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ORDOVICIAN CORALS OF THE WILLISTON BASIN PERIPHERY

Frank Phillip Caramanica, Ph.D.

The University of North Dakota, 1973 Faculty Advisor: Professor F. D. Holland, Jr.

Tabulate and rugose corals are described from the Ordovician Red River, Stony Mountain, and Stonewall Formations in southern Manitoba and the Ordovician Bighorn Formation in northern Wyoming. Fifty-four species, 12 of which are new, are distributed in 20 genera. The Flower Model of coral evolution, based on wall microstructure of colonial corals, is extended to include the septal microstructure of colonial and solitary corals. "Primitive" corals are characterized by nontrabeculate walls and septa whereas "advanced" forms are characterized by trabeculate walls and septa. "Mid-range" corals are those with intermediate stages of trabecular development in walls and septa. Corals in the Red River Formation are primarily colonial, "primitive" and "mid-range," and are geographically widespread, ranging from New Mexico to Greenland in a northeast-southwest trending belt defining an Ordovician equatorial realm, but rarely occurring elsewhere in North America.

Solitary corals in the Red River fauna were ancestral to those in the Stony Mountain fauna, but the colonial forms in the Red River Formation were not ancestral to those in the Stony Mountain. Corals in the Stony Mountain and Stonewall Formations in Manitoba and the faunas in the Bighorn Formation in northern Wyoming are younger,

considerably more "advanced," and geographically more restricted than those in the Red River. The colonial corals are predominant in carbonate rocks whereas the solitary corals are most abundant in argillaceous carbonates and argillites, implying intolerance of the colonial forms for terrigenous clastics. The solitary forms were apparently not as efficient as the colonial corals in utilizing available energy under conditions of carbonate sedimentation.

A paraconformity in the subsurface of northeastern North Dakota and diastems in the type section of the Fort Garry Member of the Red River Formation indicate that the cratonic platform east of the Williston Basin was exposed for part or all of the time the evaporitic "upper Red River" was being deposited in the Basin. The paraconformity occupies the same stratigraphic position as the Fort Garry Member, the "upper Red River" and an unconformity traceable from New Mexico to the Hudson Bay region. Corals below this paraconformity and the Fort Garry are mostly primitive whereas those above them are advanced. <u>Paleofavosites</u> has its lowest stratigraphic occurrence in the Fort Garry Member. The Cat Head Member of the Red River Formation does not extend southward into northeastern North Dakota and is a dolomitized version of the underlying Dog Head Member.

Some corals are useful for correlation of Ordovician rocks from New Mexico to Greenland and reflect relatively uniform environmental conditions in the Ordovician equatorial realm but are not effective for correlation outside the realm. The widespread occurrence of <u>Paleofavosites</u> in and outside the areas of study, the change from nontrabeculate to

trabeculate septa in some solitary corals, and the "primitive" versus "advanced" characters of the coral faunas may be of future use for correlation and age determination in and outside the realm.

ORDOVICIAN CORALS OF THE WILLISTON BASIN PERIPHERY

by

Frank Phillip Caramanica

Bachelor of Arts, Portland State University, 1964 Master of Arts, State University of New York at Binghamton, 1969

A Dissertation

Submitted to the Graduate Faculty

of the

· University of North Dakota

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

Grand Forks, North Dakota

December 1973

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Frank Phillip Caramanica

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I am indebted to the following individuals for helping me complete this study. Dr. F. D. Holland, Jr., my advisor, first suggested the "Red River problem" and related topics for a dissertation study. Both he and Dr. Alan M. Cvancara spent long hours with me discussing the study and offering helpful advice. Drs. Vera Facey, Arthur F. Jacob, and B. Seshagiri Rao very kindly consented to act as committee members along with Dr. Cvancara. They have spent long hours critically reviewing the manuscript and their efforts are gratefully acknowledged.

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ABSTRACT

Tabulate and rugose corals are described from the Ordovician Red River, Stony Mountain, and Stonewall Formations in southern Manitoba and the Ordovician Bighorn Formation in northern Wyoming. Fifty-four species, 12 of which are new, are distributed in 20 genera. The Flower Model of coral evolution, based on wall microstructure of colonial corals, is extended to include the septal microstructure of colonial and solitary corals. "Primitive" corals are characterized by nontrabeculate walls and septa whereas "advanced" forms are characterized by trabeculate walls and septa. "Mid-range" corals are those with intermediate stages of trabecular development in walls and septa. Corals in the Red River Formation are primarily colonial, "primitive" and "mid-range," and are geographically widespread, ranging from New Mexico to Greenland in a northeast-southwest trending belt defining an Ordovician equatorial realm, but rarely occurring elsewhere in North America.

Solitary corals in the Red River fauna were ancestral to those in the Stony Mountain fauna, but the colonial forms in the Red River Formation were not ancestral to those in the Stony Mountain. Corals in the Stony Mountain and Stonewall Formations in Manitoba and the faunas in the Bighorn Formation in northern Wyoming are younger, considerably more "advanced," and geographically more restricted than those in the Red River. The colonial corals are predominant in carbonate rocks whereas the solitary corals are most abundant in

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A paraconformity in the subsurface of northeastern North Dakota and diastems in the type section of the Fort Garry Member of the Red River Formation indicate that the cratonic platform east of the Williston Basin was exposed for part or all of the time the evaporitic "upper Red River" was being deposited in the Basin. The paraconformity occupies the same stratigraphic position as the Fort Garry Member, the "upper Red River" and an unconformity traceable from New Mexico to the Hudson Bay region. Corals below this paraconformity and the Fort Garry are mostly primitive whereas those above them are advanced. <u>Paleofavosites</u> has its lowest stratigraphic occurrence in the Fort Garry Member. The Cat Head Member of the Red River Formation does not extend southward into northeastern North Dakota and is a dolomitized version of the underlying Dog Head Member.

Some corals are useful for correlation of Ordovician rocks from New Mexico to Greenland and reflect relatively uniform environmental conditions in the Ordovician equatorial realm but are not effective for correlation outside the realm. The widespread occurrence of <u>Paleofavosites</u> in and outside the areas of study, the change from nontrabeculate to trabeculate septa in some solitary corals, and the "primitive" versus "advanced" characters of the coral faunas may be of future use for correlation and age determination in and outside the realm.

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INTRODUCTION

Purpose

The Ordovician corals of exposed argillaceous and carbonate strata along the periphery of the Williston Basin have not previously been studied as an entity. Previous workers have dealt with a single, or a few species, or have included the corals as parts of a fossil assemblage. This study undertakes to identify the Ordovician tabulate and rugose corals that others and I have collected from exposures of the Red River, Stony Mountain, and Stonewall Formations in southern Manitoba and the Bighorn Formation in northern Wyoming.

Several questions are posed in order to identify the topics of the study.

- What corals are present in the Red River, Stony Mountain, Stonewall, and Bighorn Formations in their type areas?
- Does a method exist, or can one be devised, to determine the degree of evolutionary advancement of an Ordovician coral species?
- 3. What is the composition, stratigraphic range, and geographic distribution of the coral fauna occurring in the Ordovician rock units along the periphery of the Williston Basin?
- 4. What is the relationship of these corals to other Ordovician coral faunas in North America?

5. Do the corals possess characters which would make them useful in determining the age of units in the area peripheral to the Basin?

Corals were collected along with the rocks in which they occurred to determine the relationship between the corals and the environment. Two core sections of the Red River, Stony Mountain, and Stonewall Formations in the extreme eastern part of North Dakota (Test Holes P-1 and GF-2, Figure 1) were examined to (1) compare the formations in the cores with their exposures in southern Manitoba, (2) determine the geographic distribution of these units between their exposures and the eastern North Dakota bore-hole sites, and (3) determine faunal content. Other cores, taken from the Red River Formation in the Williston Basin in North Dakota were examined in order to find what corals are present.

Large numbers of solitary and colonial corals were used to determine ranges and means of biometric data (Appendix B). These ranges and means aid in comparing the populations studied with data for allied populations derived by other workers. These data are used to (1) demonstrate the variability within taxa, (2) establish similarity between taxa, and (3) determine the effects of geographic separation and ecologic variation on populations. The biometric data also form a numerically based starting point from which future workers in allied taxa can proceed.

Detailed study of the microskeletal features in the corals studied is based upon a model of generic interrelationships proposed by Flower (1961) for colonial coral faunas related to and occurring in Ordovician sediments of New Mexico and Texas. In this study, Flower's model is applied as a tool for recognizing interrelations between genera and as an aid in determining if the coral faunas studied have any taxonomic or

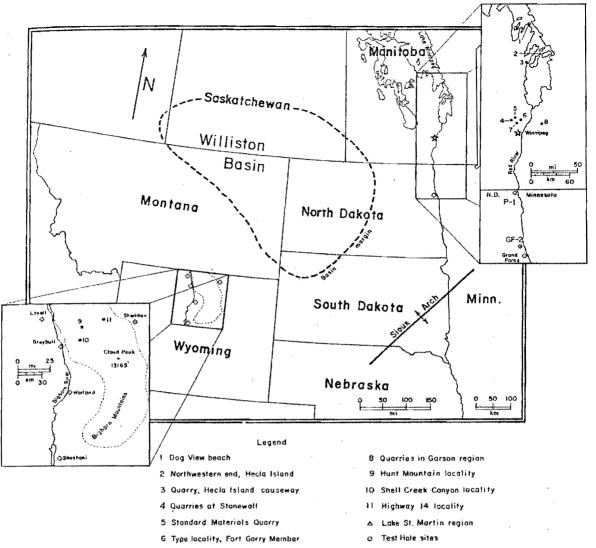


Fig. 1.--Index map showing areas studied, numbered localities, and Sioux Arch. Margin of Williston Basin from Porter and Fuller (1959).

7 Quarry at Municipality of Winnipeg plant

morphologic characters useful in age determination. In addition, Flower's model, which was restricted mainly to the microstructure of the colonial corallite wall, is extended to the microstructure of the septa of the colonial and solitary Rugosa.

Central to this study is the concept of correlation as used in stratigraphy. In this work stratigraphic correlation is used in the sense of Dunbar and Rodgers (1957, p. 271) who define correlation as "... the process by which stratigraphers attempt to determine the mutual time relations of local sections." The word is used only in the time-stratigraphic sense when both lithologic and faunal similarities between local sections offer strong evidence of time equivalence. Correlative is used to indicate that two geographically separated stratigraphic units were deposited at the same time.

Where time equivalence of two lithologically similar, separated units in similar stratigraphic position is in question, they are termed <u>physical equivalents</u>. Therefore to avoid confusion, correlation and correlative are used only when pertaining to time equivalence.

Procedure

The Ordovician corals and sedimentary rocks were studied in two regions--southern Manitoba and the Bighorn Mountains of Wyoming. In southern Manitoba the Red River, Stony Mountain, and Stonewall Formations are exposed at their type and allied localities. The combination of little relief, low dips of the units, and Pleistocene glaciation have resulted in poor exposures. The only exposures of the formations are in quarries in the vicinity of Winnipeg and along the western shore of Lake Winnipeg and on the islands in the Lake. No complete stratigraphic

succession of the three formations is exposed and most exposures are only a few tens of feet of a single formation.

In the northern portion of the Bighorn Mountains in Wyoming (Figure 1) the Bighorn Formation is completely exposed on the eastern and western flanks of the range as nearly horizontal and steeply dipping strata. Between the two regions, the Williston Basin contains, in the subsurface, the physical equivalents of the Ordovician formations exposed along the Basin periphery. Selected well cores in the collection of the North Dakota Geological Survey were examined. Cores from Test Holes P-1 and GF-2 (Figure 1) were inspected in order to determine lithology and fossil content whereas cores from the Red River Formation in the Williston Basin were inspected solely for their coral content.

The southern Manitoba and northern Wyoming exposures were sampled to obtain suites of Ordovician tabulate and rugose corals and the enclosing sedimentary rocks. Lithologic descriptions of the exposed units were made in the field and are included in Appendix A.

Paleoecologic data on exposures of small areas of bedding plane surfaces and the contained coral fauna of the Selkirk Member of the Red River Formation were gathered in quarry exposures of the unit. This afforded a unique opportunity to record the lateral placement of corals as they occurred on the Ordovician sea floor at given "instants" of geologic time.

Large numbers of corals from the Red River, Stony Mountain, and Stonewall Formations were collected for about 20 years by students and faculty of the Geology Department of the University of North Dakota. Stratigraphic control of these corals presented no problem due to the

stratigraphic intervals in the Winnipeg region. These workers and I sought to obtain the greatest number and maximum variety of collectable corals. However, systematic collection methods were unusable where scarcity, inaccessability, and extraction problems made collection difficult.

Stratigraphic control was commonly accurate to one-tenth (1/10) of a foot. Field measurements were made in feet and are converted to the metric system. Stratigraphic thicknesses and intervals are expressed both in feet and meters.

Historical Perspective

Southern Manitoba. -- The history of investigation in southern Manitoba began in 1819 when Sir John Richardson noted fossils in carbonate rocks along the northern and northwestern shores of Lake Winnipeg north of the Saskatchewan River. In 1823, bluffs of limestone were noted by Major Long at what is now Lower Fort Garry on the Red River. Between 1825 and 1827, Richardson collected fossils from carbonates along the western shore and on islands in the lake.

Owen (1852, p. 180) reported that "About twenty miles below the mouth of the Assiniboin, near Lower Fort Garry, solid ledges of limestone are exposed, of a light buff colour, sometimes mottled, spotted, or banded with light brown." Owen found fossils in these limestones that he concluded were sufficient to date the limestones. Apparently many of the same fossils occurred in Wisconsin and Iowa and the lithologies of the units in the Manitoba and Wisconsin-Iowa regions were similar. One fossil used by Owen to date the limestones was "<u>Coscinopora sulcata</u>" (<u>=Receptaculites oweni</u> Hall) that also occurred in the lower beds of the "Upper Magnesian limestone" of Wisconsin.

Around 1851, some geologists thought the carbonate strata in the shoreline exposures of Lake Winnipeg were Carboniferous (Whiteaves, 1897, p. 131) due to Milne-Edwards and Haime (1851) identifying a coral now probably referable to <u>Palaeophyllum</u> argus Sinclair from these strata as a Carboniferous species, <u>Lithostrotion stokesi</u>. According to Whiteaves (1897, p. 131), Richardson, apparently without reason, stated in 1851 that the carbonate strata represented the Black River limestone. In 1858 an exploration party to the Assiniboine and Saskatchewan Rivers led by H. Y. Hind collected fossils from the carbonates on the western shore and islands of the lake and reported that (<u>fide</u> Whiteaves, 1897, p. 131) "The Formations which have been recognized on Lake Winnipeg and in the valley of the Red River are the Chazy, Bird'seye, and Trenton formations, and the Hudson River Group."

Whiteaves (1895, p. 111) reported that in 1857 Captain Palliser stated:

At Stony Hill about fifteen miles north-west from the Upper Fort [Upper Fort Garry], there is an isolated bluff of limestone, rising from the plain level to the height of eighty feet. . . . The beds of limestone are horizontal or nearly so, and are slightly different from those at Fort Garry in their mineral aspect, having a more crystaline fracture and the colour being of a reddish hue. No fossils can be discovered in newly fractured portions but on the weathered surfaces a few obscure remains of fossils are to be seen.

Fossils in this locality were noted in 1875 by R. W. Ells in rubble from the excavation for the foundation of the Provincial Penitentiary. He collected fossils which were identified by Whiteaves (1880, p. 49c-50c) who stated:

A large portion of the mass at Stony Mountain consists of limestones, with clayey partings which are identical both in their lithological and paleontological characters with the well-known rocks of the Hudson River or Cincinnati Group of southern Ohio

and elsewhere; and secondly, that these Hudson River rocks of Stony Mountain overlie immediately and conformably the buffcoloured, fossiliferous, and more or less magnesium limestones of the Red River Valley . . . which have been assumed to be the representatives of the upper part of the Trenton limestone.

According to Whiteaves (1897), Tyrell and Dowling studied the geology of the Red River and Lake Winnipeg regions in the years 1889-1891. According to Whiteaves (1897, p. 134), Tyrell concluded that the limestones in the Red River Valley on the western side of the lake, excepting those at Stony Mountain and Stonewall should be " . . . referred to the Trenton formation, and the sandstones of Punk and Deer Islands, Grindstone point, etc., to the Chazy (St. Peter's) formation." Whiteaves (1895, p. 111) published the first complete faunal list for fossils in the "Hudson River or Cincinnati formation at Stony Mountain." In 1897 he gave the faunal content of the (p. 129) "Galena-Trenton and Black River formations of Lake Winnipeg and its vicinity." He said that the receptaculitids, colonial and solitary corals, brachiopods, gastropods, orthoceratitic nautiloids and trilobites were large.

Dowling (1900) reported on the geology, paleontology, physiography, and culture of the west shore and islands of Lake Winnipeg, summarizing nearly all of the previous geological work, plus giving detailed section descriptions for all units. He was the first worker in southern Manitoba to apply local names to the units exposed in the vicinity of Lake Winnipeg. He (1900, p. 39F) named the "... series of soft friable sandstones, shaly in the upper part, the Winnipeg sandstone." He divided the rocks overlying the Winnipeg into the "Lower Mottled limestone," exposed near Dog Head south of the Narrows in Lake Winnipeg; the middle "Cat Head Limestone," exposed along the western lake shore

south of the mouth of the Saskatchewan River and north of the Narrows; and the "Upper Mottled limestone," exposed in the Red River Valley near Lower Fort Garry.

Dowling (p. 46F) first referred to the rocks exposed at Stony Mountain as the Stony Mountain Formation and stated (p. 47F):

We might infer from this [the fossils in the Stony Mountain] that the upper part, that of which we have a section and list of fossils is referable to the Richmond group of Minnesota, and that the lower beds, mostly shales, are similar to the Utica of the Cincinnati formation.

By use of wells he determined that the Stony Mountain Formation was 110 feet thick at the provincial penitentiary, with an upper 20 feet of (p. 88F) "... solid, hard stone like that at the quarries" which was underlain by 16 feet of "... yellowish rock quite ochreous, ... thin and broken," and "solid rock." This was underlain by 10 feet of a "... reddish layer full of fossil shells," which, in turn, was underlain by 60 feet of a "... mixture of yellow and red containing some flinty material."

Kindle (1914, p. 249) included all Silurian strata of Manitoba in the Stonewall Formation, a unit named from exposures at the town of Stonewall, northwest of Stony Mountain. The type section consists of 19 feet of dolostone in the lowermost part of the unit. He placed it in the Silurian because the fauna of the Stonewall showed no clear relationship with the fauna of the underlying Stony Mountain Formation.

Until 1915, the strata exposed along the western shore of Lake Winnipeg and along the Red River near Lower Fort Garry were regarded as Trentonian due to work by Whiteaves (1897) and Dowling (1900). Bassler (1915, p. 1458) listed the cephalopod faunas under the heading of "Black River or Richmond (Manitoba)." Foerste (1928, p. 28) commented that

"This list [of Bassler's] includes the species from the Cat Head and associated formations in Manitoba. Although recorded as Mohawkian age by Whiteaves, it is probable that many of them were derived from Richmond strata." Foerste (1928, p. 26) proposed the name "Red River Formation" for the carbonate rocks along the western shore of Lake Winnipeg. He named the Lower Mottled limestone the Dog Head Member from the type locality at Dog Head on Lake Winnipeg. The Cat Head Limestone was elevated to member status, and the Upper Mottled limestone was named the Selkirk Member from a type locality on the Red River near Lower Fort Garry. Dowling described the Upper Mottled Limestone from the northwestern shore of Lake Winnipeg and from Selkirk Island in the same region. Foerste, however, did not refer to Selkirk Island when he (1928, p. 26) renamed the unit the Selkirk Member. Instead, he referred to the town of Selkirk on the Red River at the south end of the Lake.

Okulitch (1943) divided the Stony Formation into four members and listed their faunal content. He named the basal part of the unit, approximately 60 feet of shaly interbedded biosparudite, the "Stony Mountain Shale member." The next overlying unit was named the "Penitentiary member," and the massive dolostone overlying the Penitentiary was named the "Gunton member." He proposed the name "Birse member" (p. 63) for a thin-bedded dolostone overlying the Gunton. Baille (1952) gave detailed section descriptions and faunal lists for the Ordovician units in southern Manitoba but did not recognize the Birse as a separate unit, including it in the Gunton.

Twenhofel and others (1954, chart 2) placed the Ordovician strata in central Canada in the Richmondian and Gamachian stages of the

Cincinnatian Series. Gamachian is a stage name established by Twenhofel (1928, p. 36) for strata on Anticosti Island that appeared to be younger than Richmondian and older than Silurian. Thus, by the time of the preparation of the Ordovician Correlation Chart (Twenhofel and others, 1954), the concept of a Richmondian age for Ordovician strata in central Canada and the Arctic islands had been accepted by many workers. Twenhofel and others (1954, p. 282), in order to present a balanced discussion, included opinions of other workers in the Chart, notably those of Kay (1935) who maintained that the Red River Formation and its equivalents are Trentonian. Stearn (1956, p. 14) restricted the Stonewall Formation to the section exposed at the type locality and, on the basis of a predominance of Richmondian fossils, stated it was of latest Ordovician age instead of Silurian as Kindle (1914) had concluded.

