Ordovician and Silurian Coral Faunas of Western United States

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ORDOVICIAN AND SILURIAN CORAL FAUNAS OF WESTERN UNITED STATES

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ABSTRACT

A review of existing information, published and unpublished, shows that considerably more data are available on the Ordovician and Silurian coral faunas of western United States than is generally supposed.

Records of corals in the Lower and Middle Ordovician rocks of the West are few. The oldest fauna, which occurs in rocks tentatively assigned a late Early Ordovician age, consists of primitive favistellids. These early corals have been found at a good many places in western Utah and eastern Nevada. At two localities, quartzitic rocks that generally have been classed as Middle Ordovician contain horn corals. The Kinnikinic quartzite fauna of Idaho is now known to be of Late Ordovician age. The streptelasmid forms that occur in the upper beds of the Eureka quartzite at Cortez, Nev., are also suggestive of Late rather than of Middle Ordovician corals. A few Middle Ordovician corals have been found in the less quartzitic extensions of the lower part of the Eureka quartzite farther south and west in Nevada.

Corals are much more diversified and widely distributed in the Upper Ordovician rocks of the West. The Bighorn dolomite and equivalent formations in the region extending from South Dakota and Colorado west to California and from Montana and Idaho south to Texas contain an astonishingly uniform coral fauna that is related to the one characteristic of the Upper Ordovician rocks in western Canada and Arctic America. In the writer's opinion, the evolutionary stage of development exhibited by the horn corals in the basal strata of the Bighorn strongly favors a Late Ordovician—though probably a pre-Richmond—age for the lower part of the formation. The upper part of the Bighorn dolomite has long been considered of Richmond age.

The Silurian coral fauna of the West is more restricted in distribution than that of the Late Ordovician and commonly is not well preserved. Faunules from various areas, however, indicate that certain forms such as the halysitids, heliolitids, and certain Rugosa are ordinarily distinctive enough to differentiate the Silurian from the Ordovician dolomites even though other kinds of fossils are not found.

Current nomenclatural usage is briefly discussed. The more common, easily recognized, and stratigraphically useful corals in each fauna as well as certain forms that are likely to be misidentified or that cannot be relied on are mentioned. Features that help differentiate Ordovician from Silurian corals having similar growth forms are pointed out. A good many corals that have been neglected in accessible American publications or that are commonly misidentified are briefly characterized and illustrated.

INTRODUCTION

Dolomitic rocks of Late Ordovician and of Silurian age are widely distributed in western United States. Corals are by far the most abundant fossils in most of the calcareous rocks deposited in the region during these divisions of geologic time and at many localities are the only identifiable organisms. For this reason corals must be depended on, at times exclusively, for the differentiation of Upper Ordovician from Silurian strata, and in some instances for the differentiation of these older rocks from certain Devonian and Carboniferous dolomites that contain predominantly coral faunas. Devonian and Carboniferous corals are somewhat better known and in general should not pose much of a problem in stratigraphic work if attention is paid to the peculiarities of regional distribution. Considerable difficulty has been experienced by geologists and paleontologists, however, in distinguishing between the Ordovician and Silurian corals. Factors responsible for this situation are—western coral faunules of early Paleozoic age have not been described and illustrated, several of the more common elements in each fauna have growth forms that are easily confused, and the corals themselves are commonly so crudely silicified or otherwise poorly preserved that the rugose forms in particular cannot be accurately identified.

Most of the published data have appeared in reports on areal and economic geology of restricted areas. Geographic coverage, though spotty, is relatively extensive (see fig. 42). Because the corals have not been described in paleontologic papers, the existence of published information on these faunas has been overlooked by many. In a recent review of the sequence of Ordovician coral faunas throughout the world, Hill (1951) gives no indication that corals are known in the Western States. Even Bassler's faunal lists of Paleozoic corals (Bassler, 1950) records faunules from only three localities in the Upper Ordovician rocks and includes none from the Silurian rocks of the West.

As a result, some geologists and paleontologists (for example, Hintze, 1951, p. 23) have concluded that the coral faunas of the rocks considered in the present study have little significance and are not utilizable in stratigraphic work. During the past few years, the writer has identified numerous early Paleozoic corals collected in many parts of the Rocky Mountain region and Great Basin, and also has extensively reviewed earlier collections in the Survey's stratigraphic reference sets. Field investigations by the writer and associates during recent years have provided additional information on the early Paleozoic coral assemblages that occur at various localities and have verified conclusions based on studies in the laboratory.

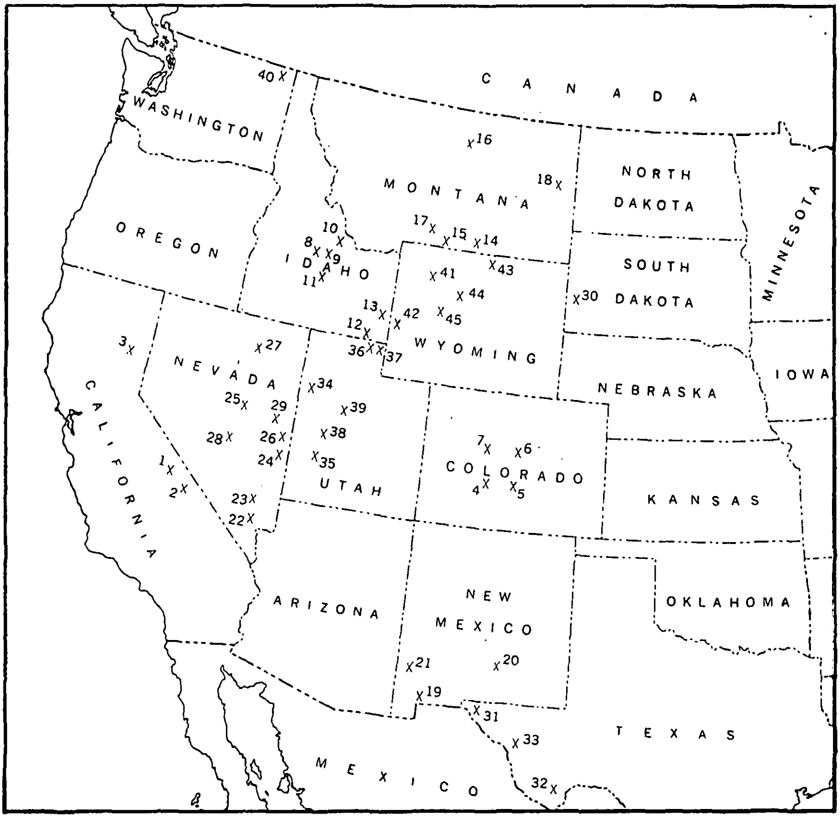

Figure 42.—Principal areas from which early Paleozoic coral faunas are known in western United States. (See Review of geographic and stratigraphic distribution, p. 212–215.)

Key to numbers on map:

California

1. Inyo Mountains
2. Panamint Range and vicinity
3. Taylorsville region

Colorado

4. Bonanza mining district
5. Canyon City area
6. Pikes Peak
7. Sawatch Range

Idaho

8. Bayhorse region
9. Borah Peak quadrangle
10. Lemhi County
11. Mackay region
12. Preston quadrangle
13. Southeastern Idaho

Montana

14. Bighorn Canyon area
15. Clark Fork area, Carbon County

Montana—Continued

16. Little Rocky Mountains
17. Red Lodge area
18. Williston basin, subsurface

New Mexico

19. Deming quadrangle
20. Sacramento Mountains
21. Silver City quadrangle

Nevada

22. Las Vegas quadrangle
23. Nevada Proving Grounds
24. Pioche district
25. Roberts Mountains and Cortez quadrangles
26. Snake Range
27. Tuscarora Mountains
28. Tybo district
29. White Pine Range

South Dakota

30. Black Hills

Texas

31. El Paso quadrangle
32. Marathon region
33. Van Horn quadrangle

Utah

34. Gold Hill quadrangle
35. Ibex area
36. Logan quadrangle
37. Randolph quadrangle
38. Thomas Mountains
39. Tintic district and vicinity

Washington

40. Metaline quadrangle

Wyoming

41. Absaroka Range
42. Afton quadrangle
43. Bighorn Mountains
44. Owl Creek Mountains
45. Wind River Mountains

This work has demonstrated that the Late Ordovician and Silurian faunas are extraordinarily consistent in their makeup and that certain forms, which are almost invariably present in any representative collection, can be used reliably in determining the age of the dolomites. In order to make this knowledge generally available, this bulletin presents a summary of basic differences, with emphasis on critical features that are easily recognized and that have general application in discrimination of the two faunas.

The writer is indebted to her colleagues Edwin Kirk and Jean M. Berdan for providing information bearing on the general nature and occurrence of the western early Paleozoic corals and for verifying data assembled for this review. The illustrations were delineated by Eleanor Stromberg, whose painstaking renditions and reconstructions faithfully portray the writer's concepts.

REVIEW OF GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION

The index map (fig. 42) indicates the extent of the territory involved. The following summary shows, by State, the areas from which Ordovician and Silurian coral faunas have been identified. Insofar as possible, formation names applied to the rocks in each area are indicated and publications listing corals are cited, so that this review of distribution serves also as a summary of previous work. Documentation is not absolutely comprehensive. The more significant sources of published information are given, but certain articles that cite only one genus or species (for example, *Streptelasma* sp. or *Halysites gracilis*) are not included, particularly if more extensive faunal data are given in other publications covering the same area. Also listed are some areas from which corals have been identified in as yet unpublished reports of the Geological Survey. Citations to unpublished information refer to collections of the Survey and of the U. S. National Museum. Most of the paleontologic and age determinations in the literature cited were made by members of the Survey—Walcott, Schuchert, and Ulrich in the earlier reports; Kirk and Kindle in subsequent years; Duncan and Berdan since 1949. Even though much of the nomenclature used in earlier reports is outmoded, it provides a general guide to the faunas if one makes allowances for the changes that inevitably occur in the course of time.

CALIFORNIA

Inyo Mountains: Mazourka formation of Phleger (1933) (supposedly an upper Lower Ordovician equivalent of the upper part of the Pogonip group; the coral reported suggests that post-Lower Ordovician rocks may have been included in the formation). (Phleger, 1933, p. 3; see also this paper p. 217.) Silurian (rocks assigned to the Devonian in older reports). (Merriam, 1940, p. 47; Waite, 1953, p. 1521.)

Panamint Range including Quartz Spring area and Ubehebe Peak quadrangle: Ely Springs dolomite (Upper Ordovician) and Hidden Valley dolomite (Silurian in part). (Hopper, 1947, p. 408; McAllister, 1952, p. 15, 16–17.)
Taylorsville region: Montgomery limestone (Silurian). (Diller, 1908, p. 16–17.)

COLORADO

Bonanza mining district: Upper member of Tomichi limestone of Crawford (1913) (Upper Ordovician). (Burbank, 1932, p. 11.)
Canyon City area, Fremont County: Fremont limestone (Upper Ordovician). (Walcott, 1892, p. 159, 161; Sweet, 1954, p. 300–301.)
Pikes Peak: Fremont limestone (Upper Ordovician). (Cross, 1894, p. [2].)
Sawatch Range: Fremont limestone (Upper Ordovician). (Johnson, 1944, p. 324.)

IDAHO

Bayhorse region, Custer County: Saturday Mountain formation (Upper Ordovician) and Laketown dolomite (Silurian). (Ross, 1937, p. 20–21, 24–25.)
Borah Peak quadrangle: Kinnikinic quartzite and Saturday Mountain formation (Upper Ordovician) and Laketown dolomite (Silurian). (Ross, 1947, p. 1104–1106.)
Lemhi County: Upper Ordovician. (Umpleby, 1913, p. 33.)
Mackay region: Saturday Mountain formation (Upper Ordovician). (Umpleby, 1917, p. 25.)
Preston quadrangle: Fish Haven dolomite (Upper Ordovician) and Laketown dolomite (Silurian). (Ordovician faunal data not published; Silurian, Berdan and Duncan, 1955.)
South-central Idaho: Kinnikinic quartzite and Saturday Mountain formation (Upper Ordovician) and Laketown dolomite (Silurian). (Ross, 1934, p. 950, 953, 958.)
Southeastern Idaho: Fish Haven dolomite (Upper Ordovician) and Laketown dolomite (Silurian). (Mansfield, 1927, p. 58–59.)

MONTANA

Bighorn Canyon area, Bighorn and Carbon Counties: Bighorn dolomite (Upper Ordovician). (Faunal data not published.)
Clark Fork area, Carbon County: Bighorn dolomite (Upper Ordovician). (Faunal data not published.)
Little Rocky Mountains: Bighorn dolomite (Upper Ordovician). (Faunal data not published.)
Red Lodge area, Carbon County: Bighorn dolomite (Upper Ordovician). (Faunal data not published.)
Williston basin, subsurface: Bighorn dolomite (Upper Ordovician) and Silurian (formation not named). (Faunal data not published.)

NEW MEXICO

Deming quadrangle: Montoya limestone (Upper Ordovician). (Darton, 1917, p. 5.)
Sacramento Mountains, Otero County: Montoya limestone (Upper Ordovician) and Fusselman(?) limestone (Silurian). (Pray, 1953, p. 1906, 1913–1914.)
Silver City quadrangle: Montoya limestone (Upper Ordovician). (Paige, 1916, p. 4.)
Southern New Mexico, general: Montoya limestone (Upper Ordovician) and Fusselman limestone (Silurian). (Darton, 1928, p. 13–14, 185–189, 200, 321.)

