularium of the cardinal quadrants, where a distinctive triangular dilation pattern is seen in transverse section. Minor septa are very short. Tabulae are thin, abundant, and more or less complete; they are mainly horizontal, but their margins are deflected downward. In most of the specimens the dissepimentarium consists entirely of anguloconcentric dissepiments occupying about half the radius of the corallum. The largest specimen observed has a single peripheral ring of lonsdaleoid dissepiments.

The material is too incomplete for specific comparison; possibly more than one species is represented.

Occurrence.—Mission Canyon limestone, USGS colln. 13898 (Shell Pine well); 13937 (Murphy East Poplar well); 15770, 15771, 15775 (Shell Northern Pacific well).

Genus ENYGMOPHYLLUM Fomichev, 1931

Diagnosis.—Solitary trochoid to cylindrical corals with short major septa and a wide, septa-free axial tabularium at maturity; septal plan radial; cardinal septum ordinarily in a poorly defined fossula; minor septa absent or poorly developed; septal dilation variable, commonly concentrated in cardinal quadrants in late stages; tabularium with concave bowl-like tabulae whose traces are commonly complete and concentric in transverse section of septa-free axial region; dissepimentarium consisting mainly of anguloconcentric dissepiments probably passing into lonsdaleoid dissepiments in peripheral zone.

Type species.—*Enygmophyllum taidonensis* Fomichev, 1931.

Discussion.—This genus was previously recorded only from the Lower Carboniferous of Russia (Fomichev, 1931, p. 71; Gorsky, 1938, p. 162–163). The diagnosis is based on descriptions and illustrations of the Russian species and the Williston basin material. *Enygmophyllum* has axially depressed tabulae like *Vesiculophyllum* but can be distinguished from the latter by its shortened septa which produce a broad, open axial region occupied only by tabulae.

Enygmophyllum sp.

Plate 17, figures 12–14

The material consists of one decorticated, partly silicified specimen in limestone matrix. The corallum is a little greater than 60 mm long (the tip is broken off) and attains a maximum diameter of about 15 mm. At 9.5 mm diameter there are 26 short dilated major septa; the cardinal septum is short and lies in a moderately well developed

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fossula. The septa-free axial tabularium is about 3 mm in diameter. At 10 by 12 mm diameter there are 32 short dilated major septa; the cardinal septum is now long, and a fossula cannot be distinguished. The axial tabularium is 7.5 by 8.5 mm in diameter at this stage. At 12 by 15 mm diameter there are 34 short dilated major septa; the cardinal septum is long and occupies an open, poorly defined fossula. The axial tabularium is reduced to 7 by 7.5 mm in diameter. A slightly higher transverse section 15 mm in diameter taken just below the base of the calyx (pl. 17, fig. 12) shows 35 short major septa less dilated than in earlier stages; the cardinal septum is indistinguishable. Short minor septa are developed for the first time. Continued reduction of the tabularium produced a structure 6 mm in diameter at this stage. At all stages observed, the tabulae are few, thin, flat in the axial region, and sharply deflected upward where they intersect the axial ends of the septa, continuing into the septal zone; they make more or less complete concentric traces on the planes of transverse section. A few large, steeply inclined dissepiments can be seen in longitudinal section, but most of the dissepimentarium appears to have been removed before burial; the dissepimentarium probably was composed at least partly of lonsdaleoid dissepiments.

Comparisons with the Russian species *Enygmophyllum taidonensis* Fomichev (1931, p. 42–43, 71–72, pl. 2, figs. 8a–b), and *E. dubium* Gorsky (1938, p. 44–46, 163–164, pl. 6, figs. 1–3; text figs. 26, 27) are difficult to make owing to the incompleteness of the Russian and American material. The Williston basin species appears to differ from *Enygmophyllum taidonensis* by its smaller size, smaller number of septa, and short minor septa and possibly in the nature of the dissepimentarium. *E. dubium* appears to differ from the Williston basin form by having more tabulae, more septa, a shorter cardinal septum, and dilation concentrated in the cardinal quadrants.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13885.

Genus VESICULOPHYLLUM Easton, 1944

Diagnosis.—Large solitary cylindrical corals with numerous, long major septa that closely approach or reach the axis of the corallum but do not unite; septal plan essentially radial but modified by regular or irregular grouping of septa into bunches as a result of shortening of septa in some areas; cardinal septum long in early growth stages; cardinal and counter septa poorly differentiated in late growth stages; major septa ordinarily dilated; dilation confined to axial region in late stages; minor septa short and nonpersistent or absent; dissepimentarium broad, consisting of an outer zone of lonsdaleoid dissepiments and an inner zone of anguloconcentric or herringbone dissepiments;

tabulae numerous, incomplete, commonly gradational with dissepiments, and inclined downward axially.

Type species.—*Chonophyllum sedaliense* White, 1880.

Discussion.—The above diagnosis is based on the original diagnosis of *Vesiculophyllum* Easton (1944b, p. 52), the diagnosis of *Kakwiphyllum* Sutherland (1954, p. 365), which is a junior synonym, and the Williston basin material here referred. *Vesiculophyllum* is common in the Early Mississippian coral faunas of North America; its importance has been obscured because of confusion with *Caninophyllum* and other caninoid genera. *Vesiculophyllum* differs from *Enygmophyllum* in having longer and less regular major septa and in lacking a wide, well defined, open axial region. It is distinguished from *Caninophyllum* by its generally shorter septa that are not axially confluent, its lack of a well defined cardinal fossula at maturity, and its incomplete, axially depressed tabulae.