Ross (1957, p. 446, 468) first used the name "Bighorn" (Darton, 1906) at the group level to encompass the Red River and Stony Mountain Formations in the subsurface of the Williston Basin and Manitoba. He included the Stonewall Formation in an upper, dolomitic member of the Stony Mountain Formation. Sinclair and Leith (1958, p. 244) named the "Stony Mountain Shale member" of Okulitch (1943) the Gunn Member--from a type section in a quarry at the Municipality of Winnipeg Aggregate Plant. This quarry is just north of the Provincial Penitentiary and was formerly known as the Gunn quarry (Sinclair and Leith, 1958, p. 244).

Sinclair (1959) revised the terminology and concepts of the members of the Red River Formation by eliminating the Selkirk Member, stating that the Dog Head and Selkirk Members were the same. He retained the name Cat Head Member to denote the upper dolostone unit of the Red River in the subsurface. He also visualized Dowling's (1900) "Upper

Mottled limestone" as being the same age as the Stony Mountain Formation. Although Stearn (1956) had assigned an Ordovician age to the lower part of the Stonewall Formation based on a fauna most like that of the Stony Mountain Formation, Andrichuk (1959) placed the entire Stonewall in the Silurian Interlake Group because of its lithologic resemblance to the Group.

Brindle (1960), following the terminology established by the Saskatchewan Geological Society (1958), listed the faunas for the subsurface physical equivalents of the Red River and Stony Mountain Formations of southern Manitoba. He followed Ross' (1957) usage of Bighorn Group, and included within the group the Yeoman beds (faunally equivalent to the Dog Head Member as conceived by Sinclair, 1959), the overlying Herald beds (correlative with the Cat Head Member, as conceived by Sinclair), the Stoughton beds (faunally similar and correlated by Brindle with the Gunn and Penitentiary Members of the Stony Mountain Formation in southern Manitoba), and the Stonewall Formation.

Flower (1957, 1961) compared the corals and nautiloids of the Montoya Group in New Mexico and western Texas with related forms in Manitoba and Wyoming and discussed the stratigraphic relationships in these areas. Similarly, Nelson's (1953, 1963) faunal and stratigraphic studies in the Hudson Bay region had an indirect impact on the concepts of stratigraphy in southern Manitoba. He demonstrated that Ordovician strata equivalent to the Red River, Stony Mountain, and Stonewall Formations are present in the Hudson Bay region and that the faunas in the Hudson Bay strata are correlative with those in the southern Manitoba formations.

McCabe and Bannatyne (1970), on the basis of several core holes in the Lake St. Martin region of Manitoba, found members of the Red River Formation in a single hole. They encountered the basal Dog Head Member, the overlying Cat Head Member, the Selkirk Member and a new uppermost unit, which they designated the Fort Garry Member. The type locality of this unit is the Mulder Brothers Quarry number 12, halfway between Stony Mountain and Lower Fort Garry. This revision of the members of the formation restored the original concept of the Red River Formation of southern Manitoba as originally envisoned by Dowling (1900) and Foerste (1928) and belied Sinclair's (1959) contention that the Dog Head and Selkirk Members were identical.

Cowan (1971, p. 238) named the portion of the Stony Mountain Formation overlying the Gunton Member and underlying the Stonewall Formation as the Williams Member with a type locality at a quarry immediately north of Stonewall, Manitoba. He also considered that the Stonewall contains strata of both Ordovician and Silurian age.

Northern Wyoming. --Rocks now assigned to the Bighorn Formation were noted by Comstock in 1874 and designated by him as the "Silurian Limestone" (Miller, 1930, p. 197). It was later mentioned in the report of the Hayden Survey (Miller, 1930, p. 197) and in 1894 Eldridge discussed these rocks. Miller (1930, p. 197) said that Beecher first identified fossils from these rocks in 1896 and concluded that they indicated "Trenton or Hudson" age strata. Darton (1906) first named and described the Bighorn Formation in detail and gave an extensive list of fossils (identified by Ulrich) from the unit in the Bighorn Mountains. Subsequently, Blackwelder (1918) applied the name "Leigh Dolomite Member" to a thin-bedded portion in the uppermost part of the Bighorn Formation.

Miller (1930) described the formation in the Wind River Range of central Wyoming and included a thin basal sandstone, the Lander Sandstone, within the formation. He gave extensive faunal lists for the Lander, the overlying massive dolomite, and the Leigh Member, which he stated (p. 206) was the uppermost member of the Bighorn in the Wind River Range and concluded that the Bighorn was Richmondian.

Richards and Nieschmidt (1957) restricted the Bighorn Formation to the Ordovician carbonates above the Lander and divided the carbonates into lower and upper units. They said the lower unit consisted of a lowermost massive mottlee dolomite, over 200 feet thick, overlain by a thin-bedded dolomite. Macomber (1970, p. 419) pointed out that Goodwin in 1964 divided the Bighorn differently. Goodwin included the Lander as the basal member of the Bighorn Formation, recognized the Leigh Member, and assigned names to the massive dolomite below the Leigh and to the thinly and thickly bedded dolomite above the Leigh.

Macomber (1970) concentrated on the articulate brachiopods in two thin, correlative, argillaceous limestone beds in the upper part of the Bighorn Formation on the west and east flanks of the Bighorn Mountains. He informally termed these the "Hunt Mountain" and the "Rock Creek beds." Ross (1957) had suggested that the argillaceous limestone correlated with the "Stony Mountain shale" of southern Manitoba and the Williston Basin, and Macomber (1970, p. 420) emphasized this lithologic and faunal similarity (although he derived a Maysvillian age for the Hunt Mountain/Rock Creek beds rather than a Richmondian age as did Ross [p. 459]).

The Red River Problem. -- Since Bassler's (1915) statement that the Red River Formation may be Richmondian, two opposing schools of thought have arisen. One maintains that the Trentonian age proposed by Whiteaves

(1897) and Dowling (1900) for the Red River was essentially correct in that it recognized the possibility of a pre-Richmondian age for part of the Ordovician rocks of southern Manitoba.

The alternate approach maintains that Bassler's suggestion of a Richmondian age for the Red River Formation is correct. This was bolstered by Foerste (1928) who preferred a Richmondian age assignment. He based his conclusion on Red River cephalopod genera (1928, p. 29) that also occur in beds assigned a Richmondian age in Greenland. Troedsson (1926, p. 113) had assigned a Richmondian age to cephalopods from the Cape Calhoun Formation of northern Greenland.

Although Foerste had concluded that a Richmondian age was preferable for the Red River, he harbored doubts (1929, p. 146): "Prevalence of a general Trenton facies suggests its Trenton age. The introduction of characteristic Richmond genera and species suggests its reference to the Richmond." Foerste also stated (1929, p. 137):

It is evident that a considerable part of the fauna of the Red River Formation shows affinities with the Trenton, especially with the Galena phase of the Trenton. However the direct correlation of the Red River with the Galena . . . becomes less certain when the cephalapod fauna is studied.

The workers who believed that the Red River Formation and its lithologic equivalents are older than Richmondian have maintained that taxa in addition to cephalopod genera must be considered. Kay (1935, p. 586), in discussing the Stewartville Member of the Galena Formation and the Dubuque Formation, stated:

. . . for whether the two [the Stewartville Member and the Red River Formation] are synchronous or not the former has a fauna that is most similar to the Red River. The correlation and classification of the Bighorn and related formations of Western United States is in turn dependent on the classification of the Stewartville through the Red River with which the Bighorn seems homotaxial. And the Red River fauna has been recognized in exposures throughout Arctic America.

Kay stressed the importance of the Red River Formation in determining the age of many of the Ordovician strata in the western United States, central Canada, and Arctic America. He (p. 586) continued: "The Red River problem is essentially of two aspects: first, is some part or all of the formation a correlative of the Stewartville and associated beds? and, second, if not, what is its age?"

Flower (1942) described a faunule of nautiloid cephalopods from a linear channel filling (p. 6) in the Trentonian Cynthiana Formation of Kentucky. The faunule represents a unique occurrence of cephalopod genera which had been previously considered to represent (p. 6) "... post-Trenton, and even Richmond, age of the strata in which they occur." He went on to state that the cephalapods are similar to those in Ordovician strata in the Arctic, Hudson Bay region, the Red River Formation in southern Manitoba, the Bighorn Formation of Wyoming, and the Fremont limestone of Colorado (p. 8) and that these units have been of uncertain age assignment ranging from Trentonian through Richmondian. Flower stated (p. 8) that "The Cynthiana faunule adds to the list of supposedly diagnostic Richmond genera that are now known to occur in the Trenton." Flower (1942) demonstrated that nautiloid shells floated in and came to rest prior to burial from their life zone in what he termed the "boreal faunal realm." This showed that in death the shells crossed a zoological barrier, from their realm of existence into the east-central region of the Trentonian sea before coming to rest. Thus, a very important concept was implied in that a faunal or blotic barrier existed between two faunal realms. Flower (1942, p. 8) stated that " . . . it demonstrates a connection between the east-central embayment in late Trenton time and the arctic embayment, a connection which does not seem to have been previously suspected."

Twenhofel and others (1954), in constructing the correlation chart of the Ordovician of North America, assigned the entire southern Manitoba Ordovician section to the Richmondian and Gamachian. Thev recognized that a difference of opinion existed as to the age of these strata, but Twenhofel concluded (in Twenhofel and others, 1954, p. 218) that the Red River fauna was most closely correlative with the English Head Formation on Anticosti Island. Kay, writing in Twenhofel and others (p. 282), disagreed. He pointed out that (1) most of the fauna of the Red River is known in the Trenton and not in the Richmond; (2) graptolites and conodonts from the Winnipeg Formation and its lateral equivalents are like those in strata correlated with the Black River and lower Trenton; (3) classification of the Red River and its equivalents as Richmondian would produce subsurface and paleogeographic problems; and (4) classification of these units as Trentonian does not preclude the possibility of Richmond equivalents in such basins as the Williston Basin.

Flower (1956a) stated that the Red River faunas are pre-Richmondian, possibly late Trentonian and Edenian and the faunas, that he termed boreal, migrated from a boreal faunal realm (Flower, 1956b) into an austral realm normally prevalent in the Ordovician seas of the eastern interior of the continent. He (1956b) suggested that the boreal faunas were tropical and the austral forms were in a temperate climate and that the boreal invasions represented episodes of climatic warning of the austral realm.

In 1957 Flower extensively discussed problems of Ordovician correlations. He stated (p. 18) that the age of the Red River Formation should be late Trentonian and Edenian because the type Trenton

and Eden are probably contemporaneous and reflect differing depositional facies.

His main theme was that biologic mechanisms and environmental con-

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and Eden are probably contemporaneous and reflect differing depositional facies.

His main theme was that biologic mechanisms and environmental controls were the primary reasons for the problems encountered in correlating Ordovician strata of the western interior and arctic America with strata in the type areas of the Middle and Late Ordovician in eastern North America. The eastward invasions of the boreal faunal elements into the austral faunal realm introduced boreal stocks, some of which adapted to the austral environmental conditions and became a part of that realm. According to Flower, four invasions from the west occurred during the Middle and Late Ordovician during Chazyan, Blackriveran, Coburgian, (late Trenton), and Richmondian times. According to the faunal invasion concept, environmental conditions, became favorable for boreal faunas in eastern North America, allowing them to invade another faunal realm. The ending of these favorable conditions occurred when the "typical" austral environmental conditions returned, allowing reintroduction of the austral faunas into the realm and permitting only the most adaptable of the remnant boreal elements to survive.

Ross (1957, p. 459, 460) stated that the Red River Formation and Bighorn Group are Cincinnatian. He based this conclusion on the brachiopods and corals, and recognized that objections such as that of Flower (1952, p. 25; 1957, p. 19) to it existed. Macomber (1970, p. 424) discussed the age of the upper part of the Bighorn Formation and stated that conodont faunas collected from the Rock Creek beds and on the eastern flank of the Bighorn Mountains are correlative with those in the Gunn Member in southern Manitoba (Stone and Furnish, 1959). This member has been assigned a pre-Richmondian age by Ethington and

Furnish (1960), a conclusion that Macomber (1970, p. 424) supported as being Edenian to early Maysvillian. Flower (1970, p. 480) stated that the widespread Red River faunas are of an Edenian-Coburgian age. A complete cycle of conclusions of age by various workers has taken place since the late 1800's and early 1900's when the works of Whiteaves (1897) and Dowling (1900) indicated that the Red River Formation was of Trentonian age.

Environmental control of epeiric marine faunal realms proposed by Flower (1942, 1946), has aided in forming a concept of invasion of an austral realm by boreal elements when environmental factors were suitably altered. These concepts have aided Flower (1942, 1957) who has been the primary force in promoting an acceptance of a Trentonian-Edenian age for the Red River and physically equivalent strata. Recent literature on the topic shows that Richmondian ages for these strata are now rarely proposed. Similarly, the status of the age of the Gunn Member of the Stony Mountain Formation has undergone change. Even prior to Whiteaves (1895) the unit was considered to be Richmondian. Subsequent work with conodont assemblages in this unit by Ethington and Furnish (1960) showed that they are correlative with conodont assemblages in the Rock Creek beds (Stone and Furnish, 1959), and with those in the type Maysvillian. They determined that the conodonts from the Gunn Member had only a few genera in common with those in the type Richmond. This plus other faunal evidence led Macomber (1970, p. 425) to conclude that the Hunt Mountain/Rock Creek beds and the correlative Gunn Member are more likely Maysvillian than Richmondian. According to him, much or all of Richmondian time must be represented by the upper part of the Stony Mountain Formation and the Stonewall Formation.

STRATIGRAPHY

This section includes short descriptions of the Red River-Stonewall interval in southern Manitoba--northeastern North Dakota and portions of the Bighorn Formation adjacent to and including the Hunt Mountain beds. In each region the units including well cores P-1 and GF-2 are described and discussed in ascending stratigraphic order. Lithologic descriptions in the text and Appendix A cite color names and symbols given in Goddard, and others (1963). All colors given are for fresh surfaces unless otherwise specified. If an original citation expressed the thickness of a unit in feet, the metric equivalent is expressed parenthetically.

Southern Manitoba

Red River Formation.--Present interpretations (McCabe and Bannatyne, 1970) divided the Red River Formation into four Members; the Dog Head, Cat Head, Selkirk, and the uppermost member, the Fort Garry.

The Dog Head Member of the Red River Formation conformably overlies the Winnipeg Formation and is exposed along the western shore of Lake Winnipeg in the region of the Narrows and islands in the vicinity of and on Hecla Island. This unit, as exposed at Dog Head and south of there, is a 20 to 30 foot (6.1 to 9.1 m) thick, cliff-forming, dolomitic, mottled limestone. Dowling (1900, p. 41F) had reported a maximum thickness of 70 feet for the Dog Head in the northern part of

the western shore of Lake Winnipeg. McCabe and Bannatyne (1970, p. 15) encountered a total thickness of 83 feet (25.3 m) for the member in a test hole in the Lake St. Martin, Manitoba area, which bottomed in the underlying Winnipeg Formation.

Along the northern end (locality A905, Appendix A) and eastern side (locality A909) of Hecla Island, the Dog Head conformably overlies the Winnipeg but the upward transition between the two occurs over an interval of one-half foot. The Dog Head becomes less arenaceous upsection until, at approximately 11 feet (3.5 m) above the base, the rock is a very pale orange, dolomitic, mottled limestone with bioclastic fragments.

The dolomitic mottling characteristic of the unit was observed by McCabe and Bannatyne (1970, p. 15) in cores in the Lake St. Martin region.

The "Cat Head Limestone" was described by Dowling (1900, p. 42F) as "... cream-coloured dolomitic limestones of a general even colour and texture and rather fine-grained in which are found nodules of chert of varying sizes." The contact with the underlying Dog Head has not been observed in exposures of the unit, and McCabe and Bannatyne (1970) did not discuss its character. The total thickness of the Cat Head in the type area was given by Dowling (1900, p. 42F) as 68 feet (20.8 m). McCabe and Bannatyne (p. 15) cited a total thickness of 50 feet (15.3 m) in a test hole near Lake St. Martin that penetrated the entire unit. In a quarry near Riverton, Manitoba (locality A965) the exposure consists of 11 feet (3.5 m) of thick- to massive-bedded, mottled, micro-crystaline dolostone with a saccharoidal texture and dolomitized crinoid ossicles (Appendix A).

Rare macrofossils in the quarry exposure of the Cat Head are preserved as external molds and no more than a few small, unidentifiable solitary corals were noted. No sedimentary structures other than thick and massive beds occur. The uniform saccharoidal texture of the dolomite reflects late or epigenetic dolomitization, indicating that the pre-dolomitization lithology was probably a fossiliferous, burrowed, biomicrite similar to the undolomitized Dog Head Member.

McCabe and Bannatyne (1970, p. 15) reported 75 feet (22.9 m) of conformable carbonate strata which they attributed to the Selkirk Member in the Interlake region where in subsurface it is nearly a pure limestone interbedded with dolomitic limestone and calcareous dolostone (p. 75-76). The best exposures of the Selkirk are in quarries near Garson, Manitoba. In the active quarry at Garson (locality A886) 20.8 feet (6.4 m) of the member is exposed. The lithology is uniform throughout the exposure, a very pale orange, earthy-appearing, fossiliferous, mottled, dolomitic limestone with abundant stylolitic zones (Appendix A).

The mottling is an aureole of pale yellowish brown, saccharoidal dolomite around an endobenthonic burrow. Similar mottling occurs in the Dog Head, but in that unit, the burrows are not preserved or were never as well developed as in the Selkirk. The Selkirk Member in southern Manitoba is characterized by a higher clay content than is the Dog Head, as indicated by its earthy appearance.

The Fort Garry Member is the uppermost unit in the Red River Formation. The type section is a 14 foot (4.3 m) exposure in a quarry six miles (9.6km) east of Stony Mountain, Manitoba (Appendix A, locality A851). In the Lake St. Martin area the unit is up to 96 feet (29.3 m)

thick. According to McCabe and Bannatyne (1970) the member conformably underlies the Gunn Member of the Stony Mountain Formation.

A physical equivalent of the Fort Garry Member was noted by Andrichuk (1959, p. 2359-2360) in the subsurface of southern Manitoba. He suggested it was correlative with the Selkirk Member. Porter and Fuller (1959) called this physical equivalent the "upper Red River," noting that it is characterized in the Williston Basin subsurface by anhydrite and dolomite (p. 153). The Fort Garry Member, the uppermost of the four members in the Red River Formation, has great lateral extent as evidenced by the ease with which it can be traced in the subsurface (Andrichuk, 1959; Porter and Fuller, 1959; Friestad, 1969). The physical equivalent of the Fort Garry was noted by Brindle (1960) in the subsurface of Saskatchewan and Manitoba. He called this equivalent the "Herald Beds" and said (p. 10) that it was characterized by

. . . dolomitic fossiliferous--fragmental limestones and argillaceous dolomites with bedded primary anhydrites making up two evaporitic cycles. The Herald Beds have a maximum thickness of approximately 100 feet [30.5 m] in the Province [of Saskatchewan], and the top is marked by another development of argillaceous dolomitic limestones.

Dowling (1900, p. 89F) described a well drilled through the Stony Mountain Formation at the type locality of the Gunn Member in what was then Mr. Gunn's quarry (now the quarry at the Municipality of Winnipeg Aggregate Plant). Dowling (p. 89F-90 F) stated:

The well referred to above was drilled in the quarry, beginning 15 feet 11 inches [4.8 m] below the top of the rock in the above section, and was carried down eighty-six feet [26.2 m] through soft, chiefly reddish limestone, probably clayey [the Gunn Member], to a band of hard limestone [probably the Fort Garry Member] from which a supply of water was obtained.

Dowling's description and an accompanying illustration (p. 91F) show an abrupt lithologic break between the Fort Garry Member and the overlying Gunn Member of the Stony Mountain Formation.

The four rock types in the type section of the Fort Garry are a mottled, very thick bedded dolostone with poorly preserved fossils; a thin bedded lithographic dolostone; a pale reddish brown, lutaceous dolostone with imbricate dolomite clasts; and red and green clays. The boundaries between all four types are commonly diastemic and no transitional zones were noted among the different lithologies. Fossils are rare and occur only in the mottled portion of the interval. Clay, diastems (some with small-scale scour surfaces), and the micritic dolostone breccia are discussed in more detail in subsequent portions of the text. They suggest that the Gunn may be unconformable on the Fort Garry.

Stony Mountain Formation. -- The Stony Mountain Formation is presently divided into four members (Cowan, 1971): the lowermost member-the Gunn, Penitentiary, Gunton, and the uppermost--the Williams.

Dowling (1900, p. 91F) logged a thickness of about 74 feet (22.6 m) for the Gunn Member. Okulitch (1943, p. 60) however, reported a total thickness of 60 feet (18.3 m), but Baille (1952, p. 19), and Sinclair and Leith (1958, p. 244) repeated the thickness reported by Dowling. McCabe and Bannatyne (1970, p. 16) reported a thickness of 54 feet (16.5 m) for the unit in the Lake St. Martin region.