NEVADA

Cortez quadrangle: Uppermost beds of Eureka quartzite (possibly Upper Ordovician). (Discussed in this paper p. 217.)

Las Vegas quadrangle: Ely Springs dolomite (Upper Ordovician). (Faunal data not published.)

Nevada Proving Grounds, Nye County: Lone Mountain dolomite of Hague, 1883 (Upper Ordovician and Silurian). (Faunal data not published.)

Pioche district: Tank Hill limestone (upper Lower Ordovician equivalent of the upper part of the Pogonip) and Ely Springs dolomite (Upper Ordovician). (Westgate and Knopf, 1932, p. 15–16; Hintze, 1952, p. 49; see also this paper p. 216.)

Roberts Mountains region: Middle Ordovician rocks beneath Eureka quartzite (formation unnamed), Hanson Creek formation (Upper Ordovician), and Roberts Mountains formation (Silurian). (Merriam, 1940, p. 11–12; Merriam and Anderson, 1942, p. 1687; this paper, p. 217.)

Snake Range: Upper Lower Ordovician equivalent of the upper part of the Pogonip. (Hintze, 1952, p. 32, 74.)

Tuscarora Mountains: Upper Ordovician and Silurian (formations not specified). (Faunal data not published.)

Tybo district: Lone Mountain dolomite (Silurian). (Ferguson, 1933, p. 21.)

White Pine Range: Upper Lower Ordovician equivalent of the upper part of the Pogonip. (Hintze, 1952, p. 32, 74; see also this paper p. 216.)

SOUTH DAKOTA

Black Hills: Whitewood dolomite (Upper Ordovician). (Darton, 1909, p. 20; Darton and Paige, 1925, p. 7; Furnish, Barragy, and Miller, 1936, p. 1340.)

TEXAS

El Paso quadrangle: Montoya limestone (Upper Ordovician) and Fusselman limestone (Silurian). (Richardson, 1909, p. 4.)

Marathon region: Maravillas chert (Upper Ordovician). (King, 1937, p. 41–42.)

Trans-Pecos Texas: Montoya limestone (Upper Ordovician) and Fusselman limestone (Silurian). (Richardson, 1908, p. 479–480.)

Van Horn quadrangle: Montoya limestone (Upper Ordovician). (Richardson, 1914, p. 5.)

UTAH

Gold Hill quadrangle: Fish Haven dolomite (Upper Ordovician) and Laketown dolomite (Silurian). (Nolan, 1930, p.426; Nolan, 1935, p. 16–18.)

Ibex area, Millard County: Upper Lower Ordovician equivalent of the upper part of the Pogonip. (Hintze, 1951, p. 21, 69; Hintze, 1952, p. 23.)

Logan quadrangle: Fish Haven dolomite (Upper Ordovician) and Laketown dolomite (Silurian). (Kindle, 1908a, p. 127; Kindle, 1908b, p. 17; Tomlinson, 1917, p. 129; Williams, 1948, p. 1138.)

Randolph quadrangle: Fish Haven dolomite (Upper Ordovician) and Laketown dolomite (Silurian). (Richardson, 1913, p. 409–410; Richardson, 1941, p. 17–18.)

Thomas Mountains: Upper Ordovician and Silurian. (Faunal data not published.)

Tintic district and Allen's Ranch quadrangle: Bluebell dolomite unrestricted (Upper Ordovician, Silurian, and Devonian). (Faunal data not published.)

WASHINGTON

Metaline quadrangle: Silurian (formation not named). (Faunal data not published.)

WYOMING

Absaroka Range: Bighorn dolomite (Upper Ordovician.) (Love, 1939, p. 20.)
Afton quadrangle: Bighorn dolomite (Upper Ordovician). (Faunal data not published.)
Bighorn Mountains: Bighorn dolomite (Upper Ordovician). (Darton, 1906a, p. 28–29; Darton, 1906b, p. 548–550; Fisher, 1906, p. 13; Tomlinson, 1917, p. 129–130; Savage and Van Tuyl, 1919, p. 352; Foerste, 1924, p. 23.)
Crawford Mountains, Randolph quadrangle: Upper Ordovician. (Berdan and Duncan, 1955.)
Owl Creek Mountains: Bighorn dolomite (Upper Ordovician). (Faunal data not published.)
Western and northwestern Wyoming, miscellaneous localities: Bighorn dolomite (Upper Ordovician). (Tomlinson, 1917, p. 129–130.)
Wind River Mountains: Bighorn dolomite (Upper Ordovician). (Darton, 1906b, p. 554–555; Miller, 1930, p. 198–199, 204–206.)

ORDOVICIAN FAUNAS

EARLY AND MIDDLE ORDOVICIAN

Information on pre-Late Ordovician corals in the West is meager. The earliest fauna seems to have been fairly persistent through an area in western Utah and east-central Nevada where it occurs in the upper part of the Pogonip group and rocks of equivalent age. The age of this faunal zone has been cited as "Chazy," which in Survey usage was considered to be post-Beekmantown Lower Ordovician. As now used by most geologists (see Twenhofel and others, 1954, Ordovician correlation chart), the term "Chazyan" is applied to the lower division of the "Champlainian" and is supposed to refer to the early Middle Ordovician. The unfortunate result of this confused situation is that geologists who have studied the faunas considered the upper part of the Pogonip group and equivalent rocks to be upper Lower Ordovician, whereas others have assumed that the same rocks were early Middle Ordovician because the fauna at one time had been tagged as "Chazyan." G. A. Cooper (oral communication, 1954) regards the fauna associated with the corals in the upper part of the Pogonip as Early Ordovician. Edwin Kirk (oral communication, 1954) also prefers to class these rocks as Early Ordovician and has suggested that it is entirely possible that the fauna in question is of post Beekmantown but pre-Chazy age with reference to the New York section. In the Ordovician correlation chart, all formations containing this early coral fauna were included in the Middle Ordovician ("Champlainian"). The ultimate assignment of these rocks depends on faunal studies not yet completed, and probably opinions will differ. In the present review, the upper part of the Pogonip and its equivalents are tentatively classed as upper Lower Ordovician.

To the extent that it is known, the earliest western coral fauna is less diversified than the so-called Chazy fauna of eastern America (see Hill, 1951, p. 13–16). The corals are simple compound forms, mainly *Eofletcheria* and *Lichenaria*. *Eofletcheria* is reported to form biostromal accumulations in a dolomite intercalated between a quartzite called Swan Peak(?) by Hintze (1951) and the Eureka quartzite at several places in western Utah (Hintze, 1951, p. 21, 69, 74). The same genus is said to occur in rocks equivalent to the upper part of the Pogonip at localities in eastern Nevada (Hintze, 1952, p. 23).

According to Kirk, (oral communication, 1954), the Tank Hill limestone of the Pioche district, Nevada, contains a lenticular biostrome formed by the primitive colonial corals of this early fauna. When the Tank Hill limestone was described and its fauna listed, *Tetradium* was recorded (Westgate and Knopf, 1932, p. 15). In reviewing the collections, the writer did not recognize *Tetradium* and suspects that the name was applied to the semifasciculate *Lichenaria* discussed later. The coralla of this form do, in fact, look very much like the coralla of some species of *Tetradium*. Hintze (1952, p. 49) identified corals from the Tank Hill limestone as "*Columnaria* cf. *simplissima* Okulitch." Okulitch's species was referred to *Foerstephyllum* by Bassler (1950, p. 270) (see pl. 24, figs. 3a, 3b); but without investigation of Hintze's material, it is impossible to say just what genus is involved. The Geological Survey collections from the Tank Hill limestone that have been examined by the writer contain two species of corals. One is a *Lichenaria* with large corallites (pl. 24, figs. 4a, 4b); the other comprises semifasciculate forms that are interpreted as *Lichenaria* tending to become phaceloid, that is, approaching *Eofletcheria* (see pl. 25, figs. 5a, 5b).

The writer has also identified *Eofletcheria* (pl. 25, figs. 4a, 4b) and a *Lichenaria*, characterized by small nodular coralla and small corallites, in a collection from the upper part of the Pogonip of the White Pine Range, Nev. Similar corals were collected by the writer from dolomitic rocks underlying the Eureka quartzite at the north end of the Wah Wah Range, Utah (Crystal Peak section of Hintze, 1951, p. 68–71).

Except for the material from the Pioche district and the White Pine Range in Nevada and from the Wah Wah Range in Utah, the writer has not had an opportunity to examine the Early Ordovician corals reported from other localities. It is still not clear whether genera more advanced than *Lichenaria* and *Eofletcheria* occur in this faunal zone or whether different nomenclature has been employed for some of the corals that belong to the *Lichenaria*-*Eofletcheria* complex.

The occurrence of "(?)*Streptelasma*" in the Mazourka formation of the Inyo Mountains, Calif. (Phleger, 1933, p. 3), is anomalous. The Mazourka formation of Phleger (1933) is supposed to be of the same age as the upper part of the Pogonip. Elsewhere the streptelasmid corals first appear in later rocks (post-Chazy of common usage). It is possible, of course, that younger Ordovician rocks have been included in Phleger's Mazourka formation.

Rocks commonly assigned to the Middle Ordovician in the Great Basin and Rocky Mountain region are mainly arenaceous—quartzite and sandstone. The environment in which the sands are believed to have accumulated would not have been favorable for corals, and the writer has not found any published record of their occurrence. This past year, however, a few horn corals were collected from fossiliferous Middle Ordovician rocks that occur beneath the vitreous part of the Eureka quartzite in the Roberts Mountains quadrangle, Nevada. The two species found in these rocks are comparable to *Streptelasma breve* Winchell and Schuchert and *Streptelasma corniculum* Hall.

It was of considerable interest to learn from James Gilluly that horn corals had been found in the Eureka quartzite at Cortez, Nev. Jean M. Berdan and the writer examined the section at Cortez in 1954 and located a coral zone near the top of the formation. Indications of corals are preserved as molds in vitreous quartzite. The material, of course, is not specifically identifiable, but the molds reveal that the corals were small to medium sized and had well-defined and consistently oriented curvature. Some specimens show moderately complex and raised axial structures, and some of the molds suggest that angulate coralla occur in the fauna. The morphologic features that can be determined suggest that these horn corals are considerably more advanced than the earliest streptelasmids—*Lambeophyllum profundum* and *Streptelasma corniculum.* It may well be that this coral zone belongs to the phase of the Eureka quartzite that according to Merriam (1940, p. 10–11) grades into the sandy lower part of the Upper Ordovician Hanson Creek formation. After evaluating various lines of evidence, Kirk (1933, p. 42–43) also concluded that correlation of the upper part of the Eureka with the lower part of the Bighorn dolomite "seems most nearly to explain all the observed facts."

On the lithic similarity and stratigraphic position, the Kinnikinic quartzite in south-central Idaho was originally considered to be of Early or Middle Ordovician age (Ross, 1934, p. 950); but a fauna, including corals, found subsequently proved to be of Late Ordovician age (Ross, 1947, p. 1104).

So far the writer has seen only one collection of corals from the West that can be referred indisputably to the Middle Ordovician.

It is hoped that future work on the less quartzitic western extensions of the lower part of the Eureka quartzite will provide more knowledge of Middle Ordovician corals in the region. In the course of time, more coral-bearing zones should be found in the quartzites that are ordinarily assigned to the Middle Ordovician. Such occurrences will have to be evaluated individually, however, for in most areas we have no reliable evidence on the exact age of the quartzites; and, as indicated in the preceding discussion, it is likely that zones of both Middle and Late Ordovician age are to be distinguished in at least some of the quartzites.

LATE ORDOVICIAN

The most common elements in the Late Ordovician coral faunas are *Halysites* (*Catenipora*) *gracilis* Hall (pl. 27, figs. 1a, 1c), *Calapoecia* (pl. 26, figs. 4a, 4b), the phaceloid favistellid *Palaeophyllum* (pl. 25, figs. 1a, 1b), and solitary angulate streptelasmid corals (pl. 22). Less common but just as widely distributed are a smaller species of *Catenipora*, *Favosites* (including both *Favosites* in the strict sense and *Palaeofavosites*) (pl. 26, figs. 1a, 1b, 2a, 2b), the massive favistellids (*Saffordophyllum* (pl. 24, figs. 2a, 2b), *Foerstephyllum* (pl. 24, figs. 3a, 3b), *Favistella* (pl. 24, figs. 5a, 5b), and *Cyathophylloides* (pl. 24, figs. 6a, 6b)), and *Protaraea*.

The streptelasmids are diverse. Some forms have conspicuous axial structures and are referable to the genus *Grewingkia* (pl. 21, figs. 4a, 4b). But, even though recorded in some of the older faunal lists, no examples of that very diagnostic species of the type Richmond, *Grewingkia rustica* (Billings) [=*Streptelasma rusticum*], have been seen. Western species so identified are probably identical with or related to *Streptelasma latusculum* (Billings) (pl. 21, figs. 1a, 1b). Angulate streptelasmid corals range from types that are carinate only along the cardinal septum (group of *S. prolongatum* Wilson) (pl. 22, figs. 2a, 2b) through semitriangulate forms (group of *S. foerstei* Troedsson) (pl. 22, figs. 4a, 4b) to those with nearly quadrangular cross sections (group of *S. goniophylloides* Teichert) (pl. 22, figs. 3a, 3b). *Streptelasma trilobatum* Whiteaves (pl. 21, figs. 3a, 3b), which occurs very widely in at least the upper part of the Upper Ordovician rocks, has been interpreted as the end result of this trend to angularity (Kirk, 1925, p. 446). *S. trilobatum* differs from the forms just mentioned, however, in that its coralla are longitudinally grooved—not carinate—along the alar septa. Subcalceoloid "Holophragmas" (angulate along the alar septa and flattened on the counter side) (pl. 22, figs. 1a–1c) occur throughout the western Upper Ordovician rocks; they are rarely abundant, but at least a few examples have been collected at many localities.