Vesiculophyllum sp.

Plate 18, figures 1–11

About 40 fragmentary, decorticated corals in limestone matrix are referred to *Vesiculophyllum* on the basis of internal features. Although there may be more than one species represented in this material, extreme internal variation from one growth stage to another, coupled with the lack of complete well-preserved specimens, makes specific discrimination inadvisable. The following description is a composite based on incomplete specimens.

These corals appear to have attained a length of more than 80 mm and a maximum diameter of more than 35 mm. The epitheca and outermost zones of lonsdaleoid dissepiments were eroded before burial from all the specimens studied; hence, diameter measurements are not accurate. Major septa number 28 at 6.5 by 9 mm diameter, 39–44 between 19 and 30 mm, and 48–54 between 36 and 39 mm. Minor septa are short and nonpersistent. The radial septal plan is ordinarily modified, particularly in late growth stages, by progressive shortening of major septa from the alar septum toward the cardinal and counter septa, producting a bilateral symmetry with respect to the cardinal-counter plane. The nondissepimented axial region of the coral is commonly compressed in this plane. The cardinal septum is ordinarily long in the early growth stages, and this condition may persist to maturity, although at least one specimen (Pl. 18, fig. 10) has a short cardinal lying in a poorly defined fossula in the ephebic stage. Septal dilation varies with ontogeny; ordinarily all the major septa are completely dilated in the early growth stages, but as the corallum develops, dilation becomes restricted to the axial

region, where a diamond-shaped dilation pattern is commonly developed (pl. 18, fig. 2). Tabulae are thin, numerous, and incomplete; those in the axial region are more or less horizontal, whereas peripheral ones are generally inclined downward toward the axis. The dissepimentarium consists of an inner zone of steeply inclined anguloconcentric dissepiments and a broader outer zone of lonsdaleoid dissepiments. The outer zone of dissepiments is structurally weaker owing to the absence of septa and has been almost completely eroded away in all the specimens.

Although specific discrimination is virtually impossible owing to the incomplete nature of the material, the Williston basin specimens are similar to *Kakwiphyllum dux* Sutherland (1954, p. 366–368; pl. 10, figs. 1a–c; text fig. 2), *Kakwiphyllum* cf. *K. dux* Sutherland (1954, p. 368; pl. 10, figs. 2a–c), *Vesiculophyllum sedaliense* (White) (Easton, 1944b, p. 52–53; pl. 5, figs. 5–9; pl. 17, fig. 12), and *Caninophyllum incrassatum* Easton and Gutschick (1953, p. 17–19; pl. 3, figs. 1–4).

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13880, 13890. Mission Canyon limestone, USGS colln. 13893, 13896, 13898, 13899 (Shell Pine well); 13937, 13954 (Murphy East Poplar well); 15757, 15772 (Shell Northern Pacific well). Charles formation, Shell Pine well, USGS colln. 13905.

Genus ZAPHRIPHYLLUM Sutherland, 1954

Diagnosis.—Solitary trochoid corals with a conspicuous cardinal fossula on convex side of corallum; cardinal fossula bounded laterally by cardinal lateral septa and axially by downturned edges of tabulae and confluent axial ends of major septa; septal plan pinnate in early growth stages, becoming nearly radial in later stages; major septa long, thin, their axial ends twisted and intertwined in later stages; minor septa well developed; dissepimentarium regular, well developed in ephebic stage; tabulae arched periaxially and downturned into fossula.

Type species.—*Zaphriphyllum disseptum* Sutherland, 1954.

Zaphriphyllum cf. Z. disseptum Sutherland

Plate 17, figures 17–19

One nearly complete specimen in the Williston basin material is similar to *Zaphriphyllum disseptum* Sutherland (1954, p. 364–365; pl. 9, figs. 3a–f). The corallum is about 45 mm long and has a maximum diameter of about 25 mm. There are 40 major septa at 12 mm diameter, 44 at 15 mm and 48 at 23 mm (base of calyx). This species appears to differ from *Z disseptum* by having a larger number of septa and a less open axial region produced by its smaller, less pronounced

cardinal fossula and more intimate intertwining of the axial ends of the major septa.

Occurrence.—Charles formation, Shell Pine well, USGS colln. 13907.

COLONIAL CORALS

Genus AULOPORA Goldfuss, 1829

Aulopora geometrica Girty

Plate 19, figures 5, 6

Aulopora geometrica Girty, 1899; U.S. Geol. Survey Mon. 32, pt. 2, p. 508; pl. 67, fig. 6a.

Material so identified consists of silicified fragments that compare favorably in all respects with the holotype. *A. geometrica* is the only species of *Aulopora* described from Lower Mississippian rocks of North America.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13872, 13875 (questionably), 13883 (questionably).

Aulopora sp.

Plate 19, figures 3, 4

This category comprises silicified fragments that appear to belong to a species different from *A. geometrica.* The specimens are so fragmentary as to make a characterization of the species very difficult. The species appears to have a reticulate growth habit, like *A. geometrica*, but its corallites are much smaller (about 0.5 mm at base and 1.0 mm across calyx).

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13872, 13873, 13874, 13883 (questionably).