The contact between the underlying Fort Garry Member and the overlying Gunn has been presumed to be conformable (Okulitch, 1943, p. 61) but, as previously discussed, the possibility of an unconformable contact cannot be totally eliminated. The contact between the Gunn and the overlying Penitentiary Member is gradational at the type section and Cowan (1971, p. 238) reported "the upper contact is gradational over an interval of from 2 to 5 feet [0.6-1.5 m]" in the Interlake region.

At the type locality the Gunn consists of bioturbated, fossiliferous interbeds of pale pink, calcareous shale and pinkish gray, argillaceous bioclastic limestone. The argillaceous portions have been bioturbated by infaunal burrowers. The unit is extremely fossiliferous; all the carbonate in the type exposure has been derived from skeletal material of marine invertebrates that consist predominantly of articulate brachiopods and small solitary rugose corals.

Much of the distinctive lithologic character and color of the shale and shaly limestones of the Gunn are due to the burrowing action of endobenthonic organisms, possibly polychaete annelids. The burrowing produced a sufficient change in the permeability of the sediments so that different concentrations of iron oxides in different oxidation states accentuated the outline of the burrows. Thin sections show concentrations of finely divided hematite along the perimeter of each burrow. The unburrowed portions of the unit exhibit the same type of finely divided hematite, but in lesser quantities, giving the matrix a paler, grayer aspect. The top of the member was defined in this study within a one-foot transitional zone where the preservation of the fossils changed from the calcitic type typical of the Gunn Member to the molds typical of the overlying Penitentiary Member.

The Penitentiary Member conformably overlies the Gunn and conformably underlies the Gunton Member. Okulitch (1943, p. 61) stated that its thickness is 15 feet (4.6 m) in the vicinity of Stony Mountain. The member is yellowish gray, weathering to grayish orange, argillaceous, microcrystalline dolostone. The lower eight feet (2.4 m) of the unit at the Stony Mountain exposure contains abundant fossils present only as internal and external molds which replicate minor skeletal details.

The fauna is the same as that in the underlying Gunn Member, composed predominantly of solitary corals and articulate brachiopods, commonly with the valves articulated.

The upper portion of the unit is sparsely fossiliferous and is characterized by small zones of pale red dolostone with a burrowed pattern produced by concentrations of iron oxide and paralleling the bedding planes. Biogenic reworking is seen in the yellowish gray portion of the dolostone, but it is different than in the reddish zones, both in terms of burrow diameter and concentration per unit of rock. The reddish zones contain densely packed burrows with diameters of 1.5 to 2 mm. Nearly all the sediment in the zones was reworked, and all burrows tend to parallel the bedding planes.

The Gunton Member is named for a quarry exposure a short distance south of the village of Gunton, approximately 12 miles (19 km) north of Stony Mountain. Okulitch (1943, p. 60) originally described it as being 15 to 19 feet (4.6 to 5.8 m) thick. He originally described an overlying unit, the Birse Member, as having a lithology slightly different from that of the Gunton, and a fauna very similar to that in the Stony Mountain Formation (1943, p. 64). Baille (1952) noted that the Birse of Okulitch is probably equivalent to the Gunton. He added the 15 to 17 feet (4.6 to 5.2 m) reported by Okulitch to the Gunton Member. This invalidated the concept of the Birse as a member and resulted in a total thickness of 27 feet (8.2 m) for the Gunton in the type section. McCabe and Bannatyne (1970, p. 16) reported a total thickness of 80 feet (24.4 m) in the Lake St. Martin region. The contact with the underlying Penitentiary is conformable with the change in lithology between the two members occurting over a short stratigraphic interval. The contact of the Gunton with

the overlying Stonewall Formation in the Lake St. Martin region was reported by Cowan (1971, p. 238) to be "sharp."

The Gunton in the Stony Mountain region is a massive, very pale orange, mottled microcrystalline or micritic dolostone, interspersed within layers of burrowed, grayish pink to pale red argillaceous dolostone (Figure 2). Fossils are poorly preserved, replaced by dolomite, silicified, or present as molds. The columnar stromatoporoid <u>Beatricia</u> is the organism most prominently preserved in the unit. The mottling through the Gunton Member is a secondary mineralization feature initiated by the burrowing action of infaunal organisms--probably polychaete annelids. Burrows in the argillaceous portions of the unit, like those in the argillaceous portions of the Gunn and Penitentiary Members, are densely packed and oriented parallel to the bedding planes. In addition, several bedding plane surfaces in the dolomitic portions show radiating hairline fractures reminiscent of desiccation processes which may represent thin stromatolitic or algal structures.

The Williams Member was named by Cowan (1971). Its contact with the overlying Stonewall Formation at the type locality is conformable. It consists of an abrupt upward transition from an argillaceous dolostone at the top of the Williams to an arenaceous dolostone at the base of the Stonewall. Cowan (1971, p. 238) stated that it thins toward the northwest and pinches out in the Interlake region. The Williams at the type section is a very pale orange to pale red, thin bedded, argillaceous dolostone (Figure 2, Appendix A) with scattered, angular, silt-size quartz grains. No fossils occur, and one bed shows low angle, planar cross-bedding accentuated by concentrations of iron oxide pigment.

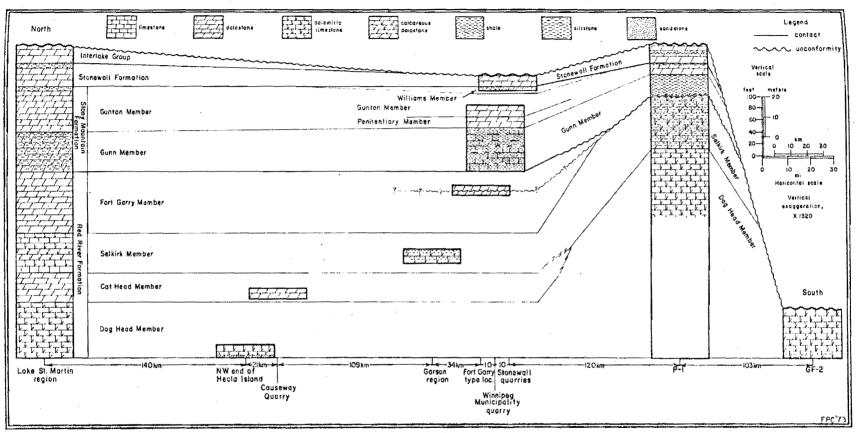


Fig. 2.--North-south cross section of exposures and cores of the Red River-Stonewall interval in southern Manitoba and eastern North Dakota. Datum--top of Winnipeg Formation. Data on Lake St. Martin region from McCabe and Bannatyne (1970).

Stonewall Formation.--The lower, Ordovician portion of the Stonewall Formation at the type locality (Cowan, 1971, p. 238), consists of 18 feet (5.5 m) of very pale orange to pale yellowish brown, thin to thick bedded, commonly mottled, finely crystalline to very finely crystalline dolostone with dolomitized fossils. The basal portion is a light greenish gray, arenaceous, very finely crystalline dolostone. An increase in argillaceous content in the dolostone produced a pale red, "nodular" (Baille, 1952, p. 55), finely crystalline dolostone with abundant burrows with a greater burrow density than the mottled dolostone (Appendix A). The angular to subrounded, sand- and silt-sized quartz detrital grains in the basal Stonewall indicate that either a monomineralic source was the only available origin for the detritus or extensive reworking caused the removal of less stable minerals, leaving only quartz. The Silurian portion of the Stonewall Formation, exposed only in the west-central Manitoba, was not studied.

Eastern North Dakota

In order to compare the Ordovician rocks of southern Manitoba with those in the subsurface of eastern North Dakota, two cores were selected from a total of eight test holes drilled by the North Dakota Geological Survey. The first core, P-1 (Figures 1, 2) was taken from a hole drilled in the northeastern corner of Pembina County, North Dakota. The second core, GF-2 came from a hole drilled in the eastern portion of Grand Forks, North Dakota.

TEST HOLE P-1 (0-505 feet [0-154 m] below surface).--The hole P-1 penetrated 303 feet (92 m) of bed rock. For complete lithologic descriptions of the units discussed below, refer to Anderson and Haraldson (1968, p. 18-20.)

Red River Formation (308-505 feet [94-154 m] below surface).--A total of 197 feet (60 m) of the Red River was penetrated. Anderson and Haraldson (1968, Figure 2) cited a total thickness of 450 feet (137 m) for the unit.

The lithology of the Dog Head Member (400-505 feet [122-154 m] below surface) is very similar to that of fresh exposures of the member along the western shore of Lake Winnipeg (Figure 2)--a massive, mottled, dolomitic limestone. No fossils were seen.

The Cat Head Member is not present in P-1 (Figure 2). Lithologies attributable to the Dog Head occupy its stratigraphic position.

The uppermost 92 feet (27 m) of the Red River Formation (308-400 feet [94-122 m] below surface) are occupied by the Selkirk Member with lithologies very similar to exposures of the Selkirk at Garson (Figure 2). One 25 foot (7.6 m) thick interval, the top of which is 27 feet (7.9 m) below the top of the Red River is exactly the same as the exposed Selkirk, with some of its characteristic fossils, <u>Receptaculites oweni</u>, <u>Armenoceras richardsoni</u>, and fragments of Grewingkia, probably G. robusta are present.

<u>Contact between Red River and Stony Mountain Formations</u> (308 feet [94 m] below surface).--A one foot thick interval, representing the basal portion of the Stony Mountain Formation is a yellowish gray limestone with micritic dolostone clasts ranging in size from 0.5 to 20 mm. This is the "breccia" of Anderson and Haraldson (1968, p. 19) and it occupies the same stratigraphic position as the Fort Garry Member in southern Manitoba (Figure 2). It indicates that the Fort Garry was either eroded or not deposited at this locality. The presence of the dolostone clasts, the absence of the Fort Garry, and the apparent

conformable bedding plane contact between the Red River and Stony Mountain Formations correspond to the criteria of Dunbar and Rodgers (1958, p. 119) for a paraconformity.

<u>Stony Mountain Formation</u> (252-308 feet [77-94 m] below surface).--The Stony Mountain is 56 feet (17 m) thick in P-1 and is apparently conformable with the overlying Stonewall Formation. Lithologies attributable to the Penitentiary Member are not present and the Gunton-type lithologies present in the Stony Mountain are more argillaceous than in southern Manitoba.

The Gunn Member (264-308 feet [81-94 m] below surface) is 44 feet (13.4 m) thick and lithologically similar to the Gunn at the type locality (Figure 2). Ten feet below the top of the Gunn, thin layers of grayish green clay are present but no fossils or bioclastic carbonates were noted.

In the "Upper Stony Mountain" (252-264 feet [77-81 m] below surface) is 2.5 feet (0.75 m) of yellowish gray, fine grained, argillaceous dolostone with small inclusions of grayish green is present. Only the argillaceous content and clay inclusions plus the stratigraphic position show this to be different from the Gunton Member. Below this 8.5 feet (2.6 m) of pinkish gray, punky, argillaceous dolostone with scattered molds of fossils are present.

Stonewall Formation (222-252 feet [68-77 m] below surface).--The Stonewall Formation is 30 feet (9.1 m) thick, thicker than the type section of the unit. Unlike the Stonewall at the type locality, there are no signs of mottling in the core samples. Fifteen feet (4.6 m) above the base of the unit several small (0.5 mm thick) inclusions of grayish blue-green clay are present. This may represent the "t horizon"

of Porter and Fuller (1959, p. 160) which Brindle (1960, p. 19) suggested represented the systemic boundary, Porter and Fuller (p. 160) described the "<u>t</u> horizon," a prominent subsurface marker, as a " . . . nonsequential bed containing numerous quartz-sand lenses interspersed through shale and argillaceous dolomite."

TEST HOLE GF-2 (0-320 feet [0-98 m] below surface).--The hole GF-2 penetrated the basal 90 feet (27 m) of the Red River Formation (Figure 2) and the uppermost 16 feet (4.9 m) of the Winnipeg Formation. Complete descriptions of the units are given by Anderson and Haraldson (1968, p. 27-29).

<u>Winnipeg Formation</u> (312-320 feet [95-98 m] below surface).--The Winnipeg Formation in the core, unlike the exposures along Lake Winnipeg, is a massive mottled argillaceous limestone or calcareous mudstone grading upward from light brownish gray with grayish red purple mottles and greenish gray clay inclusions to pinkish gray at the top.

Red <u>River Formation</u> (216-306 feet [66-93 m] below surface).--The top of the Red River Formation is formed by a post-Ordovician erosional surface at a stratigraphic level 163 feet (50 m) lower than the base of the cored interval in hole P-1 (Figure 2). This surface cuts downsection between P-1 and GF-2.

The Dog Head Member (216-306 feet [66-93 m] below surface) is a mottled dolomitic limestone similar to the Dog Head in the cores from hole P-1. The unit grades down-section into the Winnipeg Formation by an increasing argillaceous content and at a stratigraphic level of 306 feet (93 m) below the surface Anderson and Haraldson (1968, p. 28) defined the contact between the Winnipeg and Red River Formations.

Southern Manitoba to Eastern North Dakota

A north-south cross-section line from the Lake St. Martin region through the Lake Winnipeg and Winnipeg regions to the test hole sites in North Dakota shows the following (Figure 2):

- 1. The Red River Formation thickens southward.
- The Cat Head Member loses definition between the exposure near Hecla Island and northeastern North Dakota in hole P-1.
- 3. The Dog Head Member is continuous throughout the section and thickens toward the south.
- 4. The Selkirk Member is continuous from the Garson region southward to northeastern North Dakota, but loses the dolomitic mottling northward, and contains microcrystalline dolomitic limestone and calcareous dolomite (McCabe and Bannatyne, 1970, p. 15).
- 5. The Fort Garry Member pinches out southward from the type section with its stratigraphic position occupied by a paraconformity in northeastern North Dakota (P-1).
- 6. The Gunn Member of the Stony Mountain becomes dolomitic northward (McCabe and Bannatyne, 1970, p. 16) from the type area, and becomes less calcareous southward from the type area.
- The Penitentiary Member loses definition northward and southward from the type areas.
- The Gunton Member becomes more argillaceous southward from the type area.

- 9. The Williams Member may be represented in the Lake St. Martin area by the argillaceous interval at the top of the Gunton and may be partially represented in the argillaceous character of the uppermost interval of the Stony Formation in northeastern North Dakota.
- The post-Ordovician erosion surface trends downsection southward in eastern North Dakota (P-1 to GF-2).

Northern Wyoming

Upper Bighorn Formation. --- The Ordovician carbonate section exposed in the Bighorn Mountains---the Bighorn Formation, is currently divided into an unnamed lower massive portion ("lower Bighorn"), a central thin bedded portion (the Leigh Member), and an unnamed upper, thin bedded, and massive dolostone referred to as "upper Bighorn" by Macomber (1970). Macomber (1970) informally termed part of this upper Bighorn the "Hunt Mountain beds." This part of the section and the overlying Ordovician strata were sampled faunally and lithologically. Part of the strata above the Hunt Mountain beds is covered by overburden and vegetation and stratigraphic description was based on float.

Forty-two feet (13 m) of the "upper Bighorn" directly underlying the Hunt Mountain beds were sampled. The lithology is a medium- to thick-bedded, very pale orange, finely crystalline dolostone with chert nodules. Few fossils occur and no corals were present. The contact of these strata with the overlying Hunt Mountain beds is marked by a thin bed of shale, an upward change in lithology from a dolostone to an argillaceous limestone, and an increase in fossil content.

The Hunt Mountain beds are approximately 16 feet (4.9 m) thick at the Hunt Mountain locality (A544, 546), and consist of thin bedded,

grayish-orange, argillaceous bioclastic limestone interbedded with thin beds of burrowed, calcareous, silty shale of the same color. The beds are fossiliferous, and corals are primarily small and solitary. No colonial rugosans occur in these strata but several species of the tabulate genus <u>Paleofavosites</u> are present. Macomber (1970) considered this unit to be correlative with the Gunn Member of the Stony Mountain Formation.

The transition between the Hunt Mountain beds and the overlying strata is marked by a significant reduction in the argillaceous content in the basal portion of these overlying strata. The total thickness of the overlying strata is 57 feet (18 m). The basal 13 feet (4 m) are exposed and the remaining 44 feet (13.5 m) are covered by soil and vegetation. The lower 28 feet (8.5 m) of the interval is a thin bedded, very pale orange, fossiliferous limestone ranging in texture from biomicritic to coarse crystalline. The base of the interval is argillaceous but the argillaceous content decreases rapidly upsection. <u>Calapoecia ungava</u> Cox, <u>Paleofavosites</u> spp., <u>Palaeophyllum pasense</u> Stearn, a large <u>Lobocorallium</u> <u>trilobatum</u> (Whiteaves), and <u>Cyathophylloides hollandi</u> n. sp., were the only corals collected.

From 28 to 57 feet (8.5 to 18 m) above the base of the unit, the lithology changes to a thin bedded, grayish orange, medium crystalline dolostone with abundant pore spaces (5 percent of the total rock volume) formed by the molds of fragmental skeletal material. The dolostone is secondary, composed of euhedral dolomite rhombs. It is burrowed and the dolomite in the region of the burrows is more finely textured than the dolomitic rock matrix. A large cateniform rugose corallum was collected as float from this dolomitic interval; <u>Palaeophyllum sinclairi</u> n. sp.

represents the most advanced colonial rugosan encountered in the study. Corals of the argillaceous Hunt Mountain beds are generally relatively abundant, small, solitary rugosans. Colonial forms are usually very small. The reduction in argillaceous content in the rocks overlying the Hunt Mountain beds is accompanied by an increase in colonial corals and the near absence of solitary types.

Depositional History

Southern Manitoba and Eastern North Dakota.--The Red River Formation in the Williston Basin and its peripheral region is a transgressive sequence of epeiric, marine carbonates onlapping a relatively stable, cratonic platform. The transgression was initiated at the onset of the development of the Tippecance Sequence of Sloss (1963, p. 97). This onlap unconformably covered pre-existing Cambrian and Early Ordovician sediments deposited in a previous onlap-offlap cycle termed the Sauk Sequence (Sloss, p. 95). The marine advance during the early portion of the Tippecance Sequence covered not only preexisting sedimentary rocks, but also rocks of the Canadian Shield.

The basal sediments (Winnipeg Formation) deposited near the margins of the transgressing Ordovician sea mark the transgressive phase onto the cratonic platform, and over the Williston Basin, an active, intracratonic depositional basin within the platform. The Basin was first active as a depositional center during the sedimentation of the Winnipeg Formation since it is the oldest rock unit to have its depocenter nearly coincident with the basin center (Fuller, 1961, figure 7). The Red River Formation, overlying the Winnipeg, and its physical equivalents, have been traced from New Mexico to

Greenland (Porter and Fuller, 1959, p. 146), and represent the maximum transgression of the Ordovician sea.

On the cratonic platform east and north of the Williston Basin, in southern Manitoba and eastern North Dakota, the transgression began with deposition of the Winnipeg, and continued until the time of Red River deposition when the transgression reached its maximum. The extent of the transgression was stated by Fuller (1961, p. 1362): "Ordovician rocks of the Williston basin are a remnant of a once much more extensive sheet that extended in direct communication from the Appalachian geosyncline to the Cordilleran geosyncline." Fuller (1961) demonstrated that the Red River and its physical equivalents extended across the site of the Sioux Arch (p. 1356) in continuity with the Viola Formation in the subsurface of Nebraska and northern Oklahoma. Toward the northeast, Porter and Fuller (1964), and McCabe (1967) demonstrated that the Red River was formerly continuous with the Bad Cache Rapids Group of the Hudson Bay region (Nelson, 1963, p. 7; Cumming, 1971, p. 189).

The Red River Formation is characterized by mottled bioclastic limestones in the Dog Head Member in southern Manitoba. As evidenced by the near absence of terrigenous clastics, the occurrence on a cratonic platform, and the abraded condition of fossils and their fragments, the depositional environment was shallow, and there was low relief with no incoming terrigenous clastics except for a small amount of clay-sized suspended particles. The reduction in clastic sedimentation that prevailed during Winnipeg deposition permitted the establishment and development of a diverse coelenterate fauna, including several species of solitary and colonial corals: <u>Catenipora</u>, <u>Calapoecia</u>, <u>Streptelasma</u>, and <u>Grewingkia</u>.

The Cat Head Member does not extend southward into North Dakota (Figure 2). Dolomite rhombs (Folk, 1968) suggest a secondary dolostone. The faint mottled character and the complete recrystallization of the Cat Head carbonate show that the original lithology may have been a bioclastic, burrowed sediment similar to the Dog Head. According to Folk (1968, p. 170) secondary dolostones such as those in the Cat Head occur in warm, shallow waters of higher than normal marine salinity associated with "submarine 'highs'."

Since the southern end of the study area (test hole P-1) does not contain the Cat Head Member it indicates that the secondary dolomitization process was geographically restricted to the region near Lake Winnipeg (Figure 2). If shallow warm, hypersaline waters were responsible for controlling the dolomitization process and were restricted to where the Cat Head occurs, it suggests shallowing of a portion of the Ordovician sea. Lithologies characteristic of the Cat Head Member do not occur in the Williston Basin. This suggests that shallow, warm, hypersaline water occurred mainly along the margins of the basin.