The western Late Ordovician coral assemblage is related to the fauna described from Arctic America and western Canada. Hill (1951, p. 17–18) reviewed the general composition of this fauna and listed most of the references in which species mentioned here are described and illustrated. The corals have affinities with those of the Maquoketa shale and other formations of the northern Mississippi Valley region, but the fauna differs markedly from that of the Richmond in its type area in containing an abundance of *Catenipora*, *Palaeophyllum*, and angulate streptelasmid corals. Calapoecias and massive favistellids occur in both regions. Massive cerioid and halysitoid forms of *Tetradium*, which are characteristic of the Richmond in the East, are very scarce, if they occur at all, in the western Ordovician rocks. However, Jean M. Berdan recently identified *Tetradium* comparable to *T. tubifer* Troedsson from the Upper Ordovician rocks of the Tintic district, Utah. This species has a growth habit like that of *T. syringoporoides* Ulrich, a species typically developed in strata of Blackriver age in the East. The so-called single-tubed Tetradiums are possibly more widely distributed in the western Upper Ordovician rocks than collections indicate.[1] Troedsson (1928, p. 138) states that *Tetradium* is not known from the Baltic area before Late Ordovician time and that "Foerste claims that this genus did not appear in the Arctic until the Richmond."

Some of the more unusual tabulates described from Canada and the Arctic have not yet been identified in collections from western United States; it is to be expected, however, that they may eventually be found.

The fauna is best known from the Bighorn dolomite of Wyoming, but it is found from central Colorado (Fremont limestone and Tomichi limestone of Crawford (1913)) and the Black Hills of South Dakota (Whitewood dolomite) west through the Williston basin (Bighorn dolomite) to Idaho (Fish Haven dolomite, Kinnikinic quartzite, and Saturday Mountain formation) then southwest through Utah (in rocks usually called Fish Haven dolomite) into eastern Nevada (Hanson Creek formation, Ely Springs dolomite, and the lower part of the Lone Mountain dolomite of Hague, 1883) and southeastern California (Ely Springs dolomite). In west Texas and New Mexico a coral fauna with many of the same elements occurs in the Montoya limestone, and some of the same corals are reported from the Maravillas chert of the Marathon region. The Late Ordovician corals of central Texas (Duncan, 1953, p. 1037) show closer affinities with the Richmond of eastern North America. The Red River and Stony Mountain formations of Manitoba carry a coral fauna comparable to

[1] "*Tetradium* sp. nov. (occurring in small fascicles)" was reported from the Silver City area, New Mexico (Paige, 1916, p. 4). The collection containing this coral has not been located, so the identity of the coral remains unverified.

that found in the Bighorn dolomite and its equivalents. The horn corals particularly, in this widespread fauna, exhibit a stage of differentiation and complexity that it seems unlikely could have been attained by Middle Ordovician time. In any event, the horn corals are distinctly different from those characteristic of the type Trenton group in Eastern United States.

The lower Upper Ordovician rocks (Eden and Maysville groups) of the Cincinnati region are not coral bearing. This circumstance is one of several that has made it difficult to evaluate the age significance of Ordovician coral assemblages developed in other areas. Genera and species have been interpreted too loosely. Names applied to museum specimens and cited in faunal lists give very misleading ideas about actual morphologic features, variation within taxa that constitute good species, and stratigraphic ranges of generic and specific categories. Specimens that have been carelessly lumped in such "species" as *Columnaria alveolata*, *Streptelasma corniculum*, and *Halysites catenularius* obviously can be segregated into more precisely defined categories that have some stratigraphic significance. Studies of the morphologic complexity of the Ordovician corals in relation to their stratigraphic occurrence indicate that structural elaboration was progressive from the inception of the group in Early Ordovician time. General investigations of American Ordovician corals have led the writer to believe that the relatively diversified and advanced fauna in the lower part of the Bighorn dolomite and equivalent strata must be indicative of Late—probably early Late—Ordovician age. This conclusion, arrived at independently, coincides with recent interpretations of other students whose opinions are based on evidence from other groups of fossils (Miller, Youngquist, and Collinson, 1954; Sweet, 1954).

SILURIAN FAUNAS

Silurian rocks have a more restricted distribution and their coral fauna is not so well known as the fauna of the Upper Ordovician rocks, partly because in many localities the Silurian dolomites contain only shadows of fossils or altered specimens that show only form and little if any original structure. At some places, fortunately, coral beds or reeflike accumulations have been silicified. The Silurian age of the strata in question was originally established by the occurrence of pentameroid brachipods (Kindle, 1908a, p. 127), which not uncommonly are found with the corals or in associated beds.

Most of the collections from the Silurian rocks contain at least two and commonly three species of halysitids that are readily differentiated by the size of their corallites. Species with the largest corallites belong to *Cystihalysites* (pl. 27, figs. 3d–3f); those with small and medium-sized corallites generally are either *Cystihalysites* (pl. 27, figs. 3a–3c) or *Halysites* (*sensu stricto*) (pl. 27, figs. 2a–2c). A very few examples of *Catenipora* have been identified in the Silurian assemblages of the region, but species of that subgenus do occur. It should be noted, however, that *Halysites catenularius* (Linnaeus), sometimes cited as *H. catenulata*, as recorded in the old lists is not reliably identified. The name has been applied to at least three subgenera and several different species and is, in fact, meaningless. Smith (1930, p. 320) has commented on the confusion regarding the identity of *H. catenularius* in the European Silurian.

Several species of *Favosites* including squamulate forms (pl. 26, figs. 3a, 3b) are very common. *Heliolites* (pl. 26, figs. 5a, 5b) is another diagnostic Silurian coral—the genus, however, persists into the Devonian. *Alveolites* and cladoporoids are abundant in some faunules. At least two types of syringoporoids (possibly not *Syringopora* in the strict sense) have a rather haphazard distribution.

Among the Rugosa there are several colonial phaceloid forms that might be confused with the Ordovician *Palaeophyllum* or the Devonian disphyllids. One is *Circophyllum* (pl. 25, figs. 2a, 2b); another group has dissepiments (unlike any known Ordovician coral); and still others suggest colonial tryplasmids (compare with *Aphyllostylus gracilis* Whiteaves; see pl. 25, figs. 3a, 3b). *Pycnostylus* has not been recognized in any collections examined by the writer,[2] but solitary *Tryplasma* (pl. 23, figs. 3a, 3b) as well as *Porpites* have been identified from some localities. Other tentatively identified genera include *Entelophyllum* (pl. 23, figs. 5a–5d), *Pycnactis* (pl. 23, figs. 1a, 1b), and *Zelophyllum* (pl. 23, figs. 2a–2d). Cystiphyllids and large dissepimented horn corals of uncertain affinities (*Cyathophyllum* of the older reports) seem to be somewhat less common than small ceratoid and vermiform types (pl. 23, fig. 4). Some specimens show indications of axial structures.

The Silurian coral fauna is varied and contains many elements that are more readily comparable to those of Asia and the Baltic region than they are to corals described from the Silurian strata of eastern North America. It is to be expected that genera hitherto unrecorded on this continent will form a significant proportion of the fauna. Much of the material examined so far is inadequate for positive identification of genera and for description of species. However, any collection that contains an assemblage of several different generic types is usually adequate for determination of Silurian age.

The coral fauna reviewed here has been found at a good many localities in Idaho and Utah (Laketown dolomite), in the subsurface of the Williston basin in Montana, in Nevada (Roberts Mountains formation and Lone Mountain dolomite), and in southeastern California (Silurian part of the Hidden Valley dolomite). In the northern

[2] *Pycnostylus guelphensis* Whiteaves is reported by Waite (1953, p. 1521) from the Silurian rocks of the Inyo Mountains, Calif.

Sierra Nevada, Silurian corals occur in the Montgomery limestone and in rocks that have been regarded as the Kennett formation (see Merriam, 1940, p. 47–48, for discussion of the stratigraphic problem). Comparable faunules occur in the Fusselman limestone of the El Paso region, west Texas and New Mexico. Recent work indicates that a Silurian coral faunule containing several unusual genera occurs in the Metaline quadrangle, Washington.

It has been suggested that some of the Silurian in the New Mexico-Texas region may be older than Niagaran (Pray, 1953, p. 1913–1915) and that lower Upper Silurian may be present in California (Waite, 1953, p. 1521). Further stratigraphic and paleontologic work is needed before such problems of correlation can be settled.

CRITERIA USED TO IDENTIFY THE CORALS AND DIFFERENTIATE THE FAUNAS

HALYSITID CORALS

It has long been known that the halysitid corals are separable into two groups on the presence or absence of mesopores (interstitial corallites or tubuli). In 1941 Chernyshev (1941a, p. 36) proposed the name *Palaeohalysites* for the group lacking mesopores, restricted *Halysites* (*sensu stricto*) (pl. 27, figs. 2a–2c) to species with horizontal tabulae in corallites and mesopores, and defined a third genus (Chernyshev, 1941b, p. 70), *Cystihalysites* (pl. 27, figs. 3a–3f), for those species having vesicles in the mesopores and corallites. These categories are useful in stratigraphic paleontology, and the writer has applied the names in a subgeneric sense. Later (Duncan, 1953, p. 1037) it was recognized that the name *Palaeohalysites* had been erected for the group of halysitids typified by the genotype of *Catenipora* Lamarck, 1816. *Catenipora* (pl. 27, figs. 1a–1e) was therefore revived and applied to halysitid corals lacking mesopores. This usage was adopted without further investigation of nomenclatural problems that might be raised in connection with the selection of a type specimen for *H. catenularius* (Linnaeus), the genotype of *Halysites*. Neotypes for *Halysites catenularius* (Linnaeus) and *Catenipora escharoides* Lamarck were chosen recently (Thomas and Smith, 1954, p. 765–700). This action established the morphology of the genotypes so the two names can be used without hesitation for restricted taxa, which Buehler (1955) considers distinct genera. Buehler apparently did not know about Chernyshev's publication of the names *Cystihalysites* and *Palaeohalysites*. Fortunately, the writer's application of the names *Catenipora* and *Halysites* accords with nomenclatural usage stabilized by recent morphologic studies.

All known Ordovician halysitids belong to the subgenus *Catenipora*. *C. gracilis* Hall (pl. 27, figs. 1a–1c) is very easily recognized by its nearly rectangular corallites with straight adjoining sides. Not all species referable to *Catenipora,* however, have rectangular or polygonal corallites. The form identified as *Halysites* (*Catenipora*) aff. *H. jacovickii* Fischer de Waldheim (pl. 27, figs. 1d, 1e) from the Upper Ordovician strata of central Texas (Duncan, 1953, p. 1037) is an example of a species having fusiform corallites. Halysitids with round or elliptical corallites generally have to be sectioned before it can be determined whether mesopores are present as well as to ascertain the character of the tabulation. Nevertheless, if a collection contains two or more species of halysitids with elliptical or round corallites, the chances are that it came from Silurian rather than from Ordovician rocks.

FAVOSITID CORALS

Superficially, certain massive favistellids characteristic of the Ordovician might be confused with *Favosites* (pl. 26, figs. 1–3). In particular, the nondescript *Lichenaria* (pl. 24, figs. 4a, 4b) and *Nyctopora* (pl 24, figs. 1a, 1b), with its small corallites and short stout septa, are likely to be mistaken for favositids. Sections nearly always must be prepared before the generic identities of corals belonging to these groups can be established.

Collections or faunules consisting exclusively of *Favosites* (*sensu lato*) do not provide reliable evidence for dating the rocks. In dolomitized specimens, such features as mural pores and septal structures (spines and squamulae) are commonly obliterated or modified so that the subgenera cannot be identified with assurance. As in living corals, the form of corallum developed probably was influenced by factors of the physical environment. The persistence of certain types of favositids through two or more systems, the poor quality of preservation, and the labile nature of coralla are the principal factors that make the favositids less useful than any other form of coral in the discrimination of the Ordovician, Silurian, and Devonian dolomites in the West. If an age determination is needed, it is essential that other kinds of fossils be collected from the same or associated beds.

Favositids are scarce in most of the Ordovician collections examined; the small heads and patchy incrustations are composed of medium-sized corallites in which the mural pores are not necessarily confined to the angles of the walls as they are supposed to be in *Palaeofavosites* (pl. 26, figs. 1a, 1b). Locally, however, favositids are relatively abundant in Upper Ordovician strata, and coralla are reported to attain diameters of as much as 2 feet. The three species based on Ordovician material—*Favosites intermedius* Okulitch, *Palaeofavosites capax* (Billings), and *P. prolificus* (Billings)—all have corallites that range from 2 to 3 mm in diameter. Species with corallites of comparable size occur widely also in western Silurian strata, and favositids similar in growth form and corallite size are known in Devonian rocks.