Genus CLADOCHONUS McCoy, 1847

Cladochonus cf. C. longi (Rowley)

Plate 19, figures 1, 2

The material here referred consists of 13 silicified fragments, 2 of which are free and the rest imbedded in limestone. Features forming the basis for generic determination are septal striations rather than spines in the calices, diaphragms separating calices from stem, and reticulate tissue at the base of the calices. The species is similar to *Aulopora longi* Rowley (1901, p. 352, pl. 28, fig. 57), although comparison is made with difficulty owing to lack of complete well-preserved specimens from the Williston basin and insufficient detail in Rowley's description and illustration of the holotype. The specific comparison is based on the long, thin (diameter about 1 mm) stem

and relatively short, trumpet-shaped calices (maximum length 4 mm). *C. americanus* Weller (1909, p. 275; pl. 10, fig. 30), another similar species, has longer but more closely spaced calices and thinner stems.

Occurrence.—Lodgepole limestone, USGS colln. 13872 (Shell Pine well); 13923, 13928, 13931 (Murphy East Poplar well).

Genus CLEISTOPORA Nicholson, 1888

Cleistopora placenta (White)

Plate 18, figures 12, 13

Michilinia [sic]? *placenta* White, 1880, U.S. Geol. Geog. Survey Terr. 12th Ann. Rept., p. 157; pl. 39, figs. 1a–d.

Michelinia placenta White, Girty, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 510, pl. 67, figs. 3a–b.

The material here referred consists of 1 mature and 14 immature etched specimens and 2 specimens in matrix. The mature corallum is 37 by 30 mm in diameter and contains 11 corallites. Corallites are 8–11 mm in diameter.

These specimens compare favorably with White's illustrations and descriptions of *Michilinia* [sic]? *placenta.* Easton (1944b, p. 59) considered *M.? placenta* White as a junior synonym of *Leptopora typa* Winchell, which he referred to the genus *Cleistopora.* Easton also included *Leptopora gorbyi* Miller in his concept of *Cleistopora typa.* Jeffords (1955, p. 7) regarded *M.? placenta* White and *L. typa* Winchell as synonyms but revised *Cleistopora typa* to include three subspecies based on *Leptopora typa* Winchell, *L. gorbyi* White, and *L. winchelli* White.

The writer agrees with Easton and Jeffords that the proper generic placement of *Michilinia* [sic]? *placenta* White is with *Cleistopora* but regards *Cleistopora placenta* as a distinct species. *C. placenta* differs from *C. typa typa* in having a larger corallum with larger corallites. Although this difference does not appear very pronounced in collections from the Mississippi Valley area, it becomes significant in collections from the western part of the United States, where only the larger forms are known in the Madison.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13872, 13875. Mission Canyon limestone, Shell Northern Pacific well, USGS colln. 15757 (questionably).

Genus LITHOSTROTION Fleming, 1828

Subgenus SIPHONODENDRON McCoy, 1849

Subgeneric diagnosis.—Corallum fasciculate, ordinarily phaceloid; columella generally well formed and persistent, although diphymorphs

are known; septa vertically continuous, extending from periphery of corallite through dissepimentarium and generally, but not always, confluent with columella; tabulae tent shaped.

Type species.—*Siphonodendron aggregatum* McCoy, 1851.

Discussion—*Siphonodendron* is here considered a subgenus of *Lithostrotion* following the usage of Merriam (1942, p. 376–377).

Lithostrotion (Siphonodendron) sp.

Plate 19, Figures 7–12

Specimens from collections 13953 and 13957 show features typical of *Siphonodendron.* The corallum is phaceloid. The corallites are circular in transverse section and in places in mutual contact but are generally separated and may be as much as 4 mm apart. Based on measurements of 18 corallites, diameters range from 3.0 to 6.0 mm and average about 4.5 mm. The columella is bladelike, well formed, and persistent. The major septa, of which there are between 18 and 20, extend from the periphery of the corallite about ½ to ⅔ the radius; none are confluent with the comumella. The alternating minor septa are from ½ to ⅔ the length of the major septa. The tabulae are thin and tent shaped, numbering about 19 per cm. There is a single peripheral ring of dissepiments.

Specimens from collections 13954 and 13907 show the same range in length and number of septa, diameter and spacing of corallites, and development of dissepiments. These specimens differ from the others, however, by lacking a well-formed persistent columella. The tabulae are generally flat in the axial region and deflected downward at the periphery of the corallite. A few specimens show nonpersistent tenting of the tabulae but a solid columella is not developed. This development of internal features suggestive of *Diphyphyllum* is regarded as an ecologic variation or diphymorph within the species here referred to *Lithostrotion* (*Siphonodendron*).

These specimens do not appear to belong to any described species. They represent a species distinguished by medium-sized corallites, short septa, and a single series of dissepiments.

Occurrence.—Mission Canyon limestone, Murphy East Poplar well, USGS colln. 13953, 13954, 13957. Charles formation, Shell Pine well, USGS colln. 13907.

Syringopora Goldfuss, 1826

This genus is very common in Mississippian rocks of the Western United States. Most specimens have been referred to *Syringopora aculeata* or *Syringopora surcularia*—species originally described by Girty (1899) from the Madison near its type area. The Madison species are characterized by numerous spinose infundibular tabulae,

irregularly distributed connecting tubes, and well-developed septal spines. Analysis of the Williston basin specimens suggests that mean corallite diameter is the best character for specific discrimination. Mean corallite spacing and mean wall thickness appear to vary directly with mean corallite diameter. The number of septal spines and the nature and number of tabulae do not appear to be useful characters. Spacing of connecting tubes is an impractical character to use in differentiating species in the material from the cores. Four species, based on mean corallite diameter, are recognized in the Williston basin collections. These species appear to intergrade and may ultimately have to be combined but are here regarded as distinct in the hope that future work will prove them stratigraphically useful.