After deposition and dolomitization of the Cat Head the Ordovician sea evidently deepened in the region where the Cat Head lithologies were formed. This initiated the deposition of burrowed bioclastic carbonate sediments similar to those of the Dog Head Member. A slight increase in terrigenous clay resulted in an earthy character seen in the Selkirk Member. Deposition of the Selkirk was accompanied by an environment favorable for the establishment of a diverse marine fauna. Large, massive, commonly lamellar coralla are characteristic of the fauna existing on the sea floor during Selkirk deposition. Representative genera

are <u>Nyctopora</u>, <u>Trabeculites</u>, <u>Manipora</u>, <u>Calapoecia</u>, <u>Coccoseris</u>, <u>Protro-</u> <u>chischolithus</u>, <u>Catenipora</u>, and <u>Crenulites</u>. Solitary corals are a relatively minor component of the Selkirk coral fauna and are represented by four genera, <u>Streptelasma</u>, <u>Grewingkia</u>, <u>Bighornia</u>, and <u>Dieracorallium</u>.

Termination of deposition of the Selkirk Member was caused by a widespread regression of the Ordovician sea which produced a widespread regional unconformity at the top of the Red River Formation and its physical equivalents (Figure 3) outside the Williston Basin region. Within the Basin and areas peripheral to it, the regressive phase was accompanied by deposition of the diastemic Fort Garry, the formation of a paraconformity in northeastern North Dakota, and the deposition of the "upper Red River" in the Basin.

The Fort Garry Member, at its type locality, indicates by its diastemic character that the depositional process was interrupted repeatedly at about the same time the northeastern region of North Dakota was exposed and eroded. The presence of lithographic micritic dolostone ("dolomicrite" of Folk, 1968) at the base of the type section suggests according to Folk (1968) a dolostone which was probably formed as a direct dolomite precipitate or dolomitized very soon after deposition in a warm hypersaline environment such as a "semi-evaporitic" lagoon (Folk, 1968, p. 170).

Above the presumably hypersaline-lagoonal micritic dolostone, the Fort Garry consists of reddish clay to clayey dolostone with imbricate, dolostone pebble interclasts indicative of supratidal conditions (Roehl, 1967, p. 2007). This clay is most likely from a terrigenous source but no other terrigenous sediments are found in association with it. Roehl (p. 2018), in comparing Paleozoic carbonates with modern

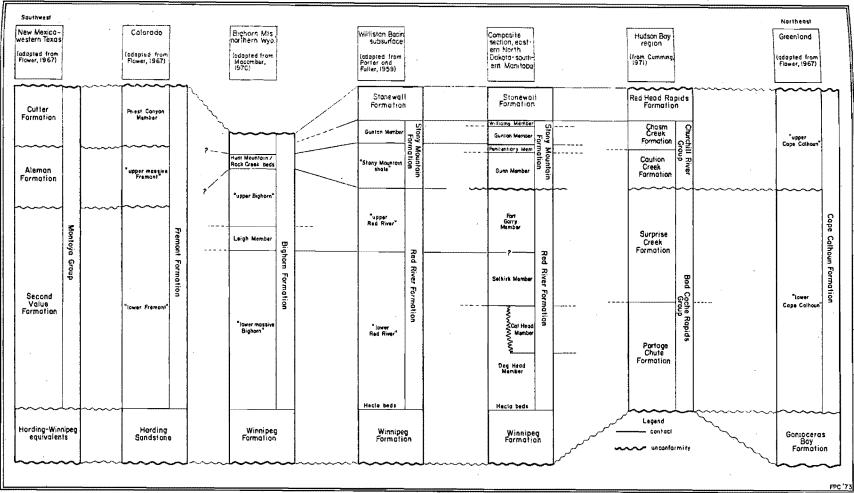


Fig. 3.--Nomenclature and relative positions of lithostratigraphic units in the middle and upper part of the Ordovician in a belt from New Mexico to Greenland. No thickness scale is implied; however, thicknesses are approximately proportional within each column. The Hunt Mountain/Rock Creek beds and the Gunn Member of the Stony Mountain Formation are herein considered to be correlative.

carbonate sediments, termed such a clay a terra rossa and commented on its presence in modern supratidal environments.

Above the "terra rossa" in the Fort Garry another lithographic dolostone is present. It is identical to the underlying dolostone (Appendix A) and reflects a change from supratidal to hypersaline environments. A return to normal marine conditions and at least partial submergence of the type area is shown in the thick bedded sequence of apparently secondary mottled dolostone overlying the lithographic dolostone. The mottling reflects the presence of a burrowing fauna which probably did not exist under supratidal or hypersaline condi-The presence of fragments of Calapoecia, Paleofavosites, and tions. Catenipora indicate that marine conditions favorable to coral life were nearby. According to Roehl (1967, p. 1987) the western margin of the Williston Basin (the Cedar Creek Anticline region) was the site of a northwest-southeast oriented series of mud banks situated on the site of a "major metastable lineament" (p. 1987) that operated during portions of the Ordovician Period as a partially restricting barrier between the Williston Basin area and the more open portion of the Ordovician sea to the west and southwest. Eustatic reductions of sea level may have reduced marine access to the Williston Basin region, resulting in the deposition of one of the rhythmic evaporite cycles described by Porter and Fuller (1959) in the "upper Red River" of the Basin.

The Fort Garry Member and the "upper Red River" are absent in the core sections of P-1 in northeastern North Dakota. A paraconformity separates the Selkirk Member of the Red River Formation from the overlying Gunn Member of the Stony Mountain Formation (Figure 2). The beds

immediately above the paraconformity contain micritic, flat pebble intraclasts. Considerable erosion or nondeposition occurred, indicating subaerial exposure while the Fort Garry Member in the type area lay within the infratidal to supratidal environments.

The Gunn Member of the Stony Mountain Formation in the type area consists of lenses and beds of argillaceous bioclastic limestones alternating with extensively burrowed, highly fossiliferous, calcareous shale. Roehl (p. 1993) described recent burrowed sediments from the intertidal zone of the Bahamas, and by comparison concluded that dense, burrowed sediments in the Stony Mountain Formation were reworked by infaunal sediment feeders within the intertidal and infratidal zones. The source of terrigenous clastics occurring in the Gunn Member in southern Manitoba and the Stony Mountain shale in the Williston was thought by Porter and Fuller (1959, p. 155) to have come from the southeastern part of the Williston Basin periphery. This is probably an example of uplift of a portion of the cratonic platform southeast of the basin margin in the vicinity of the Sioux Arch (Figure 1). Cowan (1971, p. 240) believed that Gunn Member "Stony Mountain shale" sedimentation, by virtue of a well developed coral-bryzoan fauna, indicated that a transgressive phase of the Ordovician sea was under way. This idea of Cowan's is partially borne out, in my opinion, by the widespread distribution of the coral fauna of the Gunn Member in other regions. Coral species common to the Gunn were observed in the correlative strata in the Bighorn Mountains (the Hunt Mountain beds), and in the Caution Creek and Chasm Creek Formations of the Hudson Bay Region (Nelson, 1963). The coral faunas were able to migrate freely, indicating that fairly open

marine conditions must have existed away from the Williston Basin dur-

The onset of Gunton sedimentation, according to Cowan (1971, p. 240), marked the beginning of a second regressive phase of the Ordovician sea with the lower portion of the Gunton representing a shallow intertidal environment. This is probably about the time that the "G anhydrite" of the Gunton in the center of the Williston Basin was deposited (Fuller, 1961, p. 1350).

The middle portion of the Gunton was thought by Cowan (1971) to represent a third, short lived transgression of the sea since this portion is fossiliferous in southern Manitoba. Williams Member sedimentation marked still another regression of the sea as evidenced by the cross-bedded (Appendix A) aspect of the arenaceous and argillaceous dolostone and its content of quartz grains which Smith (1963, p. 117) reported had a similarity to beach sand.

The lower part of the Stonewall Formation marked the final transgression of the sea onto the cratonic platform east of the Williston Basin by the reappearance of a coral fauna, in the type section represented by Paleofavosites, Angopora, and Tryplasma.

Cowan (1971, p. 240) considered the top of the Ordovician System to be marked by a final regression of the Ordovician sea producing the arenaceous "t-marker" of Porter and Fuller (1959).

<u>Northern Wyoming</u>.--The thin stratigraphic interval of the "upper Bighorn" appears to show a pattern of transgressions and regressions roughly similar to that deduced by various workers for the Ordovician section in southern Manitoba and the Williston Basin. Evidence for a regressive phase during deposition of the Bighorn Formation is a

breccia zone at the top of the Leigh Member (Macomber, 1970, text-figure 2). This indicates that the strata underlying the massive dolostone below the Hunt Mountain beds may have been subaerially exposed.

The upward change from the sparsely fossiliferous massive dolostone to the fossiliferous argillaceous limestone in the Hunt Mountain beds, and a coral fauna that has species common to the Gunn in southern Manitoba and the Caution Creek and Chasm Creek Formations in the Hudson Bay region indicate transgression and faunal migration among the three regions. This change, plus the corals, indicates relatively open marine conditions permitting migration. The Hunt Mountain/Rock Creek beds, correlative with the Gunn Member, evidently received the argillaceous clastics at the same time and from the same source as did the Gunn. This was also demonstrated by Porter and Fuller (1959, figure 11) who showed the subsurface continuity of the "Stony Mountain shale" from southern Manitoba to near the Bighorn region, and by Macomber (1970, p. 420) who stated that the shale could be traced to within 50 miles of the Bighorn Mountains.

The thin bedded limestones directly overlying the Hunt Mountain beds (Appendix A) contain a colonial coral fauna which indicates normal marine conditions prevailed after deposition of the Hunt Mountain beds. These limestones are the non-argillaceous version of the Hunt Mountain beds, resulting from the termination of deposition of terrigenous clastics.

The marine depositional conditions prevailing after deposition of the Hunt Mountain beds contrast with conditions in southern Manitoba during post-Gunn/Hunt Mountain time. The portion of the Stony Mountain Formation above the Gunn Member, especially the Gunton Member, reflects,

according to Cowan (1971), a regressive phase of the Ordovician sea. The limestone overlying the Hunt Mountain contains the colonial coral <u>Palaeophyllum pasense</u> that is also present in the Ordovician portion of the Stonewall Formation in Manitoba (Stearn, 1956, p. 90). The limestone has at least one species in common with the Stonewall and this hints at a tenuous, faunally based correlation between the two.

The uppermost part of the Bighorn Formation which overlies the Hunt Mountain beds (Figure 3) is a thin bedded, medium grained dolostone with euhedral dolomite rhombs and molds of fossil material (Appendix A). These lithologic characters correspond to Folk's (1968) criteria for secondary dolostones. The presence of <u>P. pasense</u> in these dolostone strata indicates that the sediments were deposited under normal marine conditions. The exact time of dolomitization is not known but is probably post-burial.

Physical Equivalence of Units

Virtually every worker who has dealt with the Red River Formation has commented on the widespread occurrence of Red River-like strata from New Mexico to Greenland (Figure 3). Flower (1967), Patterson (1961), and Fuller (1961), to name three recent workers, maintained that the advance of the Ordovician sea inundated almost the entire North American craton. The resulting sedimentary rock units, the Winnipeg Formation and the overlying Red River Formation, have physically equivalent strata approaching continental scale (Fuller, 1961, p. 1362).

Flower (1967) stated that the marine transgression that deposited the Red River Formation and its physical equivalents was the second advance during the Ordovician. He based his conclusion on an

erosional interval in the western Texas-New Mexico area between the Harding-Winnipeg equivalents (Figure 3) and the overlying Second Value Formation. The Ordovician section along the periphery of the Williston Basin shows no evidence of such an erosional interval at the base of the Red River.

Fuller (1961) noted that the Winnipeg-Red River contact is conformable (p. 1345) in the Basin interior. At least in the Basin, the Ordovician sea did not retreat enough to produce an erosional surface. The top of the Red River is marked by a prominent and widespread erosional surface at the edge of the Williston Basin itself and in many regions widely separated from it (Figures 2, 3; Flower, 1967, p. 113, Cumming, 1971, table 1).

The Stony Mountain Formation represents the second Ordovician Williston Basin transgression (third transgression of Flower, 1967). On the basis of coral faunas, similar lithologies, and stratigraphic position, correlative strata extend at least from the Hunt Mountain/Rock Creek beds through the Gunn Member of the Stony Mountain Formation to the Chasm Creek and Caution Creek Formations of the Churchill River Group in the Hudson Bay region. Furthermore, Flower (1967, p. 125) stated that strata physically equivalent to the Stony Mountain Formation extend from the Aleman Formation in New Mexico to the upper portion of the Cape Calhoun Formation in Greenland.

The New Mexico sections show a distinct erosional interval between the probable Stony Mountain and Stonewall equivalents, the Aleman and Cutter Formations (Flower, 1967, figure 5), representing the third Ordovician regression in New Mexico. A partial regression between the two southern Manitoba formations is shown where sand- and

silt-sized quart grains are present between the Williams Member of the Stony Mountain Formation and the basal part of the Stonewall.

Physical equivalents of the Stonewall, representing the final Ordovician transgression during Ordovician time, are traceable from the Cutter Formation in New Mexico through the Stonewall type area to the Red Head Rapids Formation, in the Hudson Bay region (Figure 3).

CORAL FAUNAS

Definition of "Arctic" Fauna

The term "arctic" has been used to denote the macrofauna occurring in the Red River Formation and its equivalents. The term usually has been used for the large, massive, colonial corals, receptaculitids, gastropods and cephalopods of these units. This term is misleading because it has Holocene climatic implications that do not reflect the Ordovician paleoclimate and paleogeography. It was coined due to the presence of large fossils in the region of northwestern Greenland and Baffin Island that once were thought to have migrated from the "Arctic Islands" region (Nelson, 1959a, p. 45) southward toward New Mexico. The fossil assemblage ranges in geographic extent from New Mexico to Greenland in a northeast-trending belt of Ordovician carbonates physically equivalent to the Red River Formation.

Flower (1946, p. 120) used "boreal" for the faunal elements that invaded the Cincinnati region during Trentonian time because they came from northern waters. Conversely, "austral" referred to those invading the area from the south. He suggested (p. 126) that the fossils such as those in the Red River Formation were tropical due to their large size and their occurrence in the New Mexico-Greenland belt, and that the "austral" fossils were more typical of temperate climates.

Recently, "arctic" has been restricted to the Red River faunas (Nelson, 1963, p. 21; Cumming, 1971, p. 194) and their correlatives.

present usage favors "arctic" over "boreal" (Cumming, 1971). "Arctic" is hampered in that no suitable counterpart exists for the "austral" faunas of the Ordovician of the eastern interior of the continent.

Paleoclimate and Paleogeography

The "arctic" faunas were thought by Flower (1946) and Nelson (1959a) to reflect tropical climatic conditions. Flower concluded that the large sizes of individuals in the fauna were representative of tropical conditions. Nelson suggested that the "arctic" faunas delineated a tropical climatic zone on the basis of their elongate distribution along the New Mexico-Greenland belt. The idea of the New Mexico-Greenland belt defining a climatic zone was first suggested by Flower (1946, p. 127):

. . . it may be possible to trace a faunal realm embracing these different regions. It [the "austral" region] would form essentially an arc, roughly concentric with and lying within the larger arc [the "boreal" faunal realm] extending from Colorado to Greenland, and which we have ventured to interpret as a tropical realm.

He concluded (p. 127): "It is surprising and reassuring, that this concept is not widely different from the pangaea [sic] for the Ordovician as postulated by Grabau on the basis of quite other evidence." He mentioned that a probable position for a polar region lay in the vicinity of Africa, basing this on the present position of the North American crustal plate. Nelson (1959a, p. 46) followed Flower's ideas and suggested that polar wandering, continental drift, or crustal rotation was responsible for "the anomalous distribution of the 'Arctic' fauna in relation to present-day light [solar] conditions."

Cumming (1971, p. 194) summarized the current concept of Ordo-Vician climatic patterns. Sougy (1964; <u>fide</u> Cumming, 1971) found early Paleozoic tillites in northern Africa, and Fairbridge (1970) summarized the evidence for an Ordovician glacial period in North Africa and an African location for the Ordovician South Pole. Fairbridge's conclusion on pole position agreed with Flower's earlier deduction based on different evidence.

Fell (1968, p. 142) placed the Ordovician equator near the east coast of the North American continent and Cumming (1971, p. 194) delineated a "tropical moist zone," between northeast-trending northern and southern arid climatic belts.

Smith, Briden, and Drewry (1973) constructed provisional and world maps for the Phanerozoic eon. Their Cambrian/early Ordovician interpretation of continental plate location and orientation (Figure 4) shows the North American plate and the associated Canadian Arctic islands to lie well within the Cambrian/Ordovician equatorial zone. Based solely on geometrical and geophysical data, the position of the continental plate with respect to the equator and its accompanying climatic zone agrees with Flower's (1946) suggesting a tropical climate for his "boreal" faunal realm.

Smith, Briden, and Drewry also determined the position of the Cambrian/Ordovician paleogeographic South Pole on geophysical evidence, placing it in what is now the northwestern corner of the African plate (figure 21A). This also agrees with Flower's (1946) suggestion of that pole in the African region. The Cambrian/Ordovician equator shown by Smith, Briden, and Drewry (Figure 4) cuts right through the "boreal" faunal realm of Flower (1946) defining its geographic position on geophysical evidence as equatorial. Comparison of Figure 4 (adapted from Smith, Briden, and Drewry, 1973, figure 13) with Cumming's illustration

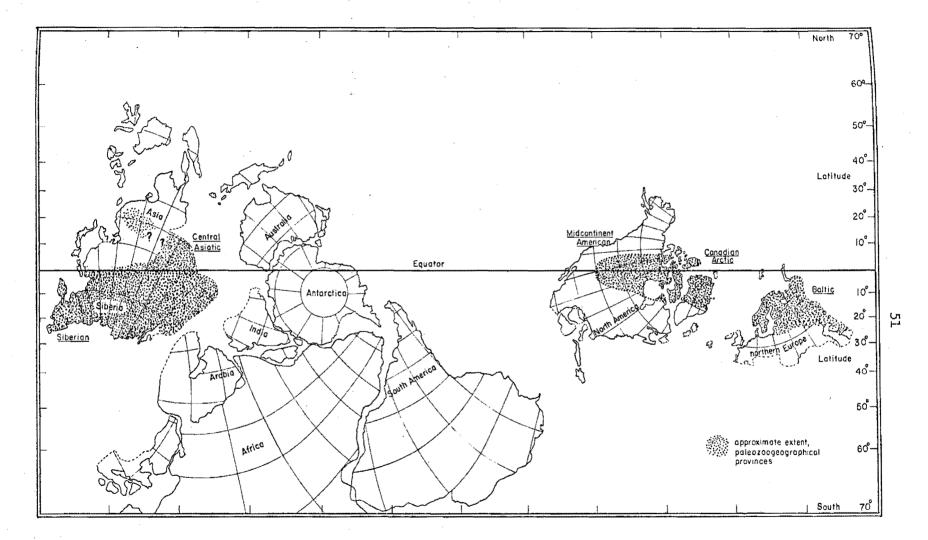


Fig. 4.--Distribution of continental plates during Cambrian/Early Ordovician time (modified from Smith, Briden, and Drewry, 1973). Modified paleozoogeographical provinces (underlined) adapted in part from Leleshus (1971).

of Ordovician climatic zones (1971, figure 5) shows a variance between the locations of the Ordovician equator. Cumming's interpreted equatorial regions trend northeastward off the present east coast of North America and southeastward across the Eurasian continent on a line between eastern Scandinavia and India. Figure 4 shows that the conclusion of Smith, Briden, and Drewry agrees with that of Cummings for northern Europe.

Paleozoogeographic tabulate coral provinces proposed by Leleshus (1971) show that tabulate genera occur in four provinces: Baltic, Central Asian, Siberian, and Arctic--all of which lie close to the equatorial position proposed by Smith, Briden, and Drewry (Figure 4).

The "boreal" faunal realm, as originally proposed by Flower (1946), is a probable tropical zone by virtue of its proximity to the equator as proposed by Fell (1968); and Smith, Briden, and Drewry (1973). Since there is a 30 degree difference in latitute between the two suggested equatorial positions, the use of Fell and Cumming's interpretation would refer to the paleogeographic position as northern with an arid climate whereas the alternate interpretation of Smith, Briden, and Drewry would be equatorial arid.

Aridity of the climate was proposed by Cumming and is demonstrated by the evaporitic cycles in the "upper Red River," the Stony Mountain, and Stonewall Formations in the Williston Basin, the <u>terra-</u> <u>rossa</u>-like clays in the type section of the Fort Garry Member, and abundant secondary dolostones in southern Manitoba.

Equatorial Faunas

The character of "arctic," plus the restriction of the term to the faunas of the Red River Formation and its lateral equivalents,

limit its usage. One term, which can encompass the Red River-Stonewall interval, its physical equivalents and contained faunas is "equatorial." It describes the paleogeographic position of the New Mexico-Greenland belt of Ordovician rocks, based on very recent geophysical evidence (Smith, Briden, and Drewry, 1973), and is used in this study for Ordovician rocks and faunas in the New Mexico-Greenland belt.

The term is used in the paleogeographical sense and contains no climatic implications other than those resulting from location in an Ordovician equatorial zone. It is used in this study to refer to the faunas occurring from New Mexico to Greenland and, within the areas studied, to refer to coral faunas present within the Red River-Stonewall interval and the Bighorn Formation.