In general favositid corals are more varied and abundant in collections from Silurian rocks than they are in older strata. Heads of considerable size as well as incrusting and branching coralla are common. Massive and laminar species characterized by corallites that are noticeably smaller (average diameter 1.5 mm) and larger (3 to 5 mm in diameter) ordinarily occur in association with the intermediate form (corallites 2 to 3 mm in diameter) mentioned above. Some species possess squamulae (pl. 26, figs. 3a, 3b), structures that are not known to have developed before Middle Silurian time. Squamulate favostitids are abundant in Devonian rocks, however, and by themselves are indicative only of post-Ordovician age.

The Silurian alveolitids, the thamnoporoids, and the reticulate and branching cladoporoids are not likely to be confused with any corals characteristic of the western Ordovician strata. Similar forms do occur, however, in the Devonian rocks of some areas in the region.

OTHER TABULATE CORALS

Poorly preserved *Heliolites* and *Calapoecia* have been and might be confused. For example, chert molds of the coral identified as *Calapoecia*? from the Fusselman(?) limestone of New Mexico (Pray, 1953, p. 1914) are generically indeterminate—but on size of the corallites, this form could be a heliolitid. Usually, however, the cribrose structure of the intercorallite areas in *Calapoecia* (pl. 26, figs. 4a, 4b) is recognizable and provides an easy means of differentiating the genus from *Heliolites* (pl. 26, figs. 5a, 5b), with its characteristic tubular reticulum and imperforate walls. According to Kirk (1927, p. 286) poorly preserved *Calapoecia* has been mistaken for *Syringopora*.

Protaraea and *Protrochiscolithus*, which occur in the western Ordovician, have been classified with the heliolitids, but they are aberrant types with skeletal structures unlike the more typical heliolitid genera of the Silurian and Devonian. A variety of peculiar so-called heliolitid genera occur in the Ordovician of Scandinavia; most of these have not been identified as yet in North American faunas. However, *Propora*, which clearly has heliolitid affinities, is reported from a good many places in the Late Ordovician of Canada and the Arctic and occurs also in western Upper Ordovician rocks. *Propora* ranges through the Silurian and cannot be relied on to differentiate the two faunas.

Syringopora in the strict sense does not occur in Ordovician faunas. The unusual Ordovician tabulates *Arcturia* and *Labyrinthites* are generally classed with the syringoporoid corals. These genera, which are probably synonymous, are based on specimens from Arctic America; they have not yet been reported from western United

States but probably will be found. A supposed syringoporoid comparable to *Reuschia* has been found in a few Ordovician assemblages, but the syringoporoids as a group are scarce in Ordovician rocks.

Some of the Silurian syringoporoids have horizontal or sagging tabulae and are not assignable to *Syringopora* (*sensu stricto*); one species suggests *Syringoporella*. Internal structures are not well enough preserved in most dolomitized specimens, however, to determine the nature of the tabulae.

FASCICULATE COLONIAL RUGOSA

Phaceloid rugose corals are the forms most likely to be misidentified in these faunas. Laboratory study is required to establish details of morphology used for family or generic assignment. In the past it was common practice to identify phaceloid corals—whether they came from the Ordovician, Silurian, or Devonian—as *Diphyphyllum*, a lithostrotionoid genus that is strictly Carboniferous. In most instances, after material is sectioned, generic identities or at least general relationships can be established.

Palaeophyllum (pl. 25, figs. 1a, 1b), the diagnostic Ordovician favistellid, lacks dissepiments and an axial structure. Very large heads of this genus occur in Upper Ordovician rocks at some localities. *P. thomi* (Hall), which occurs in the Montoya limestone of the Southwest, has an incipient axial structure and is interpreted to be a phaceloid variant of *Cyathophylloides* (pl. 24, figs. 6a, 6b).

Phaceloid corals known from western Silurian strata belong to several families. Those with dissepiments may be either columnarids or primitive disphyllids. *Circophyllum* (pl. 25, figs. 2a, 2b) has no dissepiments but is distinguished by steeply inclined tabulae and septa that meet axially thereby forming a weak axial structure. Certain phaceloid forms with acanthine septa presumably belong to *Aphyllostylus* (pl. 25, figs. 3a, 3b), included in *Tryplasma* by Stumm (1952, p. 842).

CERIOID COLONIAL RUGOSA

Massive cerioid rugose corals have not been found in Silurian rocks at most western localities, but the form Merriam (1940, p. 12, 48) described as *Strombodes*-like belongs to that category.

Cerioid favistellids (pl. 24) are fairly common in the Upper Ordovician rocks and generally can be recognized without much difficulty. *Cyathophylloides* (pl. 24, figs. 6a, 6b), which differs from *Favistella* (pl. 24, figs. 5a, 5b) in having a weak axial structure, might be mentioned as an exception. *Cyathophylloides*, however, has not been found at many localities.

SOLITARY AND SEMICOLONIAL RUGOSA

When dealing with well-preserved material, the differentiation of solitary corals of Late Ordovician age from those of Silurian age presents little difficulty. Streptelasmids seem to be confined to the Ordovician—some Silurian faunal lists carry the name *Streptelasma* sp., but these corals almost certainly belong to more advanced families. Ordovician corals as a group did not possess dissepiments, so any specimens exhibiting such structures immediately suggest post-Ordovician (Silurian to Permian) rocks. A single anomalous exception has been recorded as occurring in the Ordovician Kalstad limestone of Norway (Kiaer, 1932, p. 112–113). Verification of the occurrence and the relationships of this coral is needed.

The angulate coralla characteristic of so many of the western Late Ordovician streptelasmids help in discrimination of poorly preserved material. A very few examples of cuneate coralla (carinate along the cardinal and counter septa) have been seen in collections from Silurian rocks, but this particular type of angulation is uncommon if it developed in the streptelasmids—no matter how much coralla are compressed, the counter side is not carinate. Many Ordovician "Holophragmas" (commonly called *Lindströmia* in older lists) have subcalceoloid coralla and are subtriangular in cross section at least in the apical region. This Ordovician genus, however, has an axial structure and lacks the cysts characteristic of *Rhizophyllum*, the calceolid that has been recognized in the Silurian strata of the Inyo Mountains, Calif. (Waite, 1953, p. 1521), and that may turn up elsewhere. A good many of the Ordovician streptelasmids have conspicuous axial structures. At least some of these probably should be referred to *Grewingkia*, certain species of which (for example, *G. robusta* (Whiteaves), pl. 21, figs. 4a, 4b), attained very large size. *Streptelasma trilobatum* Whiteaves (pl. 21, figs. 3a, 3b), with its distinctive transverse section, is probably the most easily recognized and stratigraphically useful guide to the upper Upper Ordovician. At some localities the Ordovician rocks have yielded anomalous attached streptelasmids (compare with *Streptelasma cylindricum* Troedsson (pl. 21, fig. 2)) that might be taken for Silurian forms if they were not found with good Ordovician assemblages.

Rhabdocyclid corals, such as *Tryplasma* (pl. 23, figs. 3a, 3b) and *Porpites*, are excellent evidence for Silurian age in this region, for solitary rugose corals with acanthine septa have not been found in the Ordovician.[3] The simple coral *Pycnactis* (pl. 23, figs. 1a, 1b) seems to have a wide distribution in western Silurian rocks. It presumably appears as *Streptelasma* or *Zaphrentis* in the older lists; and, if material is poor, it might well be mistaken for a primitive *Streptelasma*.

[3] Hill (1953, p. 151–154), placed in *Tryplasma* Ordovician corals that appear to belong to *Calapoecia* and *Foerstephyllum*.

A group of nearly cylindrical or geniculate corals, with very short septa and a thick cortex, that formerly were probably identified as *Amplexus* seems to be assignable to *Zelophyllum* (pl. 23, figs. 2a–2d). Some examples of *Tryplasma*, also, undoubtedly have been called *Amplexus*.

Silurian cyathophyllids, some of them colonial with peripheral increase, have been identified tentatively as *Entelophyllum* (pl. 23, figs. 5a–5d). Cystiphyllids also are indicative of post-Ordovician age; this group, however, persists into the Devonian and is not to be relied on as certain evidence of Silurian age.

In comparing the external forms of the solitary corals in the Silurian rocks with the forms characteristic of the Ordovician, one is impressed by the large number of Silurian species that have elongate cylindrical (pl. 23, figs. 2, 3a), geniculate, or vermiform (pl. 23, fig. 4) coralla. Some show evidence of attachment (pl. 23, fig. 3a), and many show indications of asexual increase (pl. 23, figs. 5a, 5b) and rejuvenation (pl. 23, fig. 3a)—all features that are uncommon among Ordovician solitary corals. Information on characteristic growth forms has been obtained largely from silicified material etched from the matrix. Specimens so prepared commonly are not suitable for morphologic and ontogenetic studies needed to establish relationships or to identify genera. As studies progress and more extensive collections are made, however, it should be possible to place most of the western Silurian solitary Rugosa in their proper generic niches.

INTERPRETATION OF MOLDS AND CAVITY FILLINGS

The identification of corals whose former presence is indicated by molds or by tubes filled with crystalline dolomite is an important consideration in determining the age of some rocks. Commonly such traces only of organic remains are to be found in arenaceous rocks or in strongly altered dolomites. In general little can be done with molds of horn corals unless there is good stratigraphic control and the faunas are well known—then some inferences may be warranted. The molds of corals that occur in the Eureka quartzite at Cortez, Nev., are an example (see p. 175). Some of the horn corals in the Fremont limestone near Canyon City, Colo., are known from molds, but the form of the coralla and the calicular features are so distinctive that specimens can be identified as to genus.

Colonial corals with diagnostic growth forms and restricted regional distribution are, however, more likely to be useful to the stratigraphic paleontologist. Some of the smaller tubular cavities apparently represent syringoporoids. Careful observations on the spacing and diameter of the holes and the character of the connecting tubes or mode of increase with reference to known syringoporoid species, whether Silurian, Devonian, or Carboniferous, have provided clues that are stratigraphically applicable. Recent investigations suggest that such molds may be very useful where all other organic remains are lacking or destroyed. Indications of syringoporoids are rare or absent in Ordovician strata but are fairly common in the western Silurian and younger Paleozoic rocks. Utilization of these "fossils" requires, of course, considerable knowledge of the Paleozoic faunas of the region.

At some localities rocks that are known to be Silurian on other faunal evidence contain fasciculate tubular cavities somewhat larger than those characteristic of most *Syringopora*. Some of these probably represent phaceloid or dendroid colonial Rugosa. In other examples the walls have been preserved, but no other internal structures are identifiable. It is suspected that certain corals so preserved are either *Fletcheria* or a closely allied tabulate. *Fletcheria* (pl. 25, figs. 6a, 6b), which should not be confused with *Pycnostylus* (see Hill, 1940, p. 390 for details), occurs in the Silurian rocks of Alaska as well as of Gotland and a few other European localities. Silicified tubes from the Fusselman(?) limestone of New Mexico (Pray, 1953 p. 1914) identified as *Eridophyllum?* cf. *E. proliferum* (Foerste) exhibit quadripartite axial increase comparable to that of *Fletcheria* and *Pycnostylus*. Unfortunately, no trace of internal structure is preserved, so the affinities of this coral cannot be ascertained.

RECOMMENDATIONS

The stratigrapher or paleontologist concerned with the differentiation of the western early Paleozoic dolomites has at least one circumstance in his favor. Through most of the region, a considerable hiatus occurred between Upper Ordovician and Silurian rocks. The coral-bearing Devonian dolomites, which overlie the Silurian strata through much of the region, are apparently of Late Middle to early Late Devonian age. The fact that the depositional breaks were of considerable duration facilitates the work of the paleontologist, because the faunas had time to become significantly different and the problem of transitional faunas do not have to be coped with in most areas.

In spite of superficial resemblances, the western Ordovician coral faunules ordinarily can be distinguished from those of Silurian age if attention is directed to a relatively few critical features. On occasion an age assignment can be made on a single specimen, but assemblages consisting of several genera are highly desirable and commonly necessary. A geologist experienced with the faunas may be able on casual examination to distinguish Ordovician from Silurian assemblages in the field; but laboratory examination, including the preparation of oriented thin or polished sections, is ordinarily required for certain identification.

Detailed morphologic and systematic studies, not confined to western faunas, are required to clarify many nomenclatural problems. Careful stratigraphic collecting throughout the region is needed before faunal zones, which presumably exist in both the Upper Ordovician and the Silurian rocks, can be recognized. Efforts should also be made to get completely representative and extensive collections from localities where corals are comparatively well preserved so that enough material will be available for studies leading to description and illustration of these faunas.

ILLUSTRATIONS OF IMPORTANT CORALS IN WESTERN ORDOVICIAN AND SILURIAN FAUNAS

The accompanying plates illustrate a number of corals that either have not been described and figured in American publications or that are inadequately figured and not well understood. To facilitate comparisons and to clear up some current misapprehensions, illustrations of a good many other corals are also presented. Such corals as *Halysites*, *Calapoecia*, *Favosites*, and *Heliolites* should be recognized by anyone who has studied invertebrate paleontology, but they have been misidentified in the past and probably will give trouble in the future.

No attempt was made to illustrate all the diagnostic Ordovician and Silurian corals known in western faunas. Some forms are uncommon; others are hardly subject to misinterpretation. The alveolitids, cystiphyllids, disphyllids, syringoporoids, *Porpites*, *Pycnostylus*, *Tetradium*, and other corals mentioned in the discussion are treated to some extent in readily available texts. More attention has been paid to the Ordovician faunas because they contain more corals with which the average geologist is not familiar. The writer believes it is unlikely that the more advanced Silurian and Devonian corals will be mistaken for Ordovician forms once the critical differences are understood.