Type species.—*Syringopora ramulosa* Goldfuss, 1826.

Syringopora aculeata Girty

Plate 20, figures 1–4

Syringopora aculeata Girty, 1899, U. S. Geol. Survey Mon. 32, pt. 2, p. 509; pl. 67, figs. 5a, b.

This species includes colonies with a mean corallite diameter of 1.6–1.8 mm. Mean corallite spacing ranges from 0.8 to 1.4 mm. Mean wall thickness ranges from 0.14 to 0.17 mm.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13880. Mission Canyon limestone, Shell Northern Pacific well, USGS colln. 16304. Charles formation, Shell Pine well, USGS colln. 13905.

Syringopora surcularia Girty

Plate 20, figures 5–8

Syringopora surcularia Girty, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 510; pl. 67, figs. 4a, b.

This species includes colonies with a mean corallite diameter of 2.0 to 2.5 mm. Mean corallite spacing ranges from 1.0 to 1.8 mm. Mean wall thickness ranges from 0.10 to 0.32 mm.

Occurrence.—Mission Canyon limestone, USGS colln. 13899 (Shell Pine well); 13937 (questionably), 13950, 13954, 13957 (Murphy East Poplar well).

Syringopora aff. S. surcularia Girty

Plate 20, figures 9–12

This species includes colonies with a mean corallite diameter of 2.7 to 3.1 mm. Mean corallite spacing ranges from 1.8 to 3.0 mm. Mean wall thickness ranges from 0.20 to 0.32 mm.

Occurrence.—Mission Canyon limestone, Murphy East Poplar well, USGS colln. 13938, 13944. Charles formation, Shell Pine well, USGS colln. 13905.

Syringopora aff. S. gigantea Thompson

Plate 19, figures 13–16

One colony and a fragment with a mean corallite diameter of 4.1 mm are placed in this category. Mean corallite spacing is 2.7 mm, and mean wall thickness is 0.30 mm.

This species appears to be closely related to *Syringopora gigantea* Thompson (1883, p. 329, pl. 3, fig. 24), which was described from the Lower Carboniferous of Scotland. According to Helen Duncan (written communication, 1957), "*Syringopora* with corallites of comparable size to those of *S. gigantea* occurs sporadically in the Lower Mississippian rocks of Utah, Nevada, and California."

Occurrence.—Lodgepole limestone, USGS 13930 (questionably). Mission Canyon limestone, USGS 13945. Both from Murphy East Poplar well.

Syringopora sp.

This category includes fragmentary material inadequate for specific determination.

Occurrence.—Lodgepole limestone, Shell Pine well, USGS colln. 13876, 13878, 13879, 13883, 13890 (questionably). Mission Canyon limestone, USGS colln. 13892, 13894 (Shell Pine well); 13951 (Murphy East Poplar well). Charles formation, Shell Pine well, USGS colln. 13904, 13906, 13916 (questionably).

REGISTER OF COLLECTIONS

SHELL PINE WELL

Lodgepole limestone

USGS Carboniferous collection	*Depth below top of well (feet)*	*USGS Carboniferous collection*	*Depth below top of well (feet)*
13869	8505	13879	8310
13870	8455	13880	8298–8300
13872	8418–8421	13881	8293–8295
13873	8408–8410	13883	8262–8270
13874	8402–8405	13885	8247
13875	8400	13886	8240
13876	8323–8326	13887	8237
13878	8312	13890	7984–7990

Mission Canyon limestone

13891	7790	13895	7739
13892	7772	13896	7734
13893	7768	13898	7604
13894	7745	13899	7598

Charles formation

13902	7464	13907	7424–7425
13903	7454–7460	13916	7175
13904	7452	13917	7170
13905	7445–7448	13920	7162
13906	7433–7438		

MURPHY EAST POPLAR WELL

Lodgepole limestone

USGS Carboniferous collection	*Depth below top of well (feet)*	*USGS Carboniferous collection*	*Depth below top of well (feet)*
13923	6980	13929	6565–6580
13926	6740	13930	6540–6560
13928	6620	13931	6510–6515

Mission Canyon limestone

13932	6410	13949	5942
13933	6370–6380	13950	5928–5930
13937	6250–6260	13951	5923
13938	6235–6242	13953	5896–5898
13944	6000–6008	13954	5865–5875
13945	5980–5990	13957	5843–5847

SHELL NORTHERN PACIFIC WELL

Lodgepole limestone

15747	8139	15750	7939–7953

Mission Canyon limestone

15757	7798	15772	7415–7423
15764	7700–7704	15774	7318
15766	7631–7634	15775	7288–7296
15769	7578–7580	16304	7425
15770	7540	16306	7273
15771	7517		

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INDEX

[Italic numbers indicate descriptions]

PLATES 16–20

PLATE 16

[Figures natural size unless otherwise indicated]

FIGURES 1–5. *Zaphrentites excavatus* (Girty) (p. 173).
1, 2. Alar and counter views, respectively, USNM 119776 from USGS colln. 13906.
3. Transverse ephebic section at base of calyx, USNM 119775 from USGS colln. 13906.
4, 5. Serial subcalicular transverse sections, USNM 119774 from USGS colln. 15764.