Equatorial corals.--Coral faunas referred to as "arctic" by other workers are well developed in the Selkirk Member of the Red River Formation. They are characterized by massive-hemispherical, ceroid and cateniform coralla of the orders <u>Tabulata</u> and <u>Rugosa</u> (Table 1). Most of the colonial coralla are large, up to one meter in diameter and are lamellar, composed of successive layers of skeletal material interspersed with carbonate sediment. Only one rugosan colonial coral, <u>Paleophyllum argus</u>, was not massive.

Solitary corals are in a distinct minority in the faunas in the Red River, both in terms of numbers of species and numbers of individual coralla. Only representatives of one genus, <u>Grewingkia</u>, are large. The other solitary genera are represented by no more than three very small individuals. Often, only one individual of a genus was available for study.

TABLE 1.--Distribution of coral genera in post-Winnipeg strata in northern Wyoming and southern Manitoba. Question marks indicate listings of Dowling for the Dog Head and Cat Head Members

		Rec	l Riv	er Fm.	•	Sto	ony M Fm	lountai	in	St		Bighc Fm.		
	Genera	Dog Head	Cat Head	Selkirk	Fort Garry	Gunn	Penitentiary	Gunton	Williams	tonewall Fm.	lower massive	Hunt Mt. beds	0-26 ft above beds	26-57 ft above beds
Order Ta	Trabeculites Nyctopora Manipora Calapoecia Protarea Coccoseris	?		X X X X X	x	X	?	?				x	x	
Tabulata	Protrochischolithus Paleofavosites Angopora Favosites Catenipora	? X	?	X X	X X	x x	x	X		X X	X	X X	Х	
Rugosa	Streptelasma Palaeophyllum Grewingkia Lobocorallium Dieracorallium	x		X X X X		X X X	x x			х	X	X X X	x x	X

TABLE 1.--Continued

					- 1		•				· · · · · · · · · · · · · · · · · · ·			+
	Genera	Dog Head	Cat Head	Selkirk	Fort Garry .	Gunn	Penitentiary	Gunton	Williams	Stonewall Fm.	lower massive	Hunt Mt. beds	0-26 ft above beds	26-57 ft above beds
Rugosa				X X		X				x	X	x	x	
	Order Tabulata, % Order Rugosa, %	60 40	100	54 46	100 0	43 57	50 50	100 0		66 33	33 66	50 50	66	0 100
	Colonial genera, % Solitary genera, %	60 40	100	69 31	100 0	42	50 50	100		100	<u>33</u> 66	50 50	66 33	100 0

One characteristic of the coral fauna in the Red River is the development of a lateral angulation on the cardinal side of the coralla of <u>Grewingkia</u> and <u>Dieracorallium</u>. All solitary corals are closely related or show fairly direct descendence from the genus Streptelasma.

The coral fauna of the Stony Mountain Formation differs from the Red River fauna. The colonial genera are not as abundant as in the Red River (Table 1). Most are favositids, and no descendency from the Red River colonial forms is apparent. The solitary rugosans, on the other hand are predominantly angulate and have ancestral forms in the Red River since the genera <u>Streptelasma</u>, <u>Bighornia</u>, and <u>Dieracoral</u>lium are common to both the Red River and Stony Mountain faunas.

Ordovician Coral Faunas

<u>Generic content</u>.--Of the 20 genera encountered in the study 14 of them (70%) occur in the Red River Formation and eight (40%) were collected from the Stony Mountain Formation.

In northern Wyoming only three genera (15%) were collected or documented from the lower massive portion of the Bighorn Formation. The Hunt Mountain beds in the "upper Bighorn" contain eight genera (40%), the most diverse fauna found in the formation. The lowermost 28 feet (8.5 m) of strata overlying the Hunt Mountain beds contain five genera (25%) and the higher interval yielded only one genus.

The equatorial faunas, when broken down into generic taxa, are predominantly tabulate colonial (Table 1). The fauna of the Gunn Member shows a generic shift toward solitary rugose corals, <u>Streptelasma</u> or genera descendent from it. The fauna of the Penitentiary Member is basically the same as that of the underlying Gunn, but not all the

rugose genera present in the Gunn persisted in the Penitentiary deposi-

The fauna in the lower part of the Bighorn Formation is not completely represented but it shows a definite relationship to the fauna of the Red River Formation. The Hunt Mountain beds contain the same rugose genera as does the Gunn Member, but part of the tabulate genera in the beds are the same as those in the Red River Formation (Table 1).

The basal 28 feet (8.5 m) of the strata overlying the Hunt Mountain beds yielded genera that have affinities with the coral faunas of both the Gunn and Red River. <u>Lobocorallium</u> and <u>Paleofavosites</u> occur in both the Hunt Mountain beds and the Gunn, but <u>Calapoecia</u> is found in the Selkirk Member of the Red River Formation and the Gunton Member of the Stony Mountain Formation. The dolomitized portion of the strata overlying the Hunt Mountain beds (Appendix A) contained one collectable genus, Palaeophyllum.

<u>Geographic Distribution of Genera.</u>--Many of the tabulate and rugose genera in the study are not restricted to North America. Ivanovsky (1966) and Leleshus (1971) considered the world-wide distribution of Ordovician rugose and tabulate genera. Their tabular data divided the generic distribution into Middle and Late Ordovician assemblages. I have adapted and modified the tables of both and limited the tables to the genera found in the study to illustrate the distribution of the genera in question (Table 2).

Several genera, especially <u>Paleofavosites</u> and <u>Catenipora</u>, are <u>Very</u> widely distributed. Others, such as <u>Nyctopora</u>, <u>Calapoecia</u>, <u>Palaeophyllum</u>, <u>Streptelasma</u>, and <u>Grewingkia</u> are widely distributed <u>outside</u> the North American continent and the Arctic Islands. All of

Rug	ose data from Ivanov	sky	y (.	196	6, 1	ab.	les	3,	4)									
	Paleozoogeographic Provinces	al	Mi d-	Continent	rrovince	Canadian	Arctic		Baltic	Province	Central	Asian	<i>L</i> TOVINCE		Arctic	Province		
	Genera	THOTADAAA	New Mexico	Wyoming	Southern Manitoba	Hudson Bay	Arctic Islands	Greenland	Baltic Region	Scandanavia	Urals	Kazakhstan	Central Asia	China	Southwest Siberia	Siberian Platform		
Order Tabulata	Trabeculites Nyctopora Manipora Calapoecia Protarea Coccoseris Protrochischolithus Paleofavosites Angopora Favosites Catenipora	3	x x x x x x x x x	x x x x x x x x	X X X X X X X X X X X X X	x x x x x x	x	? X X X	x x x	x x	x x x x	x x x x	x x x	x	x x x x	x x x x		
Order Rugosa	<u>Streptelasma</u> <u>Palaeophyllum</u> <u>Grewingkia</u> <u>Lobocorallium</u> <u>Dieracorallium</u> <u>Bighornia</u> <u>Crenulites</u> <u>Cyathophylloides</u> <u>Tryplasma</u>		x x x	X X X X X X X X X	X X X X X X X X	X X X X X	x x	X X X ? X	x x x	x x	X	-			X X	x	•	

TABLE 2.--Distribution of Middle and Late Ordovician coral genera encountered in study. Tabulate data from Leleshus (1971, tables 1, 2). Rugose data from Ivanovsky (1966, tables 3, 4)

the above genera, with the exception of Paleofavosites, were listed by Ivanovsky (1966, table 3) and Leleshus (1971, table 1) as originating during Middle Ordovician time. This may reflect the amount of geologic time these genera had during the Ordovician to extend their geographic range and adapt to varying marine environments. Solitary rugosans such as Dieracorallium and Bighornia, descendants of Streptelasma, and Lobocorallium, a descendant of Grewingkia, appear to have arisen from their ancestral genera within the Canadian Arctic or Mid-continent provinces. Kaljo and Klaamann (1973, p. 38), following work initiated by Ivanovsky and Leleshus, deduced that during Middle Ordovician time " . . . the developmental centre of the Middle Ordovician coral fauna was most essentially situated in the seas of North America. The latter were faunalistically very closely connected with the northern seas of Siberia." The close faunal connection of the North American and Siberian regions does not agree with the geophysically based paleographic reconstructions of Smith, Briden, and Drewry (1973) who placed the Siberian crustal plate halfway around the globe from the North American plate (Figure 4). Perhaps the close faunal connection indicates a closer proximity of the two plates than geophysical data show. Precedents exist in which paleozoogeographic distribution of biotas precede geophysical confirmation.

Kaljo and Klaamann (1973, p. 39) recognized two main faunal provinces--"Americo-Siberian" and "Eurasiatic"--the latter of which was subdivided by them into "Central-Asiatic" and "European" subprovinces on the basis of nonuniform generic content. According to them (p. 39) Late Ordovician coral faunas were characterized by about 70 genera, many of which became extinct at the end of the period, and many of which were

The Canadian Arctic and Mid-continent provinces are zoogeographical regions used here to denote the Arctic Islands-Hudson Bay region, and the southern Canada to New Mexico region; they are used in the manner of Leleshus (1971, p. 429). Table 2 shows that the Canadian Arctic province contains 15 of the 20 genera present in the Mid-continent province. The use of a formula of resemblance (Long, 1963) gives an expression of the presence of the coral genera studied in Leleshus' (1971) and my zoogeographical regions (Table 3): $_{R=} C (N_1 + N_2)$ in which R=dimensionless expression of degree of resemblance; C=number of genera common between regions, N1=number of genera in smallest regional fauna, and N2=number of genera in largest regional fauna. The formula is used only to illustrate the degree of resemblance of the Euro-Asiatic provinces to the Midcontinent and Canadian Arctic in terms of the 20 genera studied in the Mid-continent provinces. The resemblance value is only representative of how many of the 20 genera are present in the other regions. As would be expected, the Mid-continent and Canadian Arctic regions have the greatest degree of resemblance since most if not all of the genera occur in both regions. The Euro-Asiatic provinces show a lesser degree of resemblance, and the central Asiatic provinces has the fewest of the genera. Table 3, albeit combining both Middle and Late Ordovician coral genera studied, illustrates that the Midcontinent and Arctic provinces both show a greater resemblance to the Siberian province than to the others. This is based only on the genera I studied, but still it tends to vindicate Kaljo's and Klaamann's "Americo-Siberian" province.

TABLE 3.--Degrees of resemblance between genera studied in paleozoogeographical regions. Euro-Asiatic regions from Leleshus (1971). Resemblance formula from Long (1963)

Paleozoogeographical Region	American	-			
o No भ म Paleozoogeographical Region	Mid-continent	Canadian Arctic	•	ıtic	
Mid-continent American	1.0	Cana	Baltic	l Asíatíc	
Canadian Arctic	0.81	1.0	Ba.	Central	ų
Baltic	0.67	0.41	1.0	Cer	Siberian
Central Asiatic	0.6	0.47	0.58	1.0	Sib
Siberian	0.65	0.7	0.46	0.62	1.0

<u>Species Distribution in Southern Manitoba</u>.--The coral species are listed with the units in which they occur. Two coralla of <u>Strepte-</u> <u>lasma</u> were noted in the Winnipeg Formation by Macauley (1952) and have been the only corals reported to date from the unit.

This updating of the species list for the Dog Head Member of the Red River Formation is based on the premise that the species listed by Dowling (1900, p. 49F) are the same as those that occur in the Selkirk Member since I did not examine Dowling's specimens.

Calapoecia anticostiensis Billings

Catenipora robusta (Wilson)

Palaeophyllum argus Sinclair

Streptelasma sp.

Grewingkia sp.

Grewingkia robusta (Whiteaves)

[?] Protrochischolithus magnus (Whiteaves)

[?] Coccoseris astomata Flower

A degree of uncertainty exists as to whether Dowling (1900, p. 72F) was referring to <u>Protrochischolithus magnus</u> or <u>Coccoseris astomata</u>, since they are difficult to distinguish from one another.

No previous worker has cited corals in the Cat Head Member of the Red River and no readily identifiable corals, other than a fragmental external mold of a small solitary coral, were found in the exposure of the Cat Head in the vicinity of Hecla Island at locality A965 (Appendix A).

The Selkirk Member of the Red River contains that fauna commonly termed "arctic." The coral fauna is well developed with respect to species diversity, being the most diverse of any in the study. It

consists of 14 species of predominantly large, lamellar, or encrusting, cerioid and cateniform coralla and five species of solitary corals. Of particular note is the complete absence of <u>Paleofavosites</u>. Dowling (1900, p. 79F, 81F) and Baille (1952, p. 28) listed <u>Paleofavosites</u> <u>prolificus</u> (Billings) for the Selkirk, but thin section microscopy and microskeletal interpretations of colonial tabulate genera show that <u>Paleofavosites</u> is absent. <u>Trabeculites</u> and <u>Nyctopora</u> are similar to <u>Paleofavosites</u> with respect to corallum habit and cerioid, polygonal corallites. Corallite wall microstructure is significantly different from that of <u>Paleofavosites</u>, but the two genera can often be confused with Paleofavosites, both in the field and in laboratory study.

Two species of <u>Calapoecia</u> occur in the member. One, <u>C. arctica</u>, is a species originally described from the Arctic region. <u>Coccoseris</u> <u>astomata</u> is relatively abundant and, like <u>Protrochischolithus magnus</u>, it has probably been previously misidentified in the field as an encrusting stromatoporoid. <u>Coccoseris</u> cannot be easily distinguished from <u>Protrochischolithus</u> in the field. Thin section microscopy is the only reliable method for separating the two genera.

Of the colonial rugosans <u>Crenulites</u> is the only cerioid genus present and, according to Flower (1961, p. 84), is "gradational" into <u>Favistina</u> Flower (=<u>Favistella</u> Dana). <u>Palaeophyllum</u> is the only phaceloid colonial genus in the equatorial faunal elements in the Selkirk.

Of the five solitary species in the member, only <u>Streptelasma</u> <u>poulseni</u> is represented by small coralla with circular transverse sections. <u>Grewingkia robusta</u> is the largest of the solitary corals and is the most numerous. It is characterized by circular transverse sections or by a pronounced angulation in the cardinal region of the

corallum. <u>Grewingkia goniophylloides</u> is very closely related to or gradational with cardinal-angulate types of <u>G. robusta</u>. <u>Dieracorallium</u> sp. is characterized by a keel-like angulation in the cardinal region and appears to be ancestral to <u>D. manitobense</u> in the Gunn Member of the Stony Mountain Formation. <u>Bighornia tyndallensis</u> n. sp., has the lowest stratigraphic occurrence of the genus in the Ordovician system and appears to be a transitional form between <u>Streptelasma</u> and <u>Bighornia</u> in the Gunn Member. The following list gives the coral species identified from the Selkirk.

Trabeculites maculatus Flower

T. manitobensis n. sp.

<u>Nyctopora</u> <u>fissisepta</u> n. sp.

Calapoecia anticostiensis Billings

C. arctica Troedsson

Coccoseris astomata Flower

Protrochischolithus magnus (Whiteaves)

Manipora garsonensis n. sp.

M. amicarum Sinclair

Catenipora robusta (Wilson)

<u>C. rubra Sinclair and Bolton</u>
<u>Streptelasma poulseni</u> Cox
<u>Palaeophyllum argus Sinclair</u>
<u>Grewingkia robusta</u> (Whiteaves)
G. goniophylloides (Teichert)

Dieracorallium sp.

<u>Bighornia tyndallensis</u> n. sp. Crenulites rigidus Flower

C. duncanae Flower

Tabulate species comprise 58 percent of the total species present, but colonial species, both tabulate and rugose, make up 74 percent of the total.

Corals in the type section of the Fort Garry Member of the Red River are completely dolomitized and fragmental. They reflect fragmentation and pre-burial reworking in an intertidal or infratidal-nearshore environment, due to their close association with what may be intertidal and supratidal sediments a few feet downsection (Appendix A). Landward transportation probably occurred between the death of the colonies and the subsequent burial of the fragments. Three species occur in the member.

> <u>Calapoecia</u> sp. cf. <u>C</u>. <u>anticostiensis</u> Billings Paleofavosites sp. A.

Catenipora sp.

Of particular note here is the occurrence of <u>Paleofavosites</u> sp. A, the lowest documented occurrence of the genus in the type area of the Red River Formation. This occurrence is of importance in determining the age of the coral faunas studied. The absence of any solitary corals in the type section may reflect one of two factors.

- 1. No solitary corals may have been able to survive in the infratidal region from which the colonial corals came.
- 2. More likely, the solitary corals living in association with the colonial corals were not transported to the burial site of the colonies. The colonial forms occur as subrounded fragments with a lesser density and greater

potential for bottom transport than the denser, streamlined, conical, solitary corals.

The Gunn Member is the most fossiliferous unit in the Stony Mountain Formation and contains a fauna that is markedly different from the faunas in the underlying Red River Formation. The Gunn or "typical" Stony Mountain coral fauna is second only to the fauna in the Selkirk Member with respect to the number of species and numbers of individuals. The Stony Mountain fauna is characterized by relatively few genera of tabulate (4) and rugose (4) corals. Seven tabulate and five rugose species occur. Asterisks indicate a species described by Leith (1952) but not found in this study. The following species are those listed by previous workers and identified in this study.

Protarea sp. cf. P. cutleri Leith

*Praginella arborescens Leith

Paleofavosites sp. cf. P. kuellmeri Flower

P. prolificus (Billings)

Paleofavosites sp. cf. P. prolificus

P. okulitchi Stearn

Favosites manitobensis n. sp.

Streptelasma kelpinae n. sp.

Lobocorallium trilobatum (Whiteaves)

Dieracorallium manitobense Nelson

Bighornia cvancari n. sp.

B. patella (Wilson)

On the whole, the tabulate species do not reflect a direct descendence from any species or genera in the Red River corals. <u>Protarea</u> sp. cf. P. cutleri and <u>Praginella</u> arborescens however, appear to be related to <u>Coccoseris</u> and <u>Protrochischolithus</u> of the Red River coral fauna. <u>Paleofavosites</u>, directly derived from <u>Foerstephyl-</u> <u>lum</u> (Flower, 1961, p. 70), has no direct ancestor in that fauna. <u>Favosites manitobensis</u> n. sp., is unusual in being the second recorded occurrence of the genus in the Ordovician System of the Williston Basin region or within the New Mexico-Greenland belt of Ordovician rocks.

The solitary corals, however, have their ancestral stocks present in the underlying Selkirk Member. <u>Streptelasma kelpinae</u> n. sp., is derived from a simple species of <u>Streptelasma</u>, perhaps similar to the <u>Streptelasma</u> sp. occurring in the Dog Head Member of the Red River Formation. <u>Lobocorallium trilobatum</u> is a descendant from <u>Grewingkia</u> <u>goniophylloides</u> of the Red River fauna and <u>Bighornia cvancari</u> and <u>B. patella</u> are apparently descendants from <u>Bighornia tyndallensis</u> n. sp., of the Selkirk.

The basal seven feet of the Penitentiary Member of the Stony Mountain contains carry-overs of the Gunn fauna:

Paleofavosites prolificus (Billings)

Streptelasma kelpinae n. sp.

Lobocorallium trilobatum (Whiteaves)

The above three species survived up to the time of sedimentation of the Penitentiary but the remainder of the Gunn coral fauna, nine species, is not present. At stratigraphic levels greater than seven feet above the base of the Penitentiary Member the corals are absent.

The fauna of the Gunton Member of the Stony Mountain differs markedly from that of underlying members. No solitary rugosans have been reported from the Gunton. The writer observed two uncollectable molds of coralla of <u>Calapoecia</u> sp. and <u>Catenipora</u>. One favositid

coral, possibly <u>Angopora</u> sp., was the only coral collected from the unit. Okulitch (1943, p. 63) reported occurrences of possible specimens of <u>Paleofavosites okulitchi</u> and <u>P. prolificus</u> but none were observed or collected in this study. Of the six listed species reported from the Penitentiary, asterisks indicate forms listed by Okulitch (1943, p. 63).

*C. anticostiensis Billings

Calapoecia sp.

Catenipora sp.

[?] Angopora sp.

*Paleofavosites prolificus (Billings

*P. okulitchi Stearn

No fossils were reported by Smith (1963) in the uppermost unit in the Stony Mountain--the Williams member.

The uppermost 14.9 feet (4.5 m) of the 17.9 foot (5.5 m) thick type section of the Stonewall Formation contains a re-established fragmental coral fauna similar to that of the Gunton Member of the Stony Mountain Formation. The asterisk indicates a form reported by Stearn (1956) from the region of The Pas, Manitoba, but not occurring at the Stonewall type locality.

Paleofavosites prolificus (Billings)

Paleofavosites sp. A cf. P. prolificus (Billings)

P. okulitchi Stearn

Paleofavosites sp. cf. P. capax

Paleofavosites sp. B

Angopora manitobensis Stearn

*Palaeophyllum pasense Stearn

Tryplasma gracilis (Whiteaves)

No solitary species occur; the fauna is predominantly favositid, comprising six out of a total of eight species. Both favositid genera, <u>Paleofavosites</u> and <u>Angopora</u>, are also present in the Gunton Member of the Stony Mountain Formation and the Stonewall forms probably are descendants of the Gunton species. All coralla collected at the Stonewall type locality are fragmental, and like those in the Fort Garry Member of the Red River Formation, may have been transported prior to burial. The lack of solitary coralla could also be due to the resistance of the conical corallum to bottom transport.