It is not the purpose of this paper to describe individual species. A few that are particularly useful in stratigrapihic work (for example, *Streptelasma trilobatum* and *Halysites* (*Catenipora*) *gracilis*) are briefly discussed and illustrated. But for the most part emphasis is placed on larger categories—species groups, subgenera, or genera. As far as possible, however, the illustrations are based on species that occur in or are closely related to species found in the western faunas. The principal differences between Ordovician and Silurian coral faunas and the critical features that can be used for stratigraphic purposes are mentioned without going into technicalities any more than necessary. The use of some morphologic terminology was unavoidable. Most of these terms are defined in American textbooks or are self-explanatory. A few less well known terms are explained in the comments about the corals given on the plate explanations. These comments are by no means diagnoses or complete descriptions of the corals referred to. In many instances, really critical features (for example, septal structure), which are of fundamental importance in classification, are not mentioned at all. Preservation of most of the western Ordovician and Silurian corals is such that minute details of skeletal structure were destroyed. The paleontologist must depend, therefore, on those characters that can be observed, such as shape and curvature of coralla, growth forms, peculiarities of septal development and arrangement, axial structures if any, attitude of the tabulae, and type of asexual increase in colonial forms.

The illustrations are semidiagrammatic. They are intended to portray general concepts rather than individual specimens. Especially diagnositic features are emphasized. Structures not essential for the recognition of genera, subgenera, or species groups (for example, septal spines in the halysitids and tabulae in the streptelasmids) are not shown. Most of the illustrations are composite interpretations based on suites of specimens, thin and polished sections, and published figures.

External features of the solitary and semicolonial rugose corals (pls. 21–23) are illustrated at natural size. The student is warned, however, to place no great reliance on size at the generic or species-group level. In some instances it was expedient to illustrate small forms—the figures of *Grewingkia robusta* (pl. 21, figs. 4a, 4b), for example, are based on specimens that are only about half the size attained by some individuals in the species. On the other hand, the figures of *Streptelasma trilobatum* (pl. 21, figs. 3a, 3b) are based on exceptionally large specimens; most specimens referable to this species do not exceed an inch or so in length. Following customary American practice, views of calices and transverse sections of the horn corals are oriented with the cardinal septum, if distinguishable, at the bottom of the figure.

Coralla of the strictly colonial rugose and tabulate corals are not figured because sections are nearly always required for identification of the genera. Except for the halysitids for which transverse sections showing the corallites at natural size are figured (pl. 27, figs. 1b, 1d, 2b, 3b, 3e), all the transverse and vertical sections of colonial corals are magnified two times or more. In using these illustrations, one must keep in mind that the average diameter of corallites is one of the specific characters in massive cerioid and phaceloid corals. Considerable range in size is to be expected within a genus.

In a review of this sort, it was thought inadvisable to go into the controversial matter of a classification for the early Paleozoic corals. The groupings used by Bassler (1950, p. 255–276) for the Ordovician corals seem to the writer to be more natural than those used by Hill (1951, p. 8–13). *Lichenaria*, *Eofletcheria*, *Nyctopora*, and probably *Calapoecia* are considered to be more closely related to the rugose (tetracoral) line than they are to the Tabulata, the order in which they are placed by Hill. *Palaeophyllum*, which Hill (1951, p. 13) includes in the family Streptelasmidae, is interpreted by Bassler (1950, p. 274) and the writer to be a favistellid. The assignment of these primitive corals to any particular family depends on personal experience and is more subjective than objective. None of the classifications for the Paleozoic Rugosa offered in recent years is very satisfactory. For this reason the writer has avoided using formal family names. Adjectives and nominatives derived from well-known generic names are used to indicate relationships where necessary.

In assembling the plates, no particular attempt was made to arrange the illustrations according to any scheme of classification. To emphasize the more easily recognizable differences between Ordovician and Silurian corals, the illustrated material was segregated by growth form and by stratigraphic occurrence. Wherever possible, categories that have been or that are likely to be mistaken for each other are figured on the same plate.

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PLATES 21–27

PLATE 21

[All figures natural size]

Streptelasma aff. S. latusculum (Billings)

Figures 1a, 1b

The corallum of this species is erectly trochoid in form. Expansion is gradual, and the corallum does not become cylindrical in adult stages. The calyx is fairly deep. Illustrations of *S. latusculum* indicate that Billings' species has a moderately well developed axial structure. In this western species, which resembles *S. latusculum* in form and size of corallum, the axial structure is extremely weak or nonexistent. Corals of this sort are probably the forms identified as *Streptelasma rusticum* in older reports. Actually, *S. rusticum* has a complicated axial structure and is closely related to *Grewingkia robusta* (figs. 4a, 4b). The illustrations are based on specimens, which are about the largest examples known, collected from the top of the Bighorn dolomite. FIGURE 1a, view of the cardinal side of the corallum. 1b, diagrammatic view of the calyx, showing the long, thin cardinal septum, the short minor septa, and the long major septa that meet axially, some being slightly twisted.

Streptelasma aff. S. cylindricum Troedsson

Figure 2

Streptelasmas with a broad basal area for attachment have been found in some collections from Upper Ordovician rocks but are less common than free coralla. The form illustrated has a very deep calyx, and the primary septa are not easily distinguishable. The illustration is based on specimens from the Upper Ordovician rocks of British Columbia. FIGURE 2, an alar view of the corallum, showing the broad irregular roots at the base and the nearly cylindrical form.

Streptelasma trilobatum Whiteaves

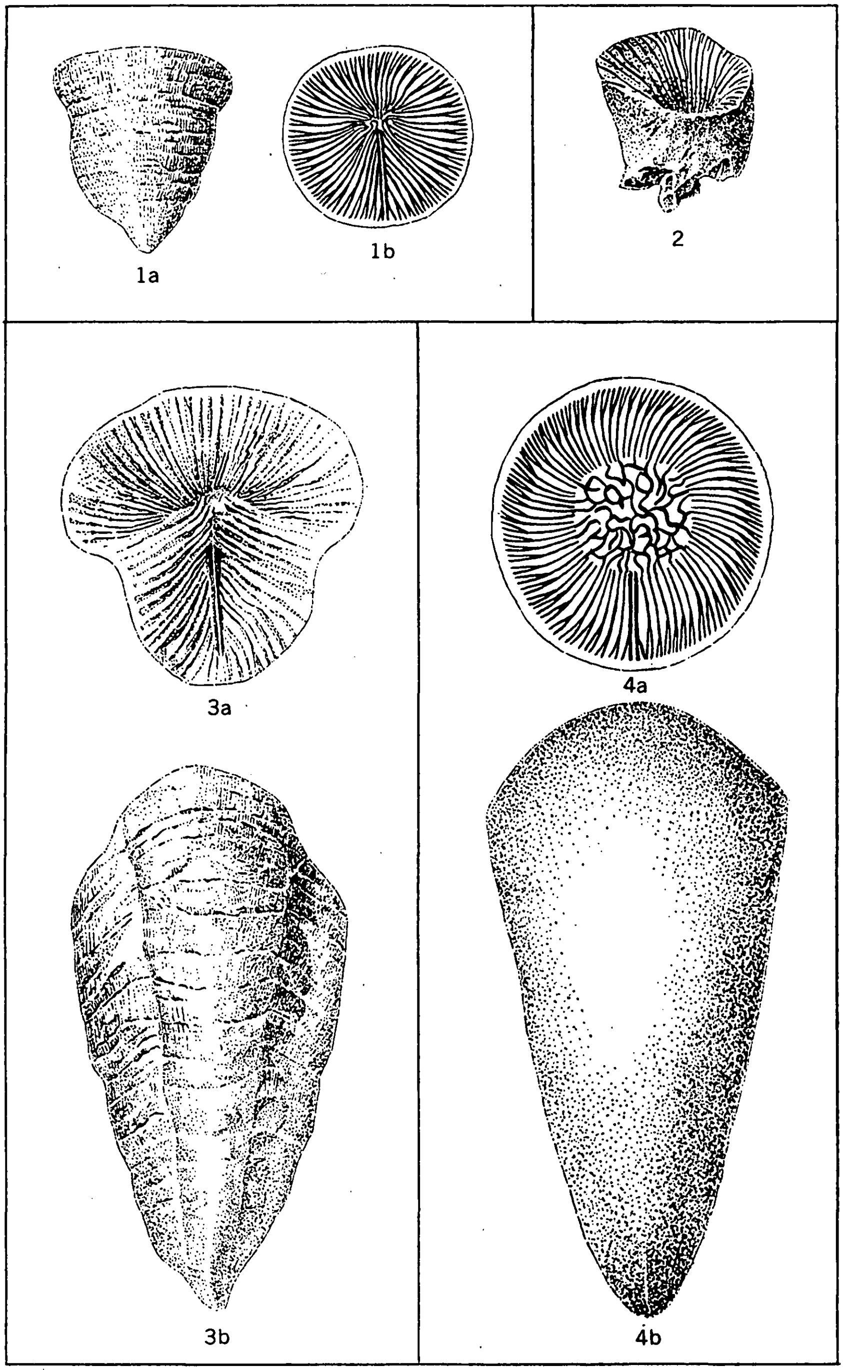
Figures 3a, 3b

As in most species of *Streptelasma*, the cardinal side of the corallum is convex and the counter side is concave. Carination is developed for a few millimeters along the cardinal septum at the apical end, but the cardinal lobe is rounded distally. The corallum is constricted along the alar septa so that the cross section in adult stages is bilobate. The cardinal septum is long and thin and extends to the axial region. This species does not have a *Grewingkia*-like axial structure; the major septa meet in the axial region and, in some specimens, twist slightly. The illustrations are based on some of the largest known specimens, collected from the top of the Bighorn dolomite. FIGURE 3a, diagrammatic view of the calyx, showing arrangement of the septa. 3b, view of the convex cardinal side of the corallum.

Grewingkia robusta (Whiteaves)

Figures 4a, 4b

This is the largest horn coral known in the Upper Ordovician rocks of the West. The corallum is curved trochoid in shape and convex on the cardinal side. Carination is developed along the cardinal septum for a few millimeters in the apical region. The corallum gradually expands in diameter; it does not become cylindrical as does the common Richmond species *Grewingkia rustica* (Billings) [= *Streptelasma rusticum* of common usage]. Axial structures are similar in both species. The disrupted axial parts of the major septa anastomose, dilate, and combine with up-arched tabulae to form an axial boss in the calyx. The illustrations are based on small to medium-sized specimens from the Selkirk limestone of Manitoba and from the lower part of the Bighorn dolomite of Wyoming. The species is known to attain a length of at least 7 inches measured along the convex side. FIGURE 4a, diagrammatic transverse section near the base of the calyx. 4b, view of the convex cardinal side of a small corallum.



NONANGULATE ORDOVICIAN STREPTELASMID CORALS

PLATE 22

All figures natural size except where otherwise indicated]

"Holophragma"

Figures 1a–1c

Corals belonging to this genus have subcalceoloid coralla, at least in the earliest growth stages. The counter side of the corallum is convex and commonly somewhat flattened. The cardinal side is concave and in many forms is subangular along the trace of the cardinal septum. The coralla are markedly angulate along the traces of the alar septa especially in the early stages. Transverse sections are subtriangular in some species. Others have cross sections that are essentially circular in adult stages, and still other species are extremely elongate in the plane of the alar septa and the transverse sections are crescentic. An axial structure is conspicuous in most species; the counter septum is dominant and commonly dilated at the axial end to form a solid columella. Unlike the other streptelasmid corals illustrated, the cardinal septum is aborted and the cardinal fossula is conspicuous. The illustrations are based on material from the top of the Bighorn dolomite and from the Stony Mountain formation in Manitoba. FIGURE 1a, view of a corallum from the alar side showing angulation along the alar septum and the curvature of the corallum—convex on the counter side, concave on the cardinal. 1b, view of the concave cardinal side showing calyx obliquely. 1c, diagrammatic transverse section showing the subtriangular outline, the short cardinal septum, fossula, and columella.

Streptelasma aff. S. prolongatum Wilson

Figures 2a, 2b

Streptelasmids belonging to this species group are angulate only along the trace of the cardinal septum. Transverse sections through adult coralla are ovate. Coralla are convex on the cardinal side. The cardinal septum is long and thin, and the cardinal fossula is commonly inconspicuous. Most of the specimens that belong to this category have a slightly raised elongate axial structure. The illustrations are based on a suite of specimens from the Kinnikinic quartzite. FIGURE 2a, diagrammatic view of a calyx in which the axial structure is dominated by the counter and cardinal septa. 2b, view of the convex cardinal side of a corallum.