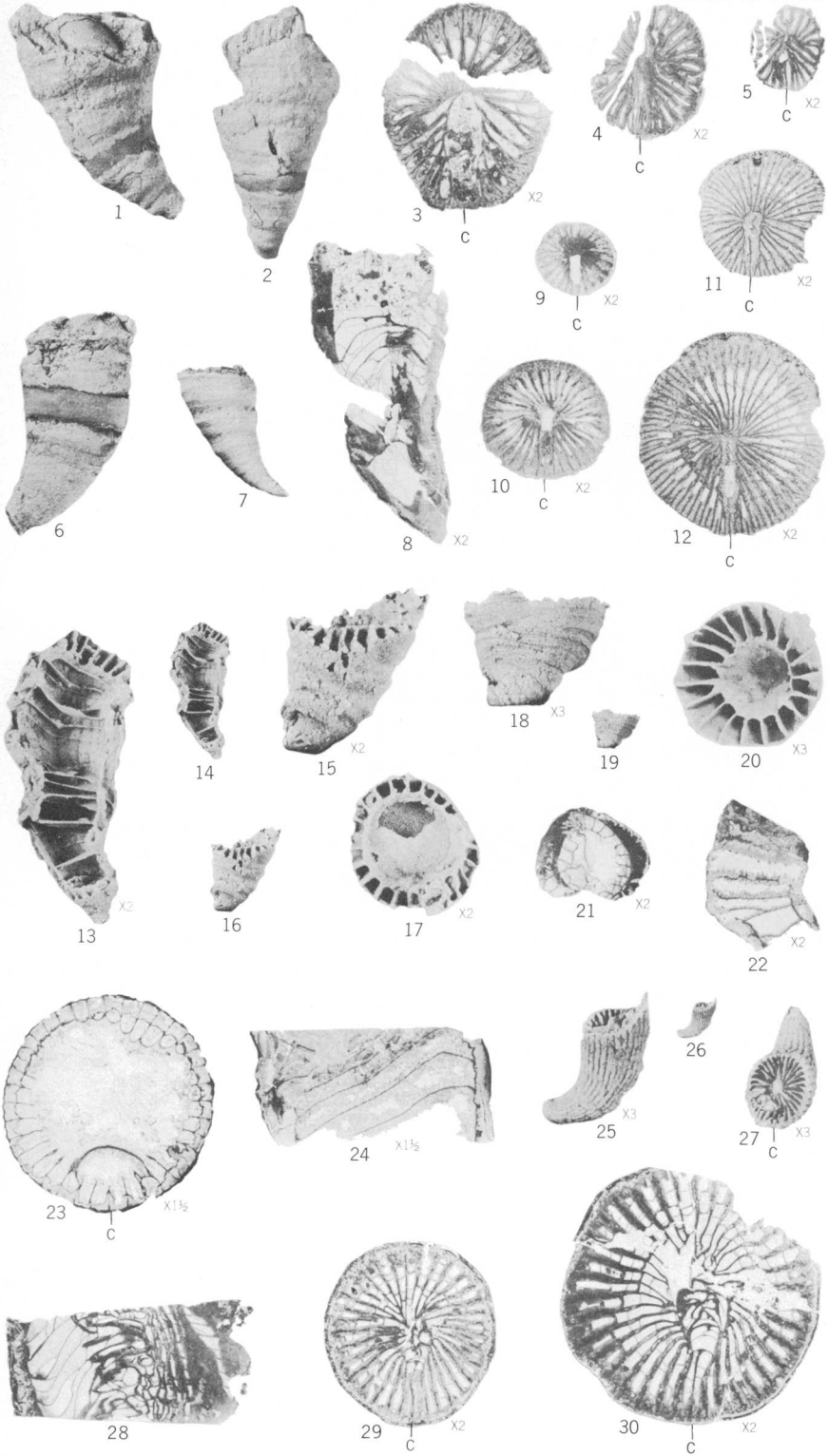
6–12. *Homalophyllites* cf. *H. subcrassus* Easton and Gutschick (p. 169).
6. Alar view of large variant, USNM 119785 from USGS colln. 13883.
7. Alar view of small variant, USNM 119784 from USGS colln. 13905.
8. Longitudinal section of small variant, USNM 119781 from USGS colln. 13905.
9, 10. Serial transverse sections of small variant, USNM 119782 from USGS colln. 13904.
11, 12. Serial transverse sections of large variant, USNM 119783 from USGS colln. 13899.

13–22. *Amplexocarinia* aff. *A. heimoi* Heritsch (p. 166).
13, 14. Side view of broken silicified mature individual, USNM 119780 from USGS colln. 13872.
15–17. Side and calicular views of a silicified neanic individual, USNM 119779 from USGS colln. 13872.
18–20. Side and calicular views of a silicified neanic individual, USNM 119778 from USGS colln. 13872. This is the earliest growth stage observed. Note funnel-shaped tabular floor of aulos.
21. Transverse section showing rejuvenation, USNM 119777 from USGS colln. 13874.
22. Longitudinal section of same specimen.