<u>Species Distribution in Northern Wyoming</u>.--In northern Wyoming the few species collected with adequate stratigraphic documentation occurred within the basal 133 feet (41 m) of the lower massive portion of the Bighorn Formation.

**Catenipora robusta (Wilson)

*Grewingkia robusta (Whiteaves)

Grewingkia goniophylloides (Teichert)

Crenulites rigidus Flower

C. duncanae Flower

The single asterisk indicates a species listed by Duncan (1956, plate 22, figure caption 3) from the lower massive portion of the formation. The double asterisks indicates a species collected by J. J. Delimata, a graduate student at the University of North Dakota from an unspecified stratigraphic level. <u>Grewingkia goniophylloides</u> occurred 70 feet (21 m) above the base of the unit; <u>C. rigidus</u> was collected from 40 feet (12 m) above the base, and <u>C. duncanae</u> came from 133 feet (41 m) above the base. The above species also are present in the Selkirk Member of the Red River Formation and the occurrence of <u>G</u>. robusta and <u>G</u>. goniophylloides in Wyoming represents the southwesternmost range of the species (Tables 4, 5).

The fauma of the Hunt Mountain/Rock Creek beds in the Bighorn Formation contains species that are also present in the Gunn Member of the Stony Mountain Formation. The species in the list below that are shared with the Gunn are preceded by an asterisk. Those which have been reported by Ross (1957) in the Rock Creek beds on the eastern side of the Bighorn range and also occur in the Gunn are preceded by double asterisks.

Coccoseris sp.

Paleofavosites kuellmeri Flower

*Paleofavosites skulitchi Stearn

Paleofavosites sp. cr. P. okulitchi Stearn

Angopora wyomingensis n. sp.

Manipora bighornensis n. sp.

**Streptelasma kelpinae n. sp.

S. sheridanensis n. sp.

**Lobocorallium trilobatum (Whiteaves)

*Dieracorallium manitobense Nelson

**Bighornia patella (Wilson)

B. parva Duncan

B. bottei Nelson

The inclusion of five species also present in the Gunn Member With the others, indicates faunal communication around or across the Williston Basin with southern Manitoba. In addition, four of those species, <u>P. okulitchi</u>, <u>L. trilobatum</u>, <u>D. manitobense</u>, and <u>B. patella</u> have been reported by Nelson (1963) from the Caution Creek and Chasm Creek formations of the Churchill River Group in the Hudson Bay region. Moreover, <u>L. trilobatum</u> was also reported and described by Troedsson (1929) from northern Greenland. The Hunt Mountain/Rock Creek beds appear to represent a mixture of species from the sub-Arctic and southern Canada, new species with unknown geographic ranges, and a species from the Montoya Group of New Mexico (Flower, 1961). The Hunt Mountain/Rock Creek coral faunas contain a mixture of corals from both ends of the New Mexico-Greenland belt of Ordovician rocks. The faunas show a predominance in terms of many individuals representing each species of solitary coral. Each colonial species, on the other hand, is represented by a single specimen.

The thin-bedded limestones in the lowermost 28 feet (8.5 m) of the limestone overlying the Hunt Mountain beds show an influx of advanced species of colonial rugosans, apparent holdovers from the fauna in the Hunt Mountain beds. The species listed below are present in the interval.

> <u>Calapoecia ungava</u> Cox <u>Paleofavosites mccullochae</u> Flower <u>Paleofavosites sp. cf. P. prayi</u> Flower <u>Palaeophyllum pasense</u> Stearn <u>Lobocorallium trilobatum</u> (Whiteaves) Cyathophylloides hollandi n. sp.

<u>Calapoecia ungava</u> is a descendant of the <u>C. arctica</u> - <u>C. anti-</u> <u>Costiensis</u> lineage in the Red River and associated faunas. <u>Paleo</u>-<u>favosites</u> sp. cf. <u>P. prayi</u> and <u>P. mccullochae</u> are species originally

described from the Montoya Group in New Mexico by Flower (1961). <u>Palaeophyllum pasense</u> was originally described by Stearn (1956) from the Stonewall Formation. This gives a hint that these strata may be of Stonewall age. However, this is based on only one shared species. <u>Lobocorallium trilobatum</u> is a holdover from the Hunt Mountain bed coral faunas, and <u>Cyathophylloides hollandi</u> n. sp., is probably derived from species of <u>Cyathophylloides</u> described by Flower from the Montoya Group.

The dearth of solitary coral species (L. trilobatum is the only one present) may be due to two factors:

- Float samples of solitary coralla are not as easily noticeable as colonial coralla. This was considered during collection of the samples, and an attempt was made to search for solitary corals with extra care. Thus this is not likely to be the prime factor.
- Solitary species were not extensively developed in the post-Hunt Mountain bed environments.

The thin bedded dolostone portion (28-57 feet 8.5-17.5 m) above the Hunt Mountain beds has only one species, <u>Palaeophyllum</u> <u>sinclairi</u> n. sp., closely similar to <u>P. pasense</u>. Since the stratigraphic interval 13 to 57 feet (4-17.5 m) above the Hunt Mountain beds is largely covered, some inaccuracy is expected in reporting fossil occurrences. It is likely that of the coral fauna of this portion of the column was more extensive than the float collections indicate.

Table 4 illustrates the stratigraphic occurrence for the coral species in the study. Few species occur in more than one member. Several long ranging species in the Red River fauna are Calapoecia

TABLE 4.--Stratigraphic ranges of coral species in the portions studied in the Ordevician System in southern Manitoba, the Williston Basin (*) and northern Wyoming. Colonial species (o), solitary species(")

		Red	River	Fm.		Ston	y No Fm	untair •	1	ST ST		Bighon Fm.	m		
•		Dog Head	Cat Head	Selkirk	Fort Garry	Gunn	Penitentiary	Gunton	Williams	conewall Fm.	lower massive	Hunt Mt. beds	0-26 ft above beds	26-57 ft above bed	
Trab	Species eculites		<u>.</u>											ဟ 	
T. ma T. ma Nyct fi Cala an Cala an Cala an Cala Coco As Coco Prot	<u>culatus</u> <u>anitobensis</u> <u>opora</u> <u>ssisepta</u> <u>poecia</u> <u>ticostiensis</u> <u>poecia</u> sp. cf. <u>C</u> . <u>ticostiensis</u> <u>rctica</u> <u>ngava</u> <u>area</u> sp. cf. <u>P</u> . <u>tleri</u> <u>oseris</u> <u>tomata</u> <u>oseris</u> sp. <u>rochischolithus</u> <u>gnus</u>	-? -	-?-			0	0						0	ο	

TABLE 4.--Continued

Species	Dog Head	Cat Head	Selkirk	Fort Garry	Gunn	Penitentiary	Cunton	Williams	Stonewall Fm.	lower massive	Hunt Mt. beds	0-26 ft above beds	26-57 ft above beds	
Paleofavosites <u>kuellmeri</u> <u>Paleofavosites</u> sp. <u>cf. P. kuellmeri</u> <u>P. mccullochae</u> <u>Paleofavosites</u> sp. <u>cf. P. prayi</u> <u>P. prolificus</u> <u>Paleofavosites</u> sp. A <u>cf. P. prolificus</u> <u>Paleofavosites</u> sp. B <u>cf. P. prolificus</u> <u>P. okulitchi</u> <u>Paleofavosites</u> sp. B <u>cf. P. capax</u> <u>Paleofavosites</u> sp. A <u>Paleofavosites</u> sp. A <u>Paleofavosites</u> sp. A <u>Paleofavosites</u> sp. B <u>Angopora</u> <u>manitobensis</u> <u>Angopora</u> sp.				*?	0	0		0				0	0	

26-57 ft above beds		0
0-26 ft above beds	0	= =
Hunt Mt. beds	0	
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Penitentiary	0	E
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Selkirk		
Cat Head	r F	
Dog Head		
	Favosites manitobensis Manipora garsonensis M. amicarum M. bighornensis Catenipora cobusta C. rubra Catenipora sp.	Streptelasma poulseni S. kelpinae S. sheridanensis Streptelasma sp. Palaeophyllum argus P. pasense

Order Tabulata

Order Rugosa

TABLE 4. -- Continued

TABLE 4.--Continued

	Species	Dog Head	Cat Head	Selkirk	Fort Garry	Gunn	Penitentiary	Gunton	Williams	Stonewall Fm.		lower massive	Hunt Mt. beds	0-26 ft above beds	26-57 ft above beds	
Order Rugosa	Palaeophyllum sinclairi Grewingkia G. goniophylloides Grewingkia sp. Lobocorallium trilobatum Dieracorallium manitobense Dieracorallium sp. Bighornia tyndallensis B. cvancari B. patella B. parva B. bottei Crenulites rigidus C. duncanae Cyathophylloides hollandi Tryplasma gracilis				11 11 11 11 11						0		" " " " " "		0	

anticostiensis, <u>Catenipora</u> robusta, <u>Palaeophyllum</u> argus, and <u>Grewingkia</u> robusta. All four species range from the Dog Head to the Selkirk Member.

<u>Grewingkia goniophylloides</u>, <u>Crenulites rigidus</u>, and <u>C</u>. <u>duncanae</u> are in the basal strata of the Bighorn Dolomite and do not occur in the Red River lower than the Selkirk Member. This is evidence for (1) these species migrating in from the New Mexico-Texas portion of the equatorial faunal realm or (2) these species were not able to survive environmental conditions during deposition of the Dog Head Member.

Geographic Distribution of Species

The coral fauna in the Red River Formation, typified by species in the Selkirk Member, is a mixture of three kinds of species: those from the southwestern end of the equatorial realm, those from the northeastern end, and indigenous species not in either. Table 5 shows the geographic distribution of species studied. Most of the Red River species are widely distributed. <u>Trabeculites maculatus</u>, <u>Manipora</u> <u>amicarum</u>, <u>Crenulites rigidus</u> and <u>C. duncanae</u> all range from New Mexico to southern Manitoba or the Hudson Bay region. <u>Calapoecia</u> <u>anticostienses</u>, <u>C. arctica</u>, <u>Catenipora robusta</u>, <u>C. rubra</u>, <u>Grewingkia</u> <u>robusta</u>, and <u>G. goniophylloides</u> all range from Greenland and/or Baffin Island southwestward to southern Manitoba or northern Wyoming.

The Stony Mountain coral fauna, typified by that in the Gunn Member, the basal portion of the Penitentiary Member, and the Hunt Mountain beds, also contains species that are fairly widespread. <u>Calapoecia ungava, Paleofavosites prolificus, P. okulitchi, Lobocoral-</u> <u>lium trilobatum, Dieracorallium manitobense, Bighornia patella</u>, and <u>B. bottei</u> are species that range from the Hudson Bay region southwestward to southern Manitoba or northern Wyoming. <u>Paleofavosites kuellm</u>eri

Arctic Islands Baffin Islands New Mexico Hudson Bay Greenland Northern Southern Manitoba Vyoming Species Trabeculites maculatus T. manitobensis Nyctopora fissisepta Calapoecia anticostiénsis Calapoecia sp. cf. C. anticostiensis C. arctica C. ungava Protarea sp. cf. P. cutleri Coccoseris astomata Coccoseris sp. 0 Protrochischolithus magnus Paleofavosites kuellmeri Paleofavosites sp. cf. P. kuellmeri P. mccullochae Paleofavosites sp. cf. P. prayi P. prolificus Paleofavosites sp. A cf. P. prolificus Paleofavosites sp. B cf. P. prolificus 0 P. okulitchi Paleofavosites sp. cf. P. okulitchi Paleofavosites sp. cf. P. capax Paleofavosites sp. A Paleofavosites sp. B Angopora manitobensis Angopora wyomingensis Angopora sp. Favosites manitobensis n

TABLE 5.--Geographic distribution of Red River, Stony Mountain, and Stonewall coral species from New Mexico to Greenland. Red River species (*), Stony Mountain species (o), Stonewall species ("), Fort Garry (+)

TABLE 5.--Continued

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	•				Baffin Islands & Arctic Islan	
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Pooron						
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. <u>bighornensis</u>		()			
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. rubra					*	
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ghornia tyndalli		~	*		•	. •
cvancari			0			
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patella parva bottei		C) 	0		
cenulites rigidus			* *	0		
duncanae			*			-
/athophylloides hollandi		1	r			
yplasma gracilis						

and <u>P. mccullochae</u> are the only species that range from New Mexico northeastward to northern Wyoming. On the whole, the Stony Mountain species are more restricted in geographic range than are the Red River species. The only exception is <u>L. trilobatum</u>, which ranges as far northeastward as Greenland. Most of the species appear to be restricted to the northern Wyoming-Hudson Bay region.

The small solitary corals, <u>Streptelasma kelpinae</u>, <u>D. manitobense</u>, <u>B. patella</u> and <u>B. bottei</u> are absent from the New Mexico and Greenland-Baffin Island regions. Hill (1959) described and listed several species of corals from the Montoya Group of New Mexico. Only one poorly preserved specimen of <u>Streptelasma</u> was described and this was not from a physical equivalent of the Stony Mountain Formation. All the above species are small solitary corals and although unlikely, it is possible they may have been overlooked. Troedsson (1929) stated that several of the collections from the Baffin Island and Greenland regions were made during exploration expeditions and that (p. 164) "... all the collections referred to above have been collected, like the Cape Calhoun fauna, without any detailed stratigraphic examination of the succession of the strata." Under these conditions, it is possible that small solitary forms were not seen.

The Stonewall coral fauna appears to show an even more restricted geographic distribution. The only species having any considerable distribution in this fauna are <u>Paleofavosites prolificus</u> and <u>P. okulitchi</u>, both of which occur in the Stony Mountain faunas. All other Stonewall species or their presumed equivalents in the strata above the Hunt Mountain beds, with the exception of <u>Palaeophyllum pasense</u>, are apparently restricted to the Manitoba region. Nelson (1963) noted no Stonewall

corals other than <u>P</u>. <u>prolificus</u> and <u>P</u>. <u>okulitchi</u> in the Hudson Bay region. One cannot completely disregard the possibility that the apparent restriction of geographic range of the Stonewall corals may be due to poor preservation. Small or fragile coralla such as <u>Angopora manitobensis</u> or <u>Tryplasma gracilis</u> may not have been preserved outside the Manitoba outcrop region of the Stonewall. This especially holds true for the covered portion of the "upper Bighorn" in Wyoming where small forms could have been overlooked.

In summary, successive Ordovician coral faunas had an increasingly restricted geographic range until, during Stonewall time, many of the species appear to have been relatively localized.

Paleoecology

<u>Corallum Type and Substrate</u>.--The carbonates of the Red River Formation and the beds overlying the Hunt Mountain beds in the upper portion of the Bighorn Dolomite contain a primarily colonial fauna (Table 4). The Fort Garry Member, the Gunton Member, and the Stonewall Formation also contain coral faunas that are colonial. The only exceptions are the two species of solitary corals in the Stonewall near Flin Flon, Manitoba reported by Stearn (1956, p. 15). Colonial coralla in the dolomitic Fort Garry, Gunton, and Stonewall are all fragmental and appear to have undergone bottom transport.

The absence of solitary corals in the exposures of these units may be due, in part, to the resistance of these coralla to transport due to their streamlined shape. Most of the solitary types may have a higher mass per unit corallum volume than the colonial ones. This would be due to stereoplasm deposits on septa and the walls whereas

the colonial corals, especially the cerioid forms, have relatively low mass per unit volume due to relatively low volumes of stereoplasm. Moreover, relatively few solitary coral species may have lived in these particular carbonate depositional environments.

Units characterized by argillaceous lithologies, namely the Gunn Member of the Stony Mountain Formation and its correlative, the Hunt Mountain beds, have a higher number of solitary species and individuals in each (Table 4). In this lithology, the colonial species are represented by no more than one corallum each whereas the solitary species, especially <u>Streptelasma kelpinae</u> n. sp., <u>Dieracorallium manitobense</u>, and <u>Bighornia patella</u>, are represented by hundreds of individuals. A reason for the predominance of solitary coral individuals in environments of terrigenous clastic deposition may be a greater tolerance of the solitary forms for terrigenous clastics. The possession of relatively deep calices by the solitary corals may have enabled individuals either to avoid settling clastic particles by withdrawal of the polyp into their calyx, or to clean themselves off by periodic retraction and extension of the body column.

The colonial corals were not so fortunate. The interconnection between polyps by coenosarc or by the peripheral basal edges of adjacent polyps prevented them from shaking off or avoiding settling clastic particles. The sediments may have accumulated on the ectodermal polyp surface between adjacent polyp body columns. If the polyps had mutualistic zooxanthellae or chloranthellae, the sediment covering parts of the ectodermal surface may have been sufficient to cause a decrease in photosynthesis. The drop in photosynthesis may have caused a buildup of respiratory CO_2^{--} and other waste products (Goreau, 1959, p. 72).

The reduction of algal CO_2^{-} uptake may have been more than body wall diffusion could handle, resulting in a buildup of toxins that could have killed the colony. The killoff of the colony by reduced photosynthesis could have been hastened by the reduction of photosynthetic CO_2^{-} and carbohydrate output, cutting down on the amount of these materials from the mutualistic plants.

The high number of small solitary corals was probably a response of the solitary faunal elements utilizing free energy available as food not being taken up by the rare colonial corals. The cerioid colonial corals likely were more efficient gatherers of food than the solitary corals due to their close-packed arrangement of polyps over the corallum surface. They could take up much of the available food out of the water that passed over the polyps. The reduction of the numbers of colonies in a more argillaceous depositional situation would have taken a certain amount of energy-absorbing biomass out of the Ordovician marine ecosystem. This removal would enable the less efficient solitary corals to develop to the maximum permitted by environmental conditions, including a less depleted food supply.

Conversely, the lack of incoming clastics may have enabled the more efficient colonial corals to utilize nearly all the food available in the system. In conditions of autochthonous carbonate sedimentation, in an equatorial zone, the shallow marine water may have been well lighted, enabling the mutualistic algae to function efficiently. Such an efficient mutualistic microsystem resulted in optimum conditions for the colonies. The solitary corals may not have been able to compete effectively in a carbonate situation with the colonial corals since the colonial ones gathered food more efficiently.

The Search for a Suitable Substrate.--Colonial corals in the Selkirk Member are characterized by four types:

- large shield- or mound-shaped cerioid coralla, rarely up to one meter in diameter, composed of successive layers of generations often separated from the other by sediment around the periphery,
- 2. large cateniform coralla of <u>Catenipora</u> which commonly exceed one meter diameter,
- rare phaceloid coralla such as that of <u>Palaeophyllum argus</u>, and
- small, encrusting cerioid coralla of <u>Calapoecia</u>, <u>Coccoseris</u>, and <u>Protrochischolithus</u> commonly assuming the same shape as the underlying substrate.

Layers of sediment between successive layers of the cerioid coralla indicate that periodic influxes of carbonate sediment overlapped peripheral portions of the distal corallum surface, and exterminated the Surviving polyps closer to the center of the corallum affected polyps. expanded out over the offending sediment and established a growth layer over the site of the dead portion. This is most commonly observed in coralla of Crenulites which attain sizes larger than other cerioid genera. Strong bottom currents stirred up the unconsolidated carbonate sediment to such a degree that coral colonies were completely overwhelmed or partially wiped out by smothering of the polyps. Strong currents are indicated by some coralla being completely overturned and large nautiloid shells being abraded to such a degree that only the resistant ^{Siphun}cle remains. This is commonly the only way that such genera as Armenoceras, Narthecoceras, and Vaginoceras are preserved.

Shield- or mound-shaped coralla are hydrodynamically stable and resistant to overturning since a minimum surface area per unit diameter is exposed to moving water. Very low, shield-shaped coralla have a surface area hardly exceeding that of the area of a circle of similar diameter. However, because of the low skeletal volume per unit surface area the corallum mass is relatively low. Bottom scour of the sediments may have been sufficient to undermine the corallum, allowing moving water to pass underneath and overturn it.

Few of the colonies of the encrusting <u>Calapoecia</u>, <u>Coccoseris</u>, <u>Protrochischolithus</u> and lamellar stromatoporoids were overturned because they are small and heavy with a flat base and little exposed surface area.

The point of origin for several of these large cerioid coralla is commonly a small fragment of calcareous skeletal material upon which the planktonic larvae settled. The unconsolidated carbonate sediment was an unsuitable substrate, and the location of the colony was determined by the location of suitable skeletal fragment.

The encrusting corals solved the substrate problem differently. Genera such as <u>Calapoecia</u>, <u>Coccoseris</u>, and <u>Protrochischolithus</u> utilized entire skeletal structures such as a nautiloid shell, solitary coral or stromatoporoid coenosteum for a substrate where the entire exposed substrate surface served for attachment. In the latter two genera, this resulted in a corallum whose shape replicated that of the substrate. All three genera in the Selkirk Member appear to have been intolerant of direct contact with the sediment, so their diameter is limited by that of the substrate. Several coralla containing these genera came from the Selkirk Member and show the use of the same substrate by succeeding generations of coelenterates.