Streptelasma aff. S. goniophylloides Teichert

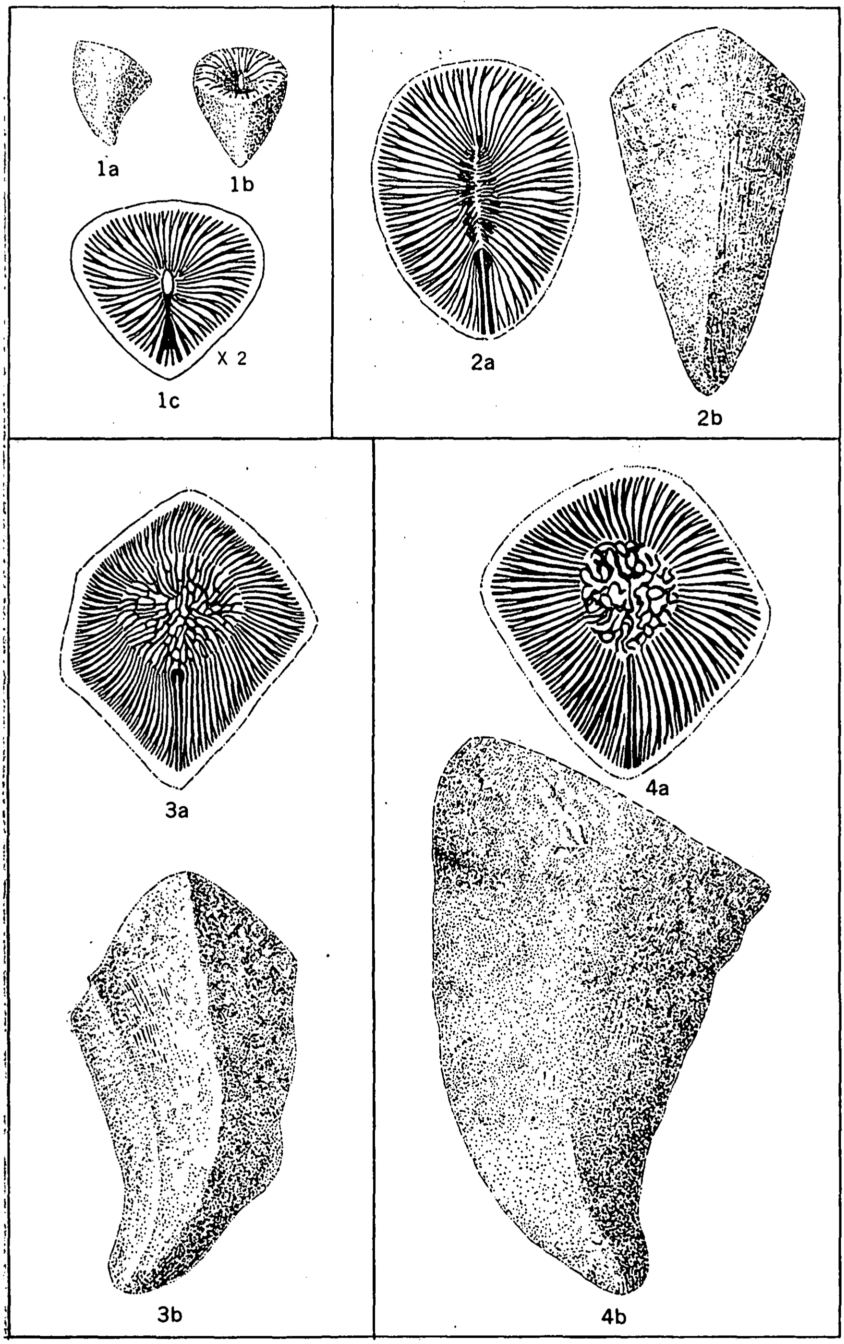
Figures 3a, 3b

Species of this group are strongly angulate along the cardinal and alar septa. Angulation of the counter side is less well defined on the outside of the corallum, but transverse sections are more distinctly polygonal than those in other species groups. The corallum is convex on the cardinal side of the corallum, but curvature is less symmetrical with reference to the cardinal-counter plane than the curvature of other nonattached streptelasmids. The cardinal septum is long and thin. Some forms have a very conspicuous axial structure comparable to that characteristic of *Grewingkia*. The illustrations are based on specimens from the base of the Bighorn dolomite. This particular species has an axial structure that is even more prominent than the kind developed in *Grewingkia robusta* (pl. 21, fig. 4a), but the septa are less disrupted and tend to rotate as in an axial vortex. FIGURE 3a, diagrammatic transverse section through the base of the calyx. 3b, view of the convex cardinal side of a corallum, showing at the left the strong angulation along one of the alar septa; the other alar angle outlines the right side of the figure.

Streptelasma aff. S. foerstei Troedsson

Figures 4a, 4b

Many of the corals that belong to this group attain considerable size. The cardinal side of the corallum is convex and strongly angulate. The alar angles are somewhat less sharp at least in ephebic stages. Curvature of the counter side is concave. Carination is not developed along the counter septum, and the counter side is rounded in transverse section. Diameters measured in the alar plane and in the cardinal-counter plane are about equal. The cardinal septum is long but more delicate than the other major septa. Many of the forms belonging to this species group have moderately to highly complicated axial structures—compare with *Grewingkia*. Illustrations are based on material from the Selkirk limestone of Manitoba and from Upper Ordovician rocks of Arctic America. FIGURE 4a, diagrammatic transverse section through the base of the calyx, showing an axial structure of the *Grewingkia* type. 4b, view of a corallum from an alar side, showing convex curvature of the cardinal side (at left) and concave curvature of the counter side (at right). This is a fairly large specimen.



ANGULATE ORDOVICIAN STREPTELASMID CORALS

PLATE 23

[All figures natural size except where otherwise indicated]

Pycnactis

Figures 1a, 1b

Most of the corals that belong to this genus are small or medium sized. Typically the cardinal side is convex and the counter is concave. The calyx is deep, and transverse sections are circular. The cardinal septum is long and is the dominant septal element in the calyx. The counter septum is not noticeably different from other major septa in the counter quadrants. The major septa are excessively dilated and fill up the corallum from the apex to the floor of the calyx. Tabulae are not developed. Silurian corals that appear to belong to *Pycnactis* have been identified from several localities in the West. As the western material is embedded in dolomite, the illustrations are based on material from Gotland and England. FIGURE 1a, view of the concavely curved counter side of the corallum. 1b, transverse section just above the floor of the calyx, showing characteristic dilation of the septa.

Zelophyllum

Figures 2a–2d

This genus was described for Silurian corals having very short strongly dilated septa, approximately horizontal tabulae, and no dissepiments. *Zelophyllum* has continuous rather than acanthine septa. The principal obvious difference between *Zelophyllum* and *Tryplasma* is the septal structure; tabulation in the two genera is similar, and species are likely to have comparable growth forms. Corals with very short contiguous and continuous septa found in a number of Silurian assemblages have been assigned to *Zelophyllum*. Although the genus has been recognized in Europe and Asia, the external features of coralla have not been described. The accompanying illustrations are based on material from Gotland, China, and Utah. FIGURE 2a, diagrammatic transverse section showing thick cortex formed by the short dilated septa. 2b, diagrammatic vertical section showing nature of tabulation. 2c, fragment of a corallum that presumably was solitary. This specimen came from China; it is somewhat weathered and shows no indications of an epitheca. Smaller fragments of a larger *Zelophyllum* collected in the Laketown dolomite of Idaho have an epitheca; therefore it seems likely that the deposit was removed by weathering. The specimen was considerably longer originally than the segment figured here. 2d, fragments of weathered and silicified corallites that appear to have been elements in a fasciculate corallum. This material was found in the Silurian rocks of Utah and is closely related to the genotype of *Zelophyllum*, *Z. intermedium* Wedekind.

Tryplasma

Figures 3a, 3b

Trochoid, ceratoid, and cylindrical forms of *Tryplasma* are fairly common in the western Silurian rocks. The genus is distinguished by its acanthine septa. Illustrations are based on material from Nevada and California. FIGURE 3a, side view of a nearly cylindrical corallum that shows periodic rejuvenation and, in the apical region, the talons by which it was attached. 3b, small trochoid corallum.

Vermiform corallum, gen. indet.

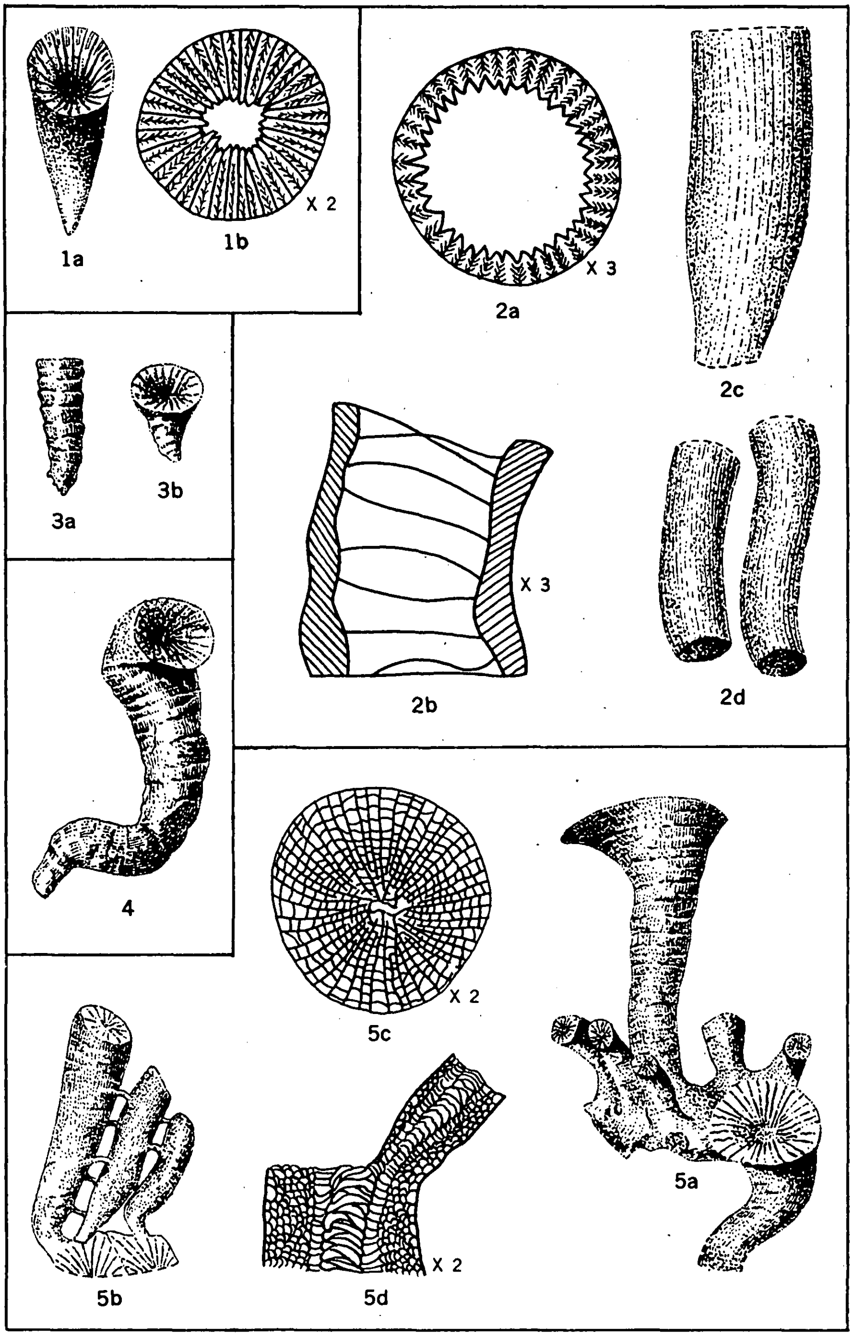
Figure 4

Vermiform and geniculate coralla are common in western Silurian faunas but are not known in the Ordovician. The specimen illustrated came from California; it has continuous septa, but other morphologic structures are not well enough preserved to establish its relationships.

Entelophyllum

Figures 5a–5d

This cyathophyllid coral is commonly colonial though solitary coralla have been assigned to the genus. Corallites of *Entelophyllum* have a peripheral dissepimentarium composed of imperfectly globose dissepiments. A tabularium, with approximately horizontal tabulae, occupies the axial part of the corallite. The illustrations are based on material from the Roberts Mountains formation of Nevada and from the European Silurian. FIGURE 5a, fragment from a compound corallum. The trumpet-shaped and cylindrical corallites proliferated asexually from the dissepimentarium of a parent corallite (peripheral increase). 5b, another fragment from a corallum of the same species shown in fig. 5a. The asexually reproduced corallites are nearly cylindrical in shape and are joined by connecting processes. 5c, diagrammatic transverse section through the upper part of a corallite showing the broad dissepimentarium. 5d, median vertical section through a parent corallite and offset, showing the axial tabularium and the broad peripheral dissepimentarium.



CHARACTERISTIC SILURIAN RUGOSE CORALS

PLATE 24

Nyctopora

Figures 1a, 1b

This genus has a massive corallum composed of relatively small prismatic (cerioid) corallites. Septa are very short and develop in a primary series of 8, then a secondary and alternating series of 8. In mature parts of the corallites, the 16 septa are all the same length. Mural pores do not occur. Tabulae are essentially horizontal and periodically are more closely spaced, a feature probably related to seasonal growth rather than a diagnostic generic character. The illustrations are based on Bassler's figures of *Nyctopora billingsi* Nicholson and on specimens from the Upper Ordovician rocks of Texas. FIGURE 1a, vertical section. 1b, transverse section.

Saffordophyllum

Figures 2a, 2b

Species assigned to this genus differ from those of *Nyctopora* in having 8, 12, or 20 septa, which are widely spaced and very short. The tabulae tend to be more closely spaced than in *Nyctopora*, and some species have much larger corallites than are known in *Nyctopora*. The illustrations were adapted from Bassler's figures of *Saffordophyllum franklini* (Salter), an Arctic species. FIGURE 2a, vertical section. 2b, transverse section.