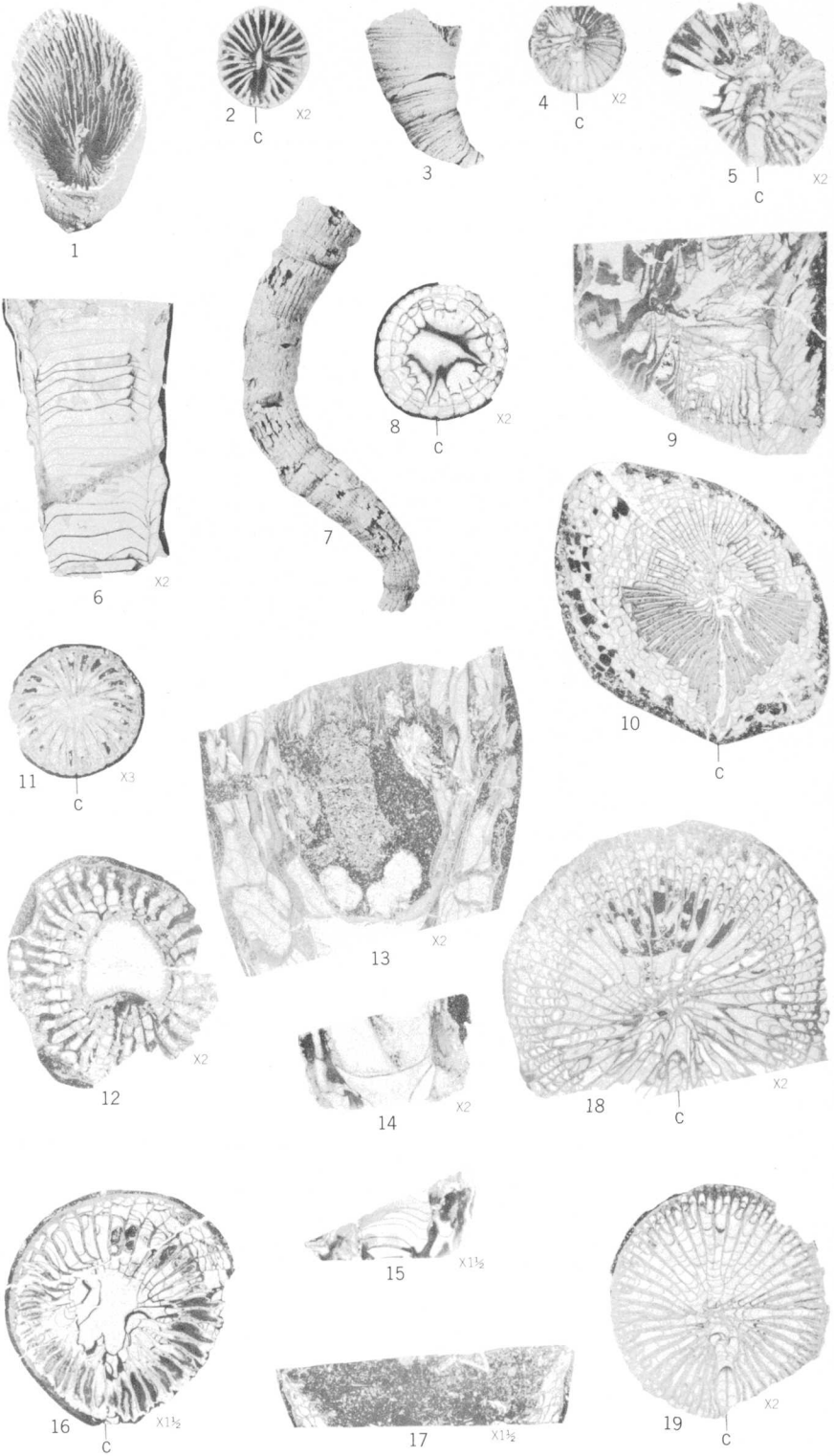
23, 24. *Amplexus* sp. (p. 167).
Transverse and longitudinal sections, respectively, USNM 119771 from USGS colln. 13872.

25–27. *Cyathaxonia arcuata* Weller? (p. 168).
Alar and calicular views of a silicified individual, USNM 119794 from USGS colln. 13873.

28–30. *Menophyllum*? sp. (p. 170).
Longitudinal and serial transverse sections, USNM 119773 from USGS colln. 15774.



ZAPHRENTITES, HOMALOPHYLLITES, AMPLEXOCARINIA, AMPLEXUS, CYATHAXONIA, AND *MENOPHYLLUM?*



RYLSTONIA, CANINIA, CANINOPHYLLUM, ROTIPHYLLUM, ENYGMOPHYLLUM, AND *ZAPHRIPHYLLUM*

PLATE 17

[Figures natural size unless otherwise indicated]

FIGURES 1–5. *Rylstonia* cf. *R. teres* (Girty) (p. 172).

1. Oblique calicular view of a large silicified individual showing prominent column and deep calyx, USNM 119789 from USGS colln. 13872.
2. Calicular view of a small silicified individual showing column and deep cardinal fossula, USNM 119788 from USGS colln. 13872.
3. Alar view of an average-sized silicified individual, USNM 119787 from USGS colln. 13872.
4, 5. Serial transverse sections of an average-sized individual, showing column, short cardinal septum, and prominent cardinal fossula, USNM 119786 from USGS colln. 13905.

6–8. *Caninia* aff. *C. arcuata* Jeffords (p. 175).

6. Longitudinal section, USNM 119762 from USGS colln. 13917.
7. Side view of silicified individual, USNM 119763 from USGS colln. 13920.
8. Transverse section, USNM 119761 from USGS colln. 13917.

9, 10. *Caninophyllum* sp. (p. 176).

Longitudinal and transverse sections, respectively, of a decorticated individual showing horizontal tabulae with downwardly deflected margins, broad anguloconcentric dissepimentarium, short cardinal septum, and triangular dilation pattern, USNM 119770 from USGS colln. 15775.