One specimen (UND Cat. No. 13728) has four generations of coelenterates: (1) Coccoseris astomata at the origin encrusted by (2) Nyctopora sp. encrusted by (3) C. astomata, which in turn, is encrusted by (4) Calapoecia arctica. Another series of coelenterate colonial skeletons, a hypotype (UND Cat. No. 13653) of Coccoseris astomata has the following: (1) Coccoseris astomata at the origin completely encrusted by (2) a large moundlike stromatoporoid coenosteum, which in turn, is completely covered by (3) a thin layer of C. astomata, which is partially covered by (4) a colony of Calapoecia arctica, which in turn, is completely covered by (5) a layer of C. astomata (6) covered by a layer of stromatoporoid coenosteum (7) capped at the distal surface by a layer of C. astomata (Plate 6, Figure 2). Seven succeeding generations of colonial coelenterates cover each other demonstrating that available substrate, at least for them, was limited to the distal surfaces of pre-existing colonies.

It is unclear whether the intercolony relationship was parasitic or was a case of a colony encrusting on one that was dead. A plauktonic larva would not have settled upon the polyp surface of a living colony. Nematocysts in the ectodermal layer would have killed any small organism settling on it. Modern anthozoan larvae resist metamorphosis to a polyp until a proper, clean substrate is encountered. A larva would drift until it was out of the range of habitation of the species and died, or found a suitable substrate. Thus the behavior of modern anthozoans gives an insight into the substrateencrusting coral relationship: a living colony on an already dead host colony.

<u>Coral Distribution over the Sea Floor</u>.--Two bedding plane exposures of the Selkirk Member of the Red River Formation at locality A889 (Appendix A) afforded a unique opportunity to map the areal distribution of the sessile benthonic organisms. The exposures were clean of overburden and contained the organisms as they were situated on the sea floor prior to burial. Figure 5a is taken from a bedding plane surface approximately three feet (0.9 m) below the top of the exposed Selkirk section whereas Figure 5b is taken from a surface 4.9 feet (1.5 m) below the top. The groups of organisms preserved on the bedding plane surfaces are as follows:

- At three feet below the top, receptaculitids comprise 61% of the total of 87 individuals, stromatoporoids are 25% of the total and the corals comprise only 14% of the organisms present.
- At 4.9 feet below the top, receptaculitids are 81% of the total, stromatoporoids are 10% and the corals are only 9% of the organisms.

Figures 5a and 5b show no clear pattern of organism distribution since such small areas as the ones illustrated show only gross features such as the predominance of the receptaculitids. In both maps the areas of coelenterate concentration do not exclude receptaculitids nor do the coelenterates reflect control by the abundant receptaculitids.

Both maps on Figure 5 show varying concentrations of organisms on the two bedding plane surfaces. In Figure 5b the number of solitary corals such as <u>Grewingkia</u> differ from those on the overlying surface. It is not clear whether these solitary corals are in situ or have undergone some transport. The unfragmented colonial coelenterates do not

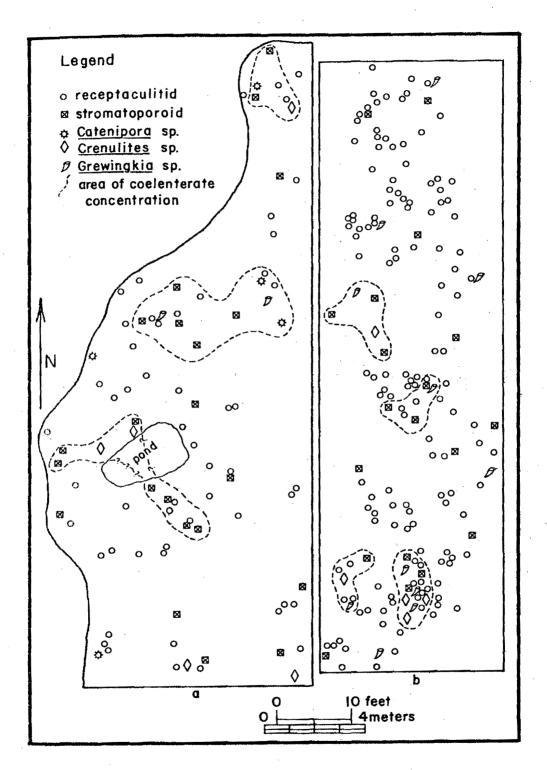


Fig. 5.--Distribution of sessile benthonic organisms on bedding plane surface in the Selkirk Member of the Red River Formation (Appendix A, locality A889), (a) three feet (0.9m) below top of exposed section, (b) 4.9 feet (1.5m) below top of exposed section. pear to have been overturned or moved from their original positions. e solitary corals, because of their cylindrical transverse section, y have been moved more easily than the massive colonial skeletons, t show no sign of having been transported.

Coral Evolution

Flower (1961) used wall skeletal microstructures to differentiate tween genera of Ordovician colonial corals and shed light on their evotion. He was able to show that the microstructure of the corallite 11 may be one of the important generic characters and the most impornt feature for determining how an Ordovician colonial genus is related other genera.

The Flower Model.--The starting point of Flower's model of evoluon of Ordovician colonial corals (Figure 6) is the genus <u>Lichenaria</u> ich Bassler (1950, p. 256) and Flower (1961, p. 25) considered to be a kely ancestor for the Paleozoic corals. <u>Lichenaria</u> has a characterisc fibrous wall that has two layers of sclerenchymal fibers abutting ong an axial plane--the <u>Lichenaria</u>-type wall, which was the starting int for seven different lineages (Figure 6).

The first lineage leads from <u>Lichenaria</u> to <u>Eofletcheria</u>. The cond leads from <u>Lichenaria</u> through <u>Quepora</u> to <u>Catenipora</u> of the .ysitidae. The second lineage includes the separation of the <u>henaria</u>-type wall into a single layer, the addition of a thin er layer, a holotheca, and arrangement of the corallites into eniform ranks. This produced <u>Quepora</u>, a genus not found in the dy. The addition of septal spines and the separation of the gle wall layer into a trabecular common wall resulted in Cateni-

a.

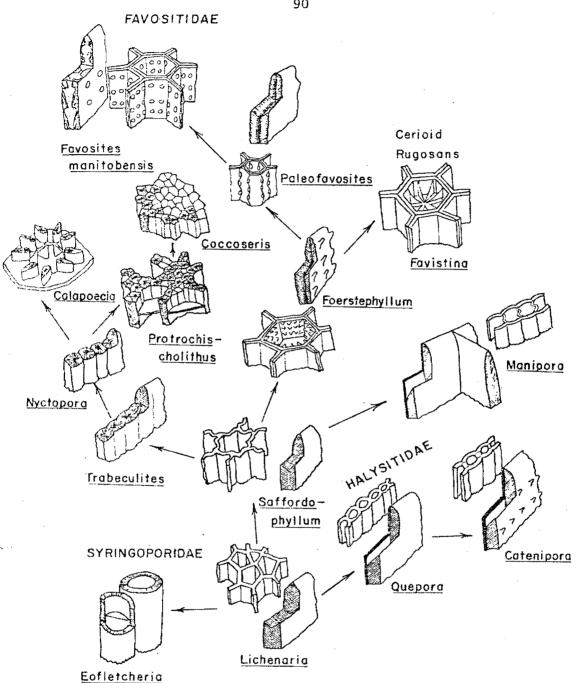


Fig. 6.--Evolutionary relationships between genera of Ordovician colonial corals (Flower, 1961) -- the Flower Model.

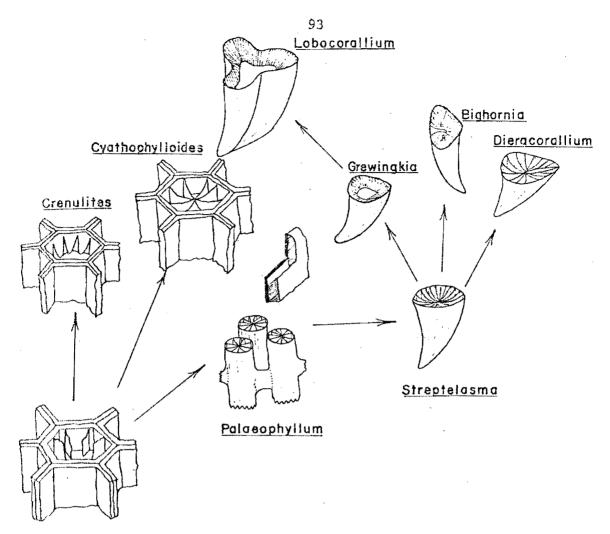
The central lineage involves the crenulation of the <u>Lichenaria-</u> type wall. The addition of septal spines and mural pores to produce <u>Saffordophyllum</u> which, according to the model, lies along the central lineage and gives rise to <u>Manipora</u>, a cateniform version of <u>Saffordo-</u> phyllum, on a third lineage.

The modification of the Lichenaria-type wall of Saffordophyllum to a wall with monacanthine trabeculae, plus the accompanying alteration of the axial planes to short planes or lines resulted in a cerioid coral; Trabeculites, in a fourth lineage characterized by the breakup of the planar wall into separate trabecular rods. This trend culminates in two subordinate lineages; the base of which is Nyctopora in which the trabeculae are more distinct than in Trabeculites. The Calapoecia lineage accentuates the increasing separation of the trabeculae whereas the Coccoseris lineage developed the closely packed arrangement of trabeculae. From Saffordophyllum to Foerstephyllum the wall gains an axial plate that is in the position of the former axial plane. In this wall type, which occurs in all the cerioid rugosans and is termed the "rugosan wall," the inner ends of the sclerenchymal fibers abut the flanks of the plate. From Foerstephyllum two main branches lead away. One accentuates the development of mural pores and the reduction of septal ridges in Foerstephyllum to separate spines, leading into Paleofavosites in which mural pores are concentrated in the corners of the walls and spines are either present or absent. Continued development of this branch is marked by a shift of the mural pore positions from the corners to the centers of the walls. In Favosites manitobensis n. sp., from the Gunn Member of the Stony Mountain Forma-^{ti}on, the rugosan-type wall develops trabeculae that appear as diffuse expansions of the axial plate.

The second branch leading from <u>Foerstephyllum</u> leads into the cerioid Rugosa. The rugosan wall is retained and the development of septa from spines of <u>Foerstephyllum</u> characterizes the cerioid genera related to <u>Favistina</u>.

<u>Crenulites</u> and <u>Cyathophylloides</u> are similar to <u>Favistina</u> but they differ in the number, extension, and differentiation of septa and the type of tabulae. The rugosan wall consists of three elements. Lateral separation of the corallites produces characters typical of <u>Palaeophyllum</u>. The rugosan wall's axial plate splits (Flower, 1961, p. 35) and becomes an epitheca around each corallite (Figure 7). This parallels and is analogous to the development of a holotheca and wall fiber layer that occurred in the lineage of the Halysitidae from <u>Lichenaria</u>. The halysitid lineage differs in that the outer wall layer may have developed within the lineage itself as there is no ancestral axial plate homologue in Lichenaria.

<u>Streptelasma</u>, according to the Flower Model, results from a decrease in budding and the development of a conical rather than a cylindrical corallite (Flower, 1961, p. 35). Figure 7 illustrates an extension of the Model into some of the Ordovician solitary corals. Here the genera related to the ancestral streptelasmid genus, possibly <u>Streptelasma</u>, differ from this genus mainly by accentuation or distortion of <u>Streptelasma</u> features. <u>Grewingkia</u> and its descendant, <u>Lobocorallium</u>, have more septa, a differing axial structure, and a change in corallum shape. <u>Bighornia</u> developed a corallum curvature in the opposite direction from <u>Streptelasma</u>, a flattened shape due to increases in corallum width along the alar septa, and an axial structure different from Streptelasma in that the counter septum is



Favistina

Fig. 7.--Extension of the Flower (1961) Model in the Order Rugosa to the solitary corals. Solitary corals oriented with cardinal sides to right.

accentuated. <u>Dieracorallium</u> is modified from <u>Streptelasma</u> by the development of a prominent angulation in the region of the cardinal septum, a promient fossula, and unmerged septa abutting at the corallum axis.

In the Flower Model and its modifications those genera characterized by a <u>Lichenaria</u>-type wall or one of its derivatives could be classed as primitive whereas those with the rugosan wall or its modifications could be arbitrarily termed as advanced.

The Flower Model in Septal Structure.--Adaptation of the wall microstructure model to the development of septal microstructure shows a development which parallels that of the corallite wall (Figure 8). For purposes of illustration only a few representative species are considered. There is no direct lineage implied in this version of the model. Rather, the species used represent the type of septa contained within a general trend of increasingly complex septa in the Ordovician tabulates and rugosans.

The simplest type of septum or septal spine consists of a series of fibers diverging from a central line or plane. In primitive genera, such as <u>Trabeculites</u> and <u>Nyctopora</u>, the septa consist of longitudinal ridges composed of fibers divergent about a central plane. As Flower (1961, p. 35) pointed out, these often are little more than extensions of the wall sclerenchymal layer. The next more advanced septal structure commonly shows a faint delineation between the septal material and the wall sclerenchyme, showing that the septa are structural entities distinct from the wall. This is illustrated in this case by the septal ridges of <u>Paleofavosites okulitchi</u>.

The colonial rugosans represent another advancement in septal structure. <u>Crenulites rigidus</u> contains two septal types, major and

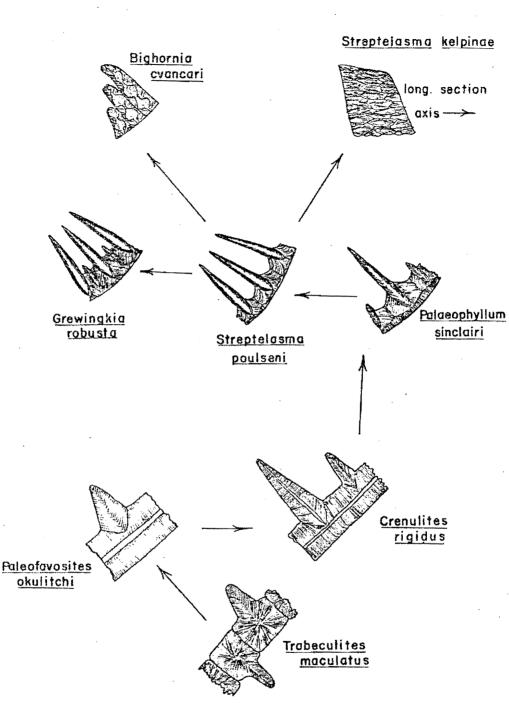


Fig. 8.--Gradation of septal microstructure from spinose to trabecular types in Ordovician corals. Arrows show progression with time from simple to complex septal structures. No evolutionary relationships are implied except for the rugosan species of <u>Palaeophyllum</u>, <u>Streptelasma</u>, <u>Grewingkia</u> and <u>Bighornia</u>. minor. The major types are commonly distinct from the wall and they take on the appearance of the rugosan wall in which two fibrous layers are separated by a septal axial plate similar in appearance to the plate in that wall type. It is not possible to tell whether the so-called septal axial plate is a homologue of the wall plate. Minor septa, on the other hand, are simple extensions of the wall sclerenchyme.

<u>Paleophyllum sinclairi</u> n. sp., <u>Streptelasma poulseni</u>, and <u>Grewing-kia robusta</u> show the septa to be distinct from the corallite wall. No axial plate appears to be present here, but the central planes of the septa appear to be occupied by a diffuse zone of translucent material. The fibers in the septa diverge laterally from the central plane. Longitudinal sections through septa of these species show no clear-cut tendency for grouping of the fibers into any recognizable structure. Another species of <u>Streptelasma</u>, <u>S. kelpinae</u> n. sp., shows a faint tendency for the septal fibers to be grouped into fascicles or bundles, producing primitive trabeculae. Both nontrabeculate and trabeculate septal microstructures occur in <u>Streptelasma</u>.

<u>Bighornia</u> possesses the best developed trabeculate septa. In <u>B. cvancari</u> n. sp., the central translucent region of the septa are laterally expanded. Longitudinal sections through the septa show well developed trabecular structures.

Not only wall structures give an indication of the evolutionary position of Ordovician coral genera, but similar analogues are seen in septal structures. Those with <u>Lichenaria</u>-like walls and nontrabeculate septa may be considered to be "primitive" and those with a rugosan wall and distinctly trabeculate septa are more "advanced."

Relative Phylogenetic Position .-- The coral fauna in the Selkirk Member, contains a large number of genera that are regarded as "primitive." Trabeculites, Nyctopora, Manipora, and Catenipora do not possess the rugosan wall. Their walls were derived from a Lichenaria-type microstructure and did not gain the characters typical of the rugosan Septal microstructures in these genera are not advanced beyond wall. the stages represented by T. maculatus and P. okulitchi (Figure 8). Protrochischolithus and Coccoseris are more advanced than Nyctopora due to the replacement of longitudinal structures such as septa, walls, and columellae by closely packed, polygonal trabeculae. Calapoecia represents the continued breakup of the Lichenaria-type wall in which separation is more pronounced than in Nyctopora. Based on wall structure and a septal structure similar to that of T. maculatus (Figure 9), Protrochischolithus, Coccoseris, and Calapoecia represent a "mid-range" of development with a more advanced wall structure than in Trabeculites, Nyctopora, Manipora, and Catenipora.

The only cerioid genus in the Selkirk Member that can be termed more advanced is <u>Crenulites</u>. It has the rugosan wall but septa that are nontrabeculate and have an axial plate-like septal structure. It appears to represent a mid-range in septal development and advancement. The solitary corals <u>Streptelasma poulseni</u> and <u>Grewingkia</u> spp. are well advanced in terms of position within the Flower Model but their septal development is not advanced to the trabeculate stage (Figures 7-9).

Figure 9 illustrates an indication as to the degree of advancement of the coral taxa based on wall and septal microstructures. Most of the corals in the Red River Formation are "primitive" or "mid-range" and those in the Hunt Mountain beds are "advanced." <u>Paleofavosites</u> and

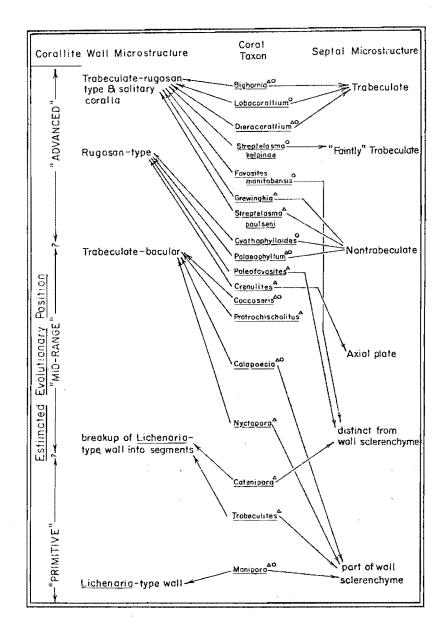


Fig. 9.--Evolutionary positions of coral genera and species studied. Red River and correlative faunas (Δ) ; Stony Mountain, Stonewall, and correlative faunas $(\mathbf{0})$.

Favosites have the rugosan wall or a trabecular modification of it. The solitary corals in the two units are also "advanced" since all of them are characterized by trabeculate septa.

Corals as Correlation and Age Indicators. -- Previous discussion in this study has indicated that the corals are quite sensitive to depositional facies and climatic factors, and should be primarily considered as facies fossils. This fact alone is sufficient to cause rejection of them as widespread correlation fossils, because no species and few genera are shared between the Middle and Late Ordovician type areas and the Several are useful for correlation within the Ordovician areas studied. equatorial realm on the North American continent because they have wide geographic distribution within it (Table 5). The distribution of these facies fossils appears to have been the result of widespread environmental conditions paralleling the Ordovician equator. Depositional facies of probable correlative strata appear to have been relatively uniform in terms of widespread lithologic similarity, in similar stratigraphic positions and widespread species distribution.

An important genus in attempting to use corals as age indicators is <u>Paleofavosites</u>. According to Leleshus (1971, table 2) <u>Paleofavosites</u> occurred during Late Ordovician time in all the paleozoogeographic provinces covering North America, the Soviet Arctic, Siberia, central Asia, and northern Europe. According to him (table 1) <u>Paleofavosites</u> did not occur in any of the provinces during Middle Ordovician time. No citations of <u>Paleofavosites</u> were given by Bassler (1950) from the type areas of the Middle and Late Ordovician, complicating the problem of dating the onset of <u>Paleofavosites</u>. Other strata of Richmondian age in northern Michigan, southern Ontario, and Anticosti Island all contain the genus,

but no strata older than these have documented occurrences of the genus. Based on Bassler's (1950) work the genus does not appear to be older than Richmondian age in the eastern United States and eastern Canada. This invalidates the conclusion of Twenhofel and others (1954, chart 2) who correlated the entire Ordovician section of southern Manitoba and northern Wyoming with the Richmondian and Gamachian strata on Anticosti Paleofavosites occurs throughout the entire Ordovician section Tsland. on the island (Twenhofel, 1928, p. 85). Twenhofel (in Twenhofel and others, 1954, p. 282) stated that the Red River fauna is very closely correlative with the English Head Formation on the island. A comparison of the Red River genera and species with Twenhofel's list of corals for the unit (1928, p. 63-65) shows one genus, Streptelasma, and one species, Calapoecia anticostiensis, in common. On the basis of Paleofavosites, all of the Red River Formation except the Fort Garry Member is pre-Richmondian if Twenhofel's citations of Paleofavosites and Richmondian-Gamachian strata are followed.