Foerstephyllum

Figures 3a, 3b

This genus is interpreted to be a forerunner of *Favistella*, from which it differs significantly only in having shorter septa. There are normally 24 or more septa. Tabulae are horizontal and tend to be more crowded in zones. Mural pores are wanting. Illustrations were adapted from Bassler's figures of *Foerstephyllum simplissimum* (Okulitch). FIGURE 3a, transverse section. 3b, vertical section.

Lichenaria

Figures 4a, 4b

This genus is characterized by its very simple structure. The prismatic corallites are not pierced by mural pores. There are no septa. Tabulae are horizontal. The illustrations are based on an undetermined species with unusually large corallites, occurring in the Tank Hill limestone of the Pioche district, Nevada. FIGURE 4a, transverse section. 4b, vertical section.

Favistella

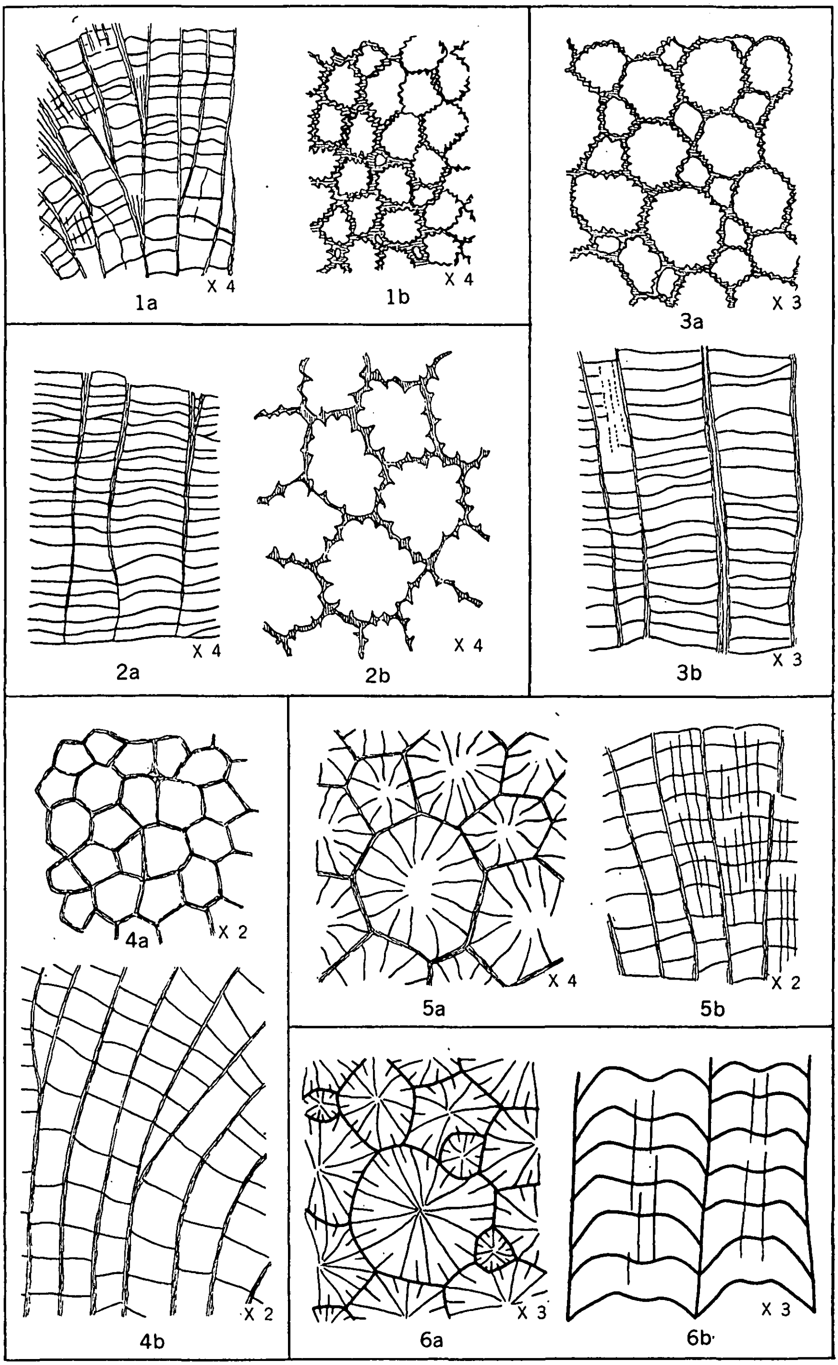
Figures 5a, 5b

The septa of *Favistella* are considerably longer than those of *Foerstephyllum*; in other respects, the two genera are very similar. Most species have 12 or more major septa; alternating minor septa occur in many forms. The illustrations were adapted from Bassler's figures of *Favistella undulata* Bassler. FIGURE 5a, transverse section 5b, vertical section.

Cyathophylloides

Figures 6a, 6b

This genus differs from *Favisteila* in having major septa that meet at the center of the corallites and produce an incipient axial structure. Tabulae are not horizontal in a true median section—the peripheral margins are turned down and the axial part is depressed. *Palaeophyllum thomi* (Hall) from the Montoya limestone of Texas is a phaceloid version of *Cyathophylloides*. The illustrations are based on material from the Burnam limestone of Texas and the Hanson Creek formation of Nevada. FIGURE 6a, transverse section. 6b, median vertical section.



MASSIVE CERIOID ORDOVICIAN FAVISTELLID CORALS

PLATE 25

Palaeophyllum

Figures 1a, 1b

This genus is a phaceloid derivative of *Favistella*. Tabulae are nearly horizontal, and in most species the septa do not reach the center of the corallites. In *P. thomi* (Hall)—from the Montoya limestone of Texas—the major septa do meet at the axis, and the tabulae are like those of *Cyathophylloides* (pl. 24, fig. 6b). The illustrations are based on material of Late Ordovician age from Utah. FIGURE 1a, transverse section showing minor septa alternating with the major septa. 1b, vertical section showing nature of the tabulation. The longitudinal lines crossing the tabulae are traces of the septa.

Circophyllum

Figures 2a, 2b

In this phaceloid Silurian genus the major septa meet and twist slightly at the center of the corallites. The tabulae are tent shaped, a feature that can be seen only in a median vertical section. Weathered surfaces exhibit a slight but persistent axial structure. The coral has no dissepiments. Asexual increase is peripheral and parricidal. The illustrations are based on specimens from the Silurian rocks of Utah, which closely resemble the Gotlandian genotype. FIGURE 2a, transverse section showing the major septa joining at the center. 2b, vertical section through two corallites showing, in the upper half, the tent-shaped tabulae as they appear in a true median section. The lower part of the illustration shows the more nearly horizontal attitude of the tabulae and the traces of the septa where the section does not cut the center of the corallites. Sections that are off center are misleading because they suggest a dissepimented coral.

Aphyllostylus

Figures 3a, 3b

Colonial tryplasmids with small phaceloid corallites had a worldwide distribution during the Silurian. They are distinguished from other phaceloid corals by their acanthine septa and conspicuously slanting tabulae. *Aphyllostylus* has been considered a synonym of *Tryplasma*, but the phaceloid form deserves subgeneric status. The illustrations are based on material from the Silurian rocks of Washington which closely resembles species occurring in Australia and China. FIGURE 3a, transverse section showing acanthine septa. 3b, vertical section showing slanting tabulae and acanthine septa.

Eofletcheria

Figures 4a, 4b

This early Ordovician coral has tubular corallites with widely spaced horizontal tabulae and no septa. *Eofletcheria* was contemporaneous with *Lichenaria* but was probably derived from the cerioid coral. Asexual proliferation was by lateral increase. The illustrations are based on material from the upper part of the Pogonip group of Nevada. FIGURE 4a, vertical section. 4b, transverse section.

Lichenaria, semiphaceloid variant approaching Eofletcheria

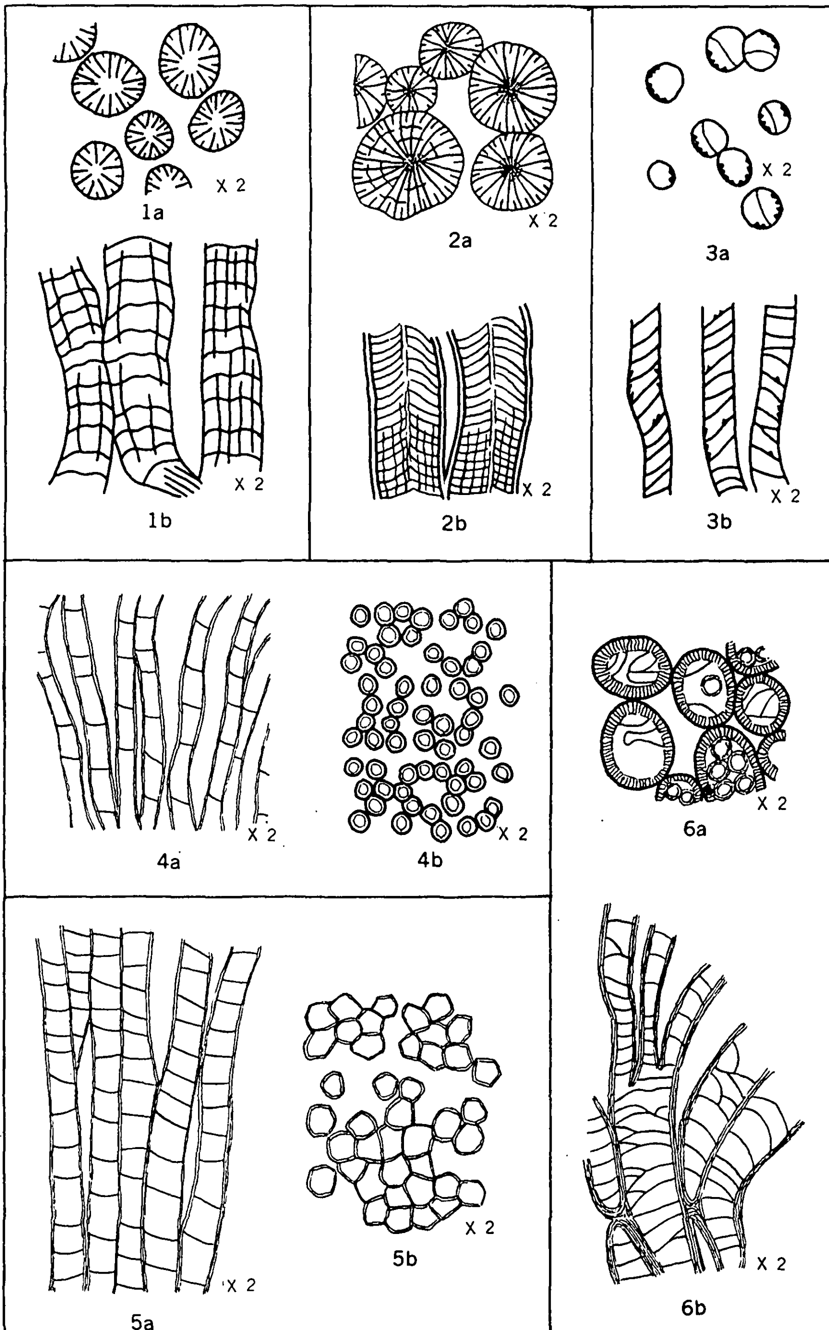
Figures 5a, 5b

This form has the same characters as cerioid Lichenarias (pl. 24, figs. 4a, 4b). Most of the corallites are in contact and have polyhedral cross sections, but some become free and tend to have circular sections like *Eofletcheria*. Tabulae are moderately abundant. Neither septa nor mural pores are developed. The illustrations are based on material from the Tank Hill limestone of the Pioche district, Nevada. FIGURE 5a, vertical section. 5b, transverse section.

Fletcheria

Figures 6a, 6b

This genus has thick walls whose structure resembles that found in the syringoporoid corals. Tabulae range from horizontal to cystose. Septa and septal spines seem to be absent. Asexual proliferation was by calicular increase and characteristically was not quadripartite as in *Pycnostylus*, which some workers have erroneously considered to be the same as *Fletcheria*. The illustrations are based on thin sections of the genotype, *F. tubifera* Milne Edwards and Haime, from the Silurian rocks of Gotland. FIGURE 6a, transverse section showing strongly thickened walls and calicular "buds." 6b, vertical section showing a corallite splitting into several individuals.



MASSIVE FASCICULATE GENERA OF ORDOVICIAN AND SILURIAN CORALS

PLATE 26

Favosites (Palaeofavosites)

Figures 1a, 1b

Favositid corals in which the mural pores are confined to the angles of junction between corallites were designated *Palaeofavosites* by Twenhofel. Investigators who based their opinions on studies of large suites of specimens of the genotype claim that mural pores are not always restricted to the angles; however, the category seems useful for a subgeneric rank. Some, but not all, Ordovician favositids belong to *Palaeofavosites*. Commonly, mural pores are not abundant. Septal spines occur in some species but are not shown here. The illustrations were adapted from Ting's figures of a nonseptate form of *Favosites asper* Orbigny, the genotype of *Palaeofavosites*. FIGURE 1a, transverse section. 1b, vertical section.

Favosites (Favosites)

Figures 2a, 2b

"Typical" *Favosites* has nearly horizontal tabulae and mural pores that perforate the flat sides of the corallite walls. Septal spines are present in many species and are illustrated here. The illustrations were adapted from Ting's figures of *Favosites hisingeri* Milne Edwards and Haime. FIGURE 2a, transverse section. 2b, vertical section.