11. *Rotiphyllum hians* Easton? (p. 171).

Transverse section just below base of calyx, USNM 119772 from USGS colln. 13926.

12–14. *Enygmophyllum* sp. (p. 177).

12. Transverse ephebic section of a decorticated individual showing short, dilated major septa and concentric traces of tabulae, USNM 119769 from USGS colln. 13885.
13, 14. Longitudinal sections in calyx and below calyx, respectively, of same specimen showing dissepiments and flat tabulae with upturned margins.

15, 16. *Caninia* sp. (p. 175).

Longitudinal and transverse sections, respectively, of a silicified individual, USNM 119760 from USGS colln. 13903.

17–19. *Zaphriphyllum* cf. *Z. disseptum* Sutherland (p. 180).

17. Longitudinal section through top of calyx showing dissepiments, USNM 119768, from USGS colln. 13907.
18, 19. Serial transverse sections of same specimen.

PLATE 18

[Figures natural size unless otherwise indicated]

FIGURES 1–11. *Vesiculophyllum* sp. (p. 179).

1. Transverse ephebic section of decorticated individual showing dilation pattern and anguloconcentric dissepimentarium, USNM 119766 from USGS colln. 13896.

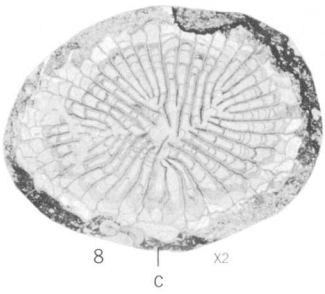
2, 3. Transverse ephebic and longitudinal sections of a decorticated individual, USNM 119765 from USGS colln. 13905. Note long cardinal septum and incomplete, axially depressed tabulae.

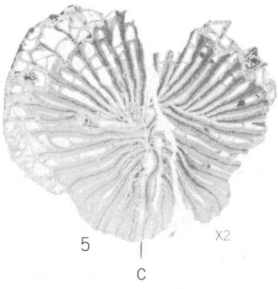
4–7. Serial transverse and longitudinal sections of a decorticated individual, USNM 119767 from USGS colln. 13896. Note long cardinal septum in all stages, variable dilation, and axially depressed tabulae. These sections are ontogenetically younger than those of figures 1–3.

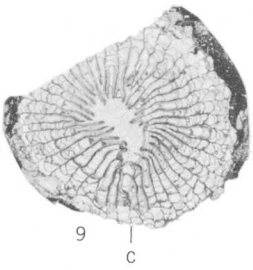
8–11. Serial transverse and longitudinal sections of a decorticated individual, USNM 119764 from USGS colln. 13937. Note short cardinal septum, variable dilation and fragmentary outermost zone of lonsdaleoid dissepiments.

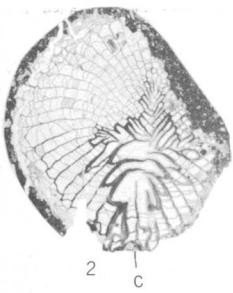
12, 13. *Cleistopora placenta* (White) (p. 182).

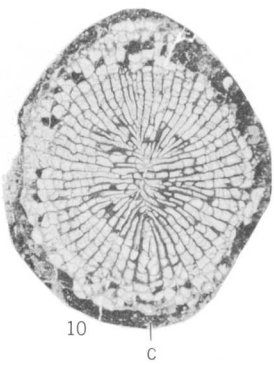
Dorsal and ventral views, respectively, of a mature silicified colony, USNM 119790 from USGS colln. 13872.

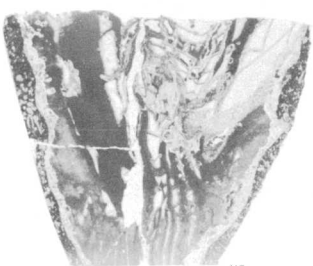


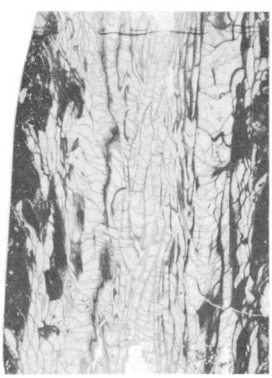


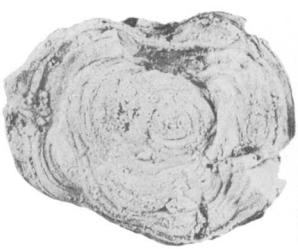




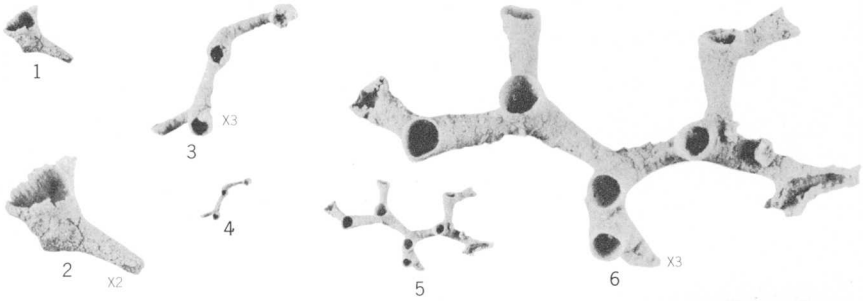








VESICULOPHYLLUM AND *CLEISTOPORA*

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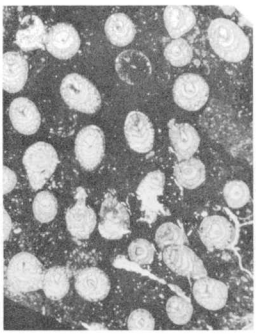
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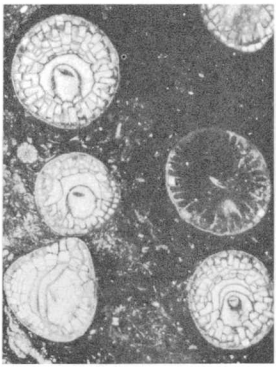
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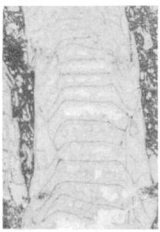
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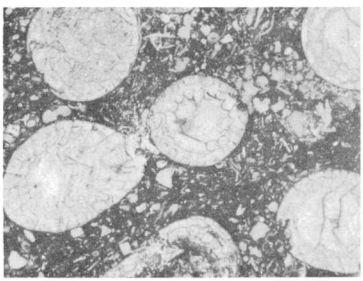
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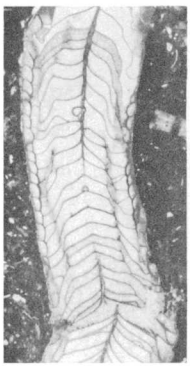
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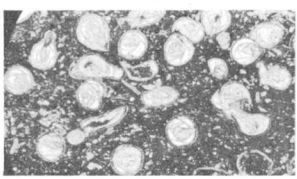
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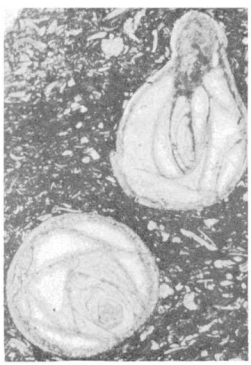
16 X5

CLADOCHONUS, AULOPORA, LITHOSTROTION, AND *SYRINGOPORA*

PLATE 19

[Figures natural size unless otherwise indicated]

FIGURES 1, 2. *Cladochonus* cf. *C. longi* (Rowley) (p. 181).
Silicified calyx, USNM 119793, from USGS colln. 13872.

3, 4. *Aulopora* sp. (p. 181).
Fragment of silicified colony, USNM 119792 from USGS colln. 13872.

5, 6. *Aulopora geometrica* Girty (p. 181).
Fragment of silicified colony, USNM 119791 from USGS colln. 13872.

7–12. *Lithostrotion* (*Siphonodendron*) sp. (p. 183).
7, 10. Longitudinal section of colony and individual corallite, respectively, USNM 119758 from USGS colln. 13957.
8, 9. Transverse section of colony, USNM 119758 from USGS colln. 13957.
11, 12. Transverse and longitudinal sections, respectively, of diphymorphic variant, USNM 119759 from USGS colln. 13954.

13–16. *Syringopora* aff. *S. gigantea* Thompson (p. 185).
13, 15. Longitudinal section of colony, USNM 119757 from USGS colln. 13945.
14, 16. Transverse section of colony, USNM 119757, from USGS colln. 13945.

PLATE 20

[Figures natural size unless otherwise indicated]

FIGURES 1–4. *Syringopora aculeata* Girty (p. 184).
1, 3. Transverse section of colony, USNM 119754 from USGS colln. 16304.
2, 4. Longitudinal section of colony, USNM 119754 from USGS colln. 16304.
5–8. *Syringopora surcularia* Girty (p. 184).
5, 7. Transverse section of colony, USNM 119755 from USGS colln. 13954.
6, 8. Longitudinal section of colony, USNM 119755 from USGS colln. 13954.
9–12. *Syringopora* aff. *S. surcularia* Girty (p. 184).
9, 11. Transverse section of colony, USNM 119756 from USGS colln. 13905.
10, 12. Longitudinal section of colony, USNM 119756 from USGS colln. 13905

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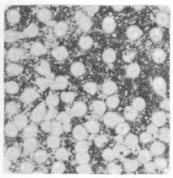

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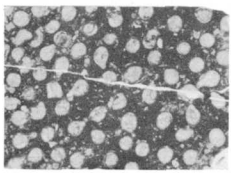

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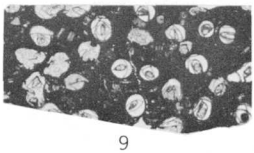

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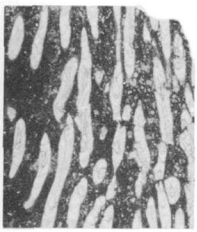

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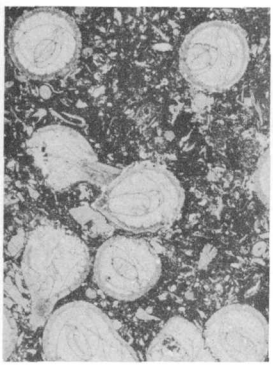

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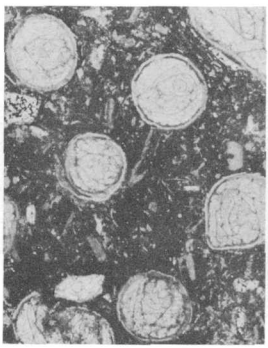

7 X5

11 X5

4 X5

8 X5

12 X5

SYRINGOPORA