Favosites (Squameofavosites)

Figures 3a, 3b

This subgenus differs from *Favosites*, in the strict sense, in having squamulae (septal spines modified into irregular linguliform or wavy transverse structures) that replace the septal spines entirely or in part. Tabulae are present but tend to be somewhat irregular. The end result of this evolutionary trend is *Emmonsia* in which squamulae are so excessively developed that they take the place of the tabulae. Chernyshev (1941a, p. 24–25) proposed *Squameofavosites* as a genus, but most students have included favositids possessing both squamulae and tabulae in *Favosites*. *Squameofavosites* seems applicable for a subgeneric category. Squamulate favositids are not known before Middle Silurian time. The illustrations were adapted from Chernyshev's figures of *Squameofavosites hemisphaericus bohemicus* (Pocta), the genotype. FIGURE 3a, transverse section showing linguliform squamulae. 3b, vertical section showing squamulae and irregular tabulae.

Calapoecia

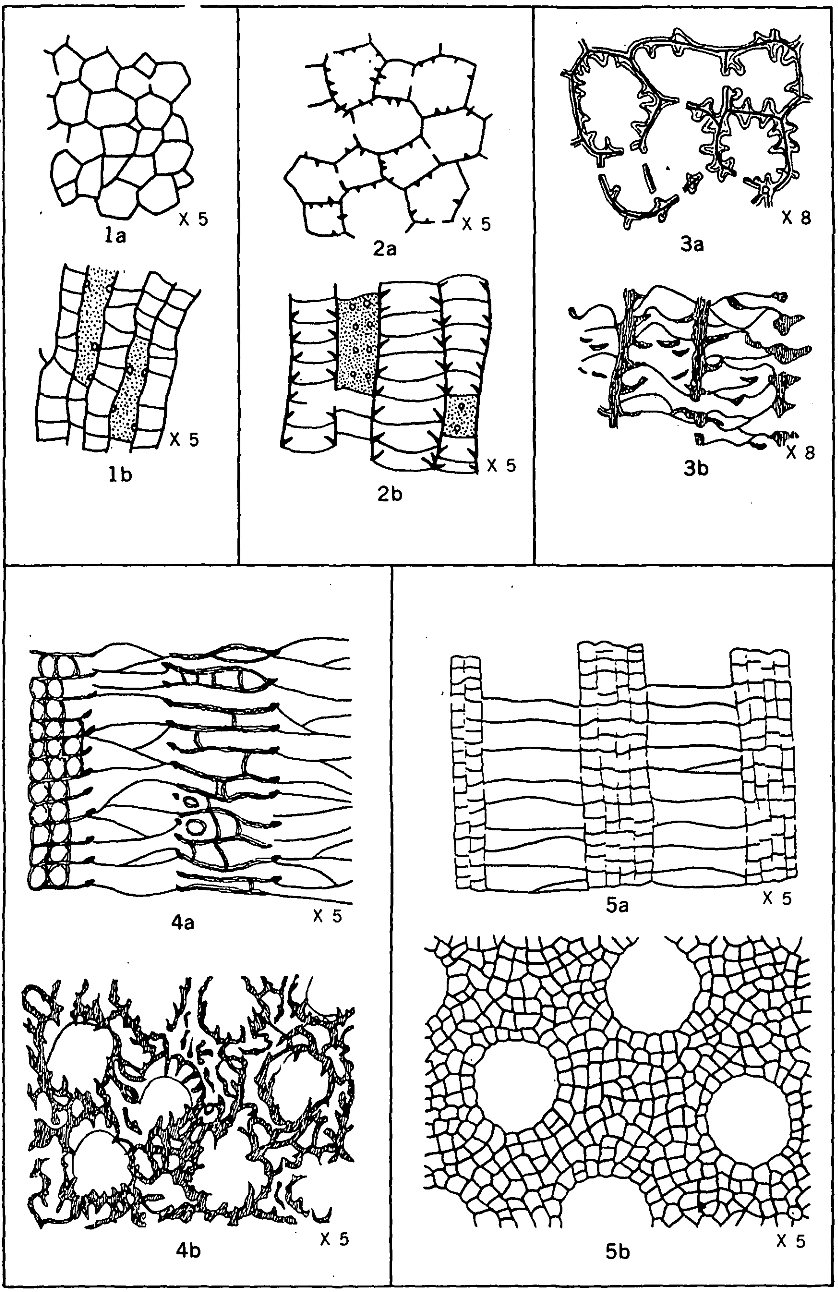
Figures 4a, 4b

The systematic position of *Calapoecia* is uncertain; some consider it an aberrant tabulate coral; others believe it is a derivative of the favistellids. The genus includes species in which the corallites are prismatic and not separated by interstitial deposits as well as forms with cylindrical corallites that are separated by "coenenchyme." Most of the western forms seem to belong to the latter category, which is illustrated here. *Calapoecia* has 20 short wedge-shaped septa that arise periodically from the septal ridges. The corallite walls are regularly perforate (cribrose). The illustrations are based on thin sections of *C. anticostiensis* Billings, the genotype. In this species the septa project as short spines into the corallites and extend into the intercorallite areas as somewhat irregular processes called costae. Tabulae in the corallites are irregular. Intercorallite spaces are crossed by thickened transverse elements called diaphragms, which with costae and vesicles form the so-called coenenchyme. FIGURE 4a, vertical section showing at the left the cribrose structure formed by intersection of costae with diaphragms near the corallite wall. A median section through intercorallite "coenenchyme" is shown at center right separating two corallites; the thickened transverse elements are diaphragms, the vertical elements are remants of costae or vesicles. 4b, transverse section showing the spinose septa with their costal processes, which are partly disrupted in the intercorallite areas.

Heliolites

Figures 5a, 5b

The skeletal morphology of *Heliolites* differs conspicuously from that of *Calapoecia*. The tabularia (macrocorallites) are separated by a reticulum of tubuli (microcorallites). The tabularia have well-defined walls and are crossed by complete tabulae. The tubuli are crossed by transverse plates called sola. There are no mural pores or perforations. Septa, when present, always number 12; they may be lamellar or spinose. The illustrations were adapted from Amsden's figures of *Heliolites spongiosus* Foerste, a Silurian species that lacks septa. FIGURE 5a, vertical section showing two tabularia and the adjoining tubuli. 5b, transverse section showing nature of the reticulum surrounding the tabularia (macrocorallites).



FAVOSITES, CALAPOECIA, AND *HELIOLITES*

PLATE 27

[All figures natural size except where otherwise indicated]

Halysites (Catenipora)

Figures 1a–1e

The compound coralla of *Halysites* are formed by small tubular corallites united in single series that intersect or anastomose with other chains. *Catenipora* differs from the other subgenera in lacking mesopores (interstitial corallites or tubuli). The corallites have horizontal tabulae. Septal spines—in cycles of 12—are present in many of the species referable to *Catenipora* but are not illustrated here. Mural pores are not developed. The illustrations are based on material from the Upper Ordovician part of the Bluebell dolomite of Utah and from the Burnam limestone of Texas. FIGURE 1a, vertical section of *Halysites* (*Catenipora*) *gracilis* Hall. 1b, transverse section through part of a corallum of *C. gracilis*, showing the nearly quadrangular shape of the corallites and the nature of the meshwork. 1c, transverse section of two corallites of *C. gracilis*, showing comparative thinness of the walls with reference to the size of the corallites. 1d, transverse section through part of the corallum of *Halysites* (*Catenipora*) cf. *C. jacovickii* Fischer de Waldheim, showing the very small corallites and the fine meshwork. The meshes are formed by very few corallites, only three or four in many instances. 1e, transverse section showing the fusiform corallites of *Catenipora* cf. *C. jacovickii*. The walls are comparatively thick. Rosettelike spots at the junctions of corallites suggest mesopores, but thin sections show that these spots are actually solid deposits in which the fibers are oriented at angles to the fibrous material of the corallite walls.

Halysites (Halysites)

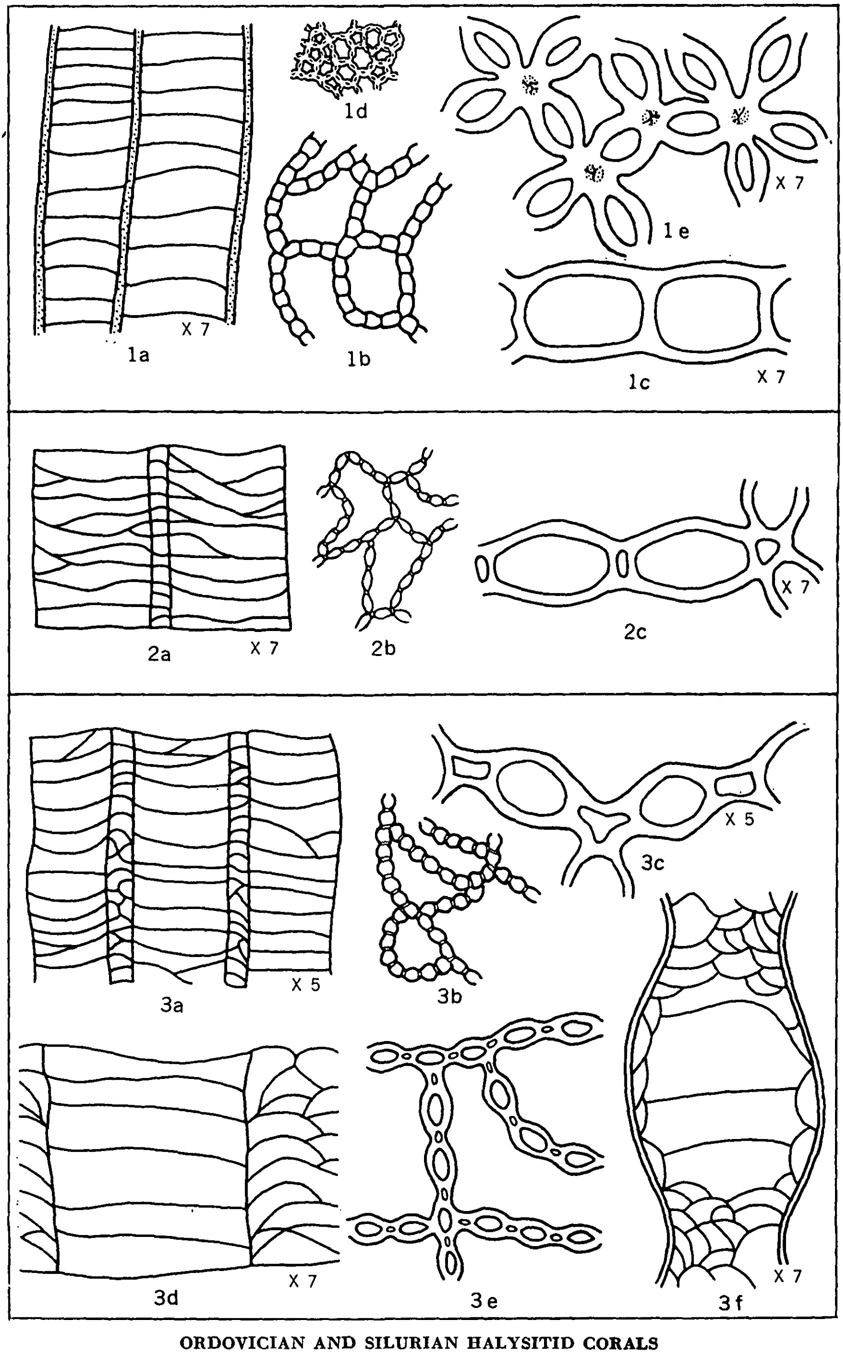
Figures 2a–2c

This section of the genus has mesopores between the corallites, which commonly are oval in transverse section. Tabulae are horizontal in the mesopores but may be somewhat flexuous in the corallites. Septal spines occur in most species but are not shown in the accompanying figures because they have no bearing on the recognition of the subgenus. Illustrations are based mainly on material from the Gotlandian of Europe and figures published by Fischer-Benzon. FIGURE 2a, vertical section, showing nature of tabulation in corallites and mesopores. 2b, transverse section through part of a corallum, showing oval corallites separated by mesopores. 2c, transverse section through two corallites.

Halysites (Cystihalysites)

Figures 3a–3f

Cystihalysites also has mesopores but differs from *Halysites* (*sensu stricto*) in having cystose tabulae in the mesopores and, in some species, lining the corallites. Septal spines occur in some species but are not shown here. Illustrations are based on material from the Silurian rocks of Utah and California and on figures published by Amsden and Chernyshev. FIGURE 3a, vertical section showing nature of tabulation in *Halysites* (*Cystihalysites*) aff. *C. brownsportensis* Amsden. 3b, transverse section through part of corallum of *Cystihalysites* aff. *C. brownsportensis*, showing nearly circular corallites separated by small mesapores. 3c, transverse section of a few corallites of *Cystihalysites* aff. *C. brownsportensis*. 3d, vertical section of a species of *Cystihalysites* having very large corallites, showing nature of tabulation in a corallite and parts of adjoining mesopores. 3e, transverse section through part of the corallum of a characteristic species of *Cystihalysites* found in the Silurian rocks of the West, showing the exceptionally large corallites and coarse meshwork. 3f, transverse section of a corallite from the form of *Cystihalysites* illustrated in figures 3d and 3e, showing extreme development of cystose tabulae in the corallite and mesopores.



ORDOVICIAN AND SILURIAN HALYSITID CORALS

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