The complete absence of <u>Paleofavosites</u> from the portion of the Red River below the Fort Garry indicates that portion may be older than the <u>Paleofavosites</u>-containing Ordovician rocks to which Bolton (1972) assigned a Richmondian age.

Flower (1961, p. 73) described <u>Paleofavosites sparsus</u> from the Second Value Formation in New Mexico, a unit possibly correlative with the Red River Formation. He did state, however, that the species had several characters also occurring in <u>Foerstephyllum</u>. He was of the opinion that it may be <u>Foerstephyllum</u> instead of <u>Paleofavosites</u>. The species appears to represent a transition between the two genera, so it is present in pre-Richmondian strata. This description by Flower

(1961) suggests that the Second Value Formation may have been where <u>Paleofavosites</u> arose from <u>Foerstephyllum</u> and did not become established until the Richmondian in eastern North Dakota when the "typical" <u>Paleo-</u> favosites had evolved.

Nelson (1963, p. 41) cited the occurrence of <u>Bighornia solearis</u> (Ladd) in Member No. 1 of the Chasm Creek Formation in the Hudson Bay region. It was originally described by Ladd (1929, p. 397) from the Fort Atkinson Member of the Maquoketa Formation in northeastern Iowa. It is closely related to <u>B</u>. <u>bottei</u>, which occurs in the same unit in the Hudson Bay region and in the Hunt Mountain beds in the Bighorn Formation. <u>Bighornia solearis</u> and <u>B</u>. <u>bottei</u> occurred at about the same time. Nelson (1963, p. 41) did mention that the former is transitional between <u>B</u>. <u>patella</u> and <u>B</u>. <u>bottei</u>, which may restrict its time of existence to that of the other two species. Based on one species, a tenuous coral-based suggestion of faunal correlation can be established between the Ordovician units in the Hudson Bay region and northeastern Iowa.

With the exception of the two above examples the corals studied do not serve well as correlation tools or index fossils outside of the New Mexico-Greenland belt of Ordovician strata due to their control by Ordovician environmental conditions.

Comparison of the microstructures of the coral faunas in the Red River and Stony Mountain Formations shows a marked distinction in the degree of evolutionary advancement of the faunas. The paraconformity between the Red River and Stony Mountain Formations and the diastemic Fort Garry Member of the Red River Formation represent the passage of an interval of geologic time.

The amount of time represented by the diastems and the paraconformity are not known but the coral faunas below and above the Fort Garry and the paraconformity are significantly different.

Corals in the Red River Formation, especially those in the Selkirk Member, are characterized by the <u>Lichenaria-type</u> wall (as in <u>Manipora</u>) or the wall type in which individual trabeculae are present (as in <u>Trabeculites</u>, <u>Nyctopora</u>, <u>Calapoecia</u>, <u>Protrochischolithus</u>, and <u>Coccoseris</u>). Those in the Gunn Member of the Stony Mountain Formation are characterized by the more advanced rugosan wall of <u>Paleofavosites</u> and Favosites.

Septal microstructures in the solitary corals below and above the Fort Carry and the paraconformity show the same contrast seen in the wall structures. Septal microstructures in the solitary corals of Thin the Red River (Streptelasma and Grewingkia) are nontrabeculate. sections through representatives of these genera show no strong evidence of septal trabeculae. All the solitary rugosans above the Fort Garry and the paraconformity (Streptelasma, Lobocorallium, Dieracorallium, and Bighornia) are trabeculate. Streptelasma is unique in that species on the lower and upper side of the erosional gap are nontrabeculate and trabeculate, respectively. The quality of septal trabeculation arises within Streptelasma (and probably other solitary genera) during the span of time represented by the diastemic Fort Garry and the paraconformity. This allows separation of the corals of the Red River from those in the Stony Mountain Formation. The progression from nontrabeculate to trabeculate septa is part of a larger trend within all Paleozoic solitary Rugosa where, with passing time, septal microstructures become increasingly complex. For example, Kato (1963,

p. 588) stated that Silurian rugosans are characterized by more complex "multitrabecular" (Appendix C) microstructures than are the Ordovician "unitrabecular" or nontrabeculate forms. No recognizeable, short-term, environmental factor appears to have been involved in the trend of increasing septal complexity for the rugosans. Instead this general tendency may reflect a method of skeletal construction that was more efficient than construction of simple, nontrabeculate structures.

The tendency for septal trabeculation and subsequent increased complexity of trabecular septa appears to have been a genetic control which affected all solitary rugosans. This study shows that all solitary forms studied, including <u>Streptelasma</u> and its descendants, exhibit this increasing complexity. Within a single genus, <u>Streptelasma</u>, species in the Red River are nontrabeculate whereas species in the Gunn Member of the Stony Mountain Formation, and the correlative Hunt Mountain beds are trabeculate.

Future work on Ordovician species of <u>Streptelasma</u> outside the North American equatorial realm would show if this change from nontrabeculate to trabeculate structures within the genus was a process that affected all Ordovician <u>Streptelasma</u> or just those in the areas studied. If the process was widespread in the genus then the presence and type of septal trabeculation has some potential for use in dating coral faunas.

The interval of time represented by the paraconformity and the diastemic Fort Garry Member appears to be critical in that it is the time that <u>Paleofavosites</u> appeared in the areas studied. It may also be the time that the genus became distributed outside the equatorial realm. This same time span represents the shift from nontrabeculation

to trabeculation of solitary coral septa and separates "primitive" coral faunas from those which are "advanced."

Age of Basinal and Basin-Peripheral Strata

For an accurate age assignment of the Ordovician strata, sources other than the environmentally controlled corals must be used. Kay (1935) maintained that faunal similarity and similar facies between the Stewartville Formation of southeastern Minnesota and northeastern Iowa and the Red River Formation provides sufficient basis for a Trentonian age assignment to both. Recent work based on conodont faunules in the basinal and basin-peripheral Ordovician strata provided range of ages by which the coral faunas can be dated.

<u>Conodont Assemblages</u>.--Holland and Waldren (1955) studied a conodont assemblage from the basal sandstones of the Winnipeg Formation in the subsurface of North Dakota and concluded that they were strongly suggestive of a Blackriveran age. Carlson (1960) also studied the conodont assemblages in the Winnipeg in the subsurface of North Dakota and concluded that the unit is of Middle Ordovician age. He stated that the assemblages are similar to those in the Glenwood, Platteville, and Decorah Formations in the Upper Mississippi Valley and assigned Blackriveran to Trentonian ages to the unit.

Ethington and Furnish (1960) studied the conodonts from the Stony Mountain Formation at the type locality. They concluded that the unit ranges in age from Maysvillian to possibly early Richmondian. Macomber (1970, p. 425) suggested that comparison of Ethington and Furnish's species lists with those of Pulse and Sweet (1960) yields an earliest Edenian to early Maysvillian age for the Stony Mountain Formation. Barnes and Munro (1973, p. 297) used conodonts to determine that he Bad Cache Rapids Formation correlated with the Red River Formation nd assigned Edenian and Maysvillian ages to the units. They also indiated that the conodont faunules of the Stony Mountain and Stonewall Forations are similar to those in the late Maysvillian and Richmondian aunules of the Churchill River and Red Head Rapids Formation (Figure 3).

Cephalopod Faunas .-- Flower has been studying Ordovician cephalaods of the western United States for about 30 years. In 1942 he escribed several "boreal" cephalopods from the Trentonian Cynthiana ormation in Kentucky. In 1956 (figure 1) he demonstrated that many of he genera of the actinoceratid cephalopods occurring in the Red River nd related faunas are chronologically long-ranging, with the longest ersisting from earliest Chazyan to latest Richmondian and beyond. hree genera, however, appear to have been restricted between early oburgian (late Trentonian) to Edenian time. These genera, Paractinoeras, Kochoceras, and Selkirkoceras were all listed by Baille (1952, . 30, 31) as occurring in the Red River Formation. Nelson (1963), owever, described species of Kochoceras and a questionable Paractinoeras from the Hudson Bay region. Kochoceras ranged from strata of ed River age to strata that were younger than those containing a charcteristic Gunn Member coral fauna. Nelson also found the questionable aractinoceras in the Red Head Rapids Formation, a physical equivalent o the Stonewall Formation. The occurrence of these genera in posted River strata placed Flower's (1957, figure 1) findings on the three enera in doubt since Nelson's work (1963) apparently extended the hronologic and stratigraphic range of at least one or two of the three enera. Based on cephalopods from the North American Arctic, Flower

(1970, p. 2480) stated that Red River faunas are of "Eden-Coburg age" (late Trentonian-Edenian).

<u>Brachiopod faunas</u>.---Macomber (1970) demonstrated that the brachiopod fauna of the Hunt Mountain/Rock Creek beds in the upper part of the Bighorn Dolomite is correlative with the brachiopods of the Gunn Member of the Stony Mountain Formation. In addition, he concluded that the brachiopod fauna he studied is of Maysvillian rather than Richmondian age based on conodonts, stratigraphic sequence, and lithologic similarity. He was able to demonstrate (1970, table 1) that many of the Hunt Mountain/Rock Creek brachiopod species also occur in the Brainerd Member of the Maquoketa Formation in Iowa, the Montoya Group (probably the Aleman and Cutter Formations) in New Mexico, and the English Head and Vaureal Formations on Anticosti Island.

Paraconformities and the Diastemic Fort Garry Member.--The paraconformity occurs between the Selkirk Member of the Red River Formation and the Gunn Member of the Stony Mountain Formation in test hole P-1 (Figures 1-3). The diastemic Fort Garry Member in southern Manitoba and the "upper Red River" in the Williston Basin occupy the same stratigraphic position as the paraconformity. The time interval represented by the paraconformity, the Fort Garry, and the "upper Red River" is later than the age of the faunas of the Red River and earlier than the age of those of the Stony Mountain.

This time interval represents the time during which:

- The character of the coral faunas changed from "primitive" to "advanced."
- 2. Trabeculae developed in the septa of the solitary rugosans.

3. <u>Paleofavosites</u> appeared in southern Canada, northern Wyoming and the Williston Basin region, and possibly eastern North America.

Using age dates derived from the conodont and cephalopod faunas in the Red River and Stony Mountain Formations and faunas correlative with these, an Edenian-early Maysvillian to late Maysvillian time span can be assigned to the paraconformity, the diastemic Fort Garry, the "upper Red River," and the above-mentioned modifications to the coral faunas.

Age of Units Above the Gunn Member.---Ethington and Furnish's (1960) age assignment of Maysvillian to early Richmondian for the Gunn Member conodont faunules and the trans-systemic aspect of the Stonewall Formation suggest that the Penitentiary, Gunton, and Williams Members of the Stony Mountain Formation and the Ordovician portion of the Stonewall Formation are Richmondian. Twenhofel's (1928) Gamachian age for Ordovician strata younger than Richmondian has not been widely used by subsequent workers, and Bolton's (1972) assignment of a Richmondian age to the Ellis Bay Formation (Twenhofel's type unit for Gamachian age strata) implied that a Gamachian age is no longer recognized even in the type area on Anticosti Island. The Richmondian strata are those younger than Maysvillian, older than Silurian, and the upper three members of the Stony Mountain and the Stonewall Formation are Richmondian.

CONCLUSIONS

1. The corals of the Red River Formation are geographically wide ranging, with representatives in areas as distant as New Mexico and Greenland. The Flower (1961) Model shows that, based on microskeletal structures, the Red River genera are in "primitive" and "midrange" stages of evolution. "Primitive" cerioid and cateniform tabulate corals are predominant, and nearly all colonial rugosans are cerioid and of one genus, <u>Crenulites</u>. Solitary corals are relatively minor constituents of the coral fauna but their genera are ancestral to solitary forms in the overlying Stony Mountain Formation. Septal structures in the Red River solitary corals are regarded as "primitive" since they are nontrabeculate. Very few of the Red River tabulate coral genera persist in the Stony Mountain Formation and units correlative with it.

2. Corals in the Stony Mountain are less wide spread geographically than those in the Red River Formation. The Flower Model shows that the genera in the Stony Mountain and units correlative with it are "advanced" in terms of evolutionary position. Rugosan-type walls are present in all cerioid colonial corals and septa in the solitary corals are all trabeculate. Nearly all the colonial tabulates are <u>Paleofavosites</u> which has its ancestor in a <u>Foerstephyllum</u>-like form in the Montoya Group but not in the Red River. Solitary corals predominate in the fauna of the Gunn Member of the Stony Mountain Formation and the correlative Hunt Mountain beds, both in terms of numbers of species and numbers of individuals.

3. Corals in the Stonewall Formation appear to be more restricted geographically than those in the Red River or Stony Mountain faunas. This may be an effect of poor preservation but of the species stratigraphically restricted to the Stonewall, only one, <u>Palaeophyllum</u> pasense, is present in both Manitoba and Wyoming.

4. Cerioid colonial corals, both tabulates and rugosans, are predominant corals in carbonate rocks whereas solitary corals dominate in argillaceous rocks.

5. A paraconformity between the Red River and Stony Mountain Formations, on the cratonic platform east of the Williston Basin is represented outside the Basin region by a widespread unconformity. The paraconformity and unconformity represent a large scale regression of the Ordovician sea.

6. The Fort Garry Member of the Red River Formation and the evaporitic "upper Red River" occupy the same stratigraphic position as the paraconformity and show that deposition continued in southern Manitoba and the Williston Basin. The Basin was less affected by erosion than southern Manitoba where diastems are present in the Fort Garry.

7. Southern Manitoba, in turn, was affected less by erosion than was eastern North Dakota where the Fort Garry was either not deposited or was removed by erosion. Areas farther from the Basin were subjected to greater amounts of erosion than the Basin itself.

8. The evolutionary break between the predominantly "primitive" corals of the Red River Formation and the "advanced" corals of the Stony Mountain and correlative Hunt Mountain beds appears at the same stratigraphic position as the paraconformity and the Fort Garry Member.

9. During the time of deposition of the Fort Garry Member, <u>Paleofavosites</u> spread from its source area into the Williston Basin and adjacent regions. The genus may have also spread to other areas on the North American continent at this time.

10. The change from nontrabeculate to trabeculate septa in the genus <u>Streptelasma</u> shows that a basic method of septal construction was altered within the lineage of <u>Streptelasma</u>. This alteration may have time-stratigraphic implications.

11. No systematic pattern of coral distribution occurs on the bedding plane exposures of the Selkirk Member. Poorly defined patches of corals are present in and outside of patches of abundant receptaculitids.

12. The Cat Head Member of the Red River Formation in southern Manitoba is discontinuous to the south on the cratonic platform east of the Williston Basin.

13. The Selkirk Member of the Red River Formation has a higher clay content than the Dog Head Member in the type area of the Selkirk and in northeastern North Dakota (test hole P-1).

14. The corals studied do not serve as effective tools for correlation outside the New Mexico-Greenland belt of Ordovician rocks. Some of the species, especially those in the faunas of the Selkirk are widespread along the belt. The presence of <u>Paleofavosites</u> indicates that the rocks containing it are probably Richmondian or younger. The change from nontrabeculate to trabeculate septa in the solitary corals may offer potential for correlation with strata outside the belt.

15. Age determinations based on conodont assemblages (Holland and Waldren, 1955; Carlson, 1960) result in a Blackriveran to Trentonian age for the Winnipeg Formation. Cephalopod dating by Flower (1957, 1970) results in a late Trentonian through Edenian age for the Red River faunas. Conodont faunules from the Gunn Member of the Stony Mountain Formation type area are, according to Ethington and Furnish (1960), Mayvillian to early Richmondian in age. The time span represented by the paraconformity, the Fort Garry Member, and the "upper Red River" is uncertain. It appears to represent a portion of Edenian or Mayvillian through late Maysvillian time. The essentially conformable Penitentiary-through-Stonewall interval was deposited in the remaining portion of Ordovician time, presumably early through late Richmondian.

16. Fifty-four species were identified in 20 genera in the Red River-Stonewall interval and in the Bighorn Formation. Thirty-three of the species (61%) are tabulates, and 21 of the species (39%) are rugosans. Forty of the species (74%) are colonial, and fourteen species (26%) are solitary.

17. Twelve species are new: <u>Trabeculites manitobensis</u>, <u>Nycto-pora fissisepta</u>, <u>Manipora garsonensis</u>, <u>M. bighornensis</u>, <u>Angopora wyomingensis</u>, <u>Favosites manitobensis</u>, <u>Streptelasma kelpinae</u>, <u>S. sheridanensis</u>, <u>Palaeophyllum sinclairi</u>, <u>Bighornia tyndallensis</u>, <u>B. cvancari</u>, and <u>Cyathophylloides hollandi</u>.

SYSTEMATICS

<u>Approach</u>.--The Ordovician corals from around the periphery of the Williston Basin have not been studied previously as a topic in themselves. I am of the opinion that, at this time, the organisms comprising these faunas must be treated as biological entities. These organisms were absorbers and utilizers of available energy in the Ordovician marine ecosystem, and their preserved skeletal components reflect the form and function of the individual and colonial polyps. Therefore strict description of external morphology is insufficient. Both the solitary and colonial corals are characterized at various taxonomic levels by their internal morphology whereas the external form, in many cases, only reflects the effect of the internal features, thereby making mandatory the study of internal features.

This study requires preparation of large numbers of transverse, longitudinal, tangential, and oblique thin sections of nearpetrographic thickness. These sections can be studied only by transmitted light microscopy due to the small sizes of individual corallites and the features involved. Plane polarized and crossed nicol microscopy is the only suitable method of study, utilizing equipment at hand for revealing the skeletal microstructures upon which must of this study is based.

It is insufficient to state in a description that a particular skeletal feature is "long" or "thick" or "of moderate length." These

are arbitrary terms and are visualized differently by various individ-Therefore I have based a large portion of the study on biometric nals. data derived through direct measurement of skeletal features by the use of vernier calipers for "large" features, or by use of a micrometer eyepiece in microscopy of features not visible or measurable with the unaided eye. Ranges of variability, means, and numbers of samples are given for every species. Extensive biometric tables are constructed for types described in this study. If a species has been described by a previous worker, any biometric data stated previously are stated and compared with data derived in this study, giving the reader an impression of the similarity of the present material with previously described types. If a species is new, biometric data are also expressed in tabular form in order to provide quantitative information which will enable a subsequent worker to compare and contrast the new species with other comparable taxa.

It is insufficient in many instances to give only absolute measurements. Radial internal features such as septa, septal spines, or features which are related to corallite circumference, are best expressed biometrically in relation to the radius or diameter of a corallite. For example, as the radius changes within an individual the relative dimension of a feature may remain constant despite the dimensional variation in absolute size.

Colonial corallites, such as those in phaceloid or cerioid coralla are usually characterized by a constant diameter throughout their adult life. Internal features within these usually possess fairly constant relative sizes throughout this state. The solitary corals however, usually have ontogenies characterized by changes in

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location, orientation, and sizes of internal features throughout their life spans which accompany and often reflect increases in length and diameter.

The solitary rugose corals are especially characterized by increases in diameter with increasing age and corallum length. Expression of the size of a feature in absolute units would be valid only for a stated distance from the corallum point of origin--the apex. In order to demonstrate or illustrate the change of size of a feature with age of the individual, measurement of that feature must be treated as a dependent variable which changes with relation to an independent variable reflecting age--corallum length. Plotting of derived data serves to illustrate that the relative size of the feature in question increases, remains constant, or decreases with distance from the apex.

Study of solitary coral ontogeny must include skeletal development during the juvenile or neanic stages. The degree of resolution necessary in the apical region requires the study of transverse sections spaced as close as 0.25 mm from the apex and each other. The use of thin sections is not possible this close to the apex due to destruction of an undue amount of material during cutting and grinding operations. The use of a serial section grinder and subsequent preparation of serial, transverse, acetate peels enables such nearapical ontogenetic study.

For comparative purposes, ink tracings have been made of selected serial peels in order to illustrate ontogenetic changes in selected coralla. Because thin section and peel techniques restrict photographic illustrations to the representation of two-dimensional

structures, portions of colonial corallites and solitary coralla are also illustrated in schematic ink drawings to point up certain skeletal microand macro-structural features.

Many tracings of serial peels contain restorations of unpreserved parts or structures. Furthermore, the schematic drawings of colonial corallites or portions thereof are often conceptual illustrations of structures, particularly skeletal microstructures, that are barely visible and unphotographable.

Repositories of type and catalogued material.---Abbreviated symbols are used in the text of the following section and in the appendix tables to denote the repository cited types and other specimens. Only specimens housed in the paleontological collection of the University of North Dakota were examined by me; although measurements of other specimens were taken from illustrations or data in the literature.

> Geological Survey of Canada GSC: MMK: Mineralogical Museum of Kopenhagen, Denmark New Mexico Bureau of Mines and Mineral Resources, Socorro NMBM: Riksmuseum of Stockholm, Sweden RMS: SMC: Sedgewick Museum, Cambridge England U. Man.: University of Manitoba, Winnipeg, Canada U. Mich: University of Michigan UND: Geology Department, University of North Dakota USNM: United States National Museum, Washington, D. C.

SYSTEMATIC PALEONTOLOGY

The systematic paleontology of the tabulate and rugose corals described in this section are based on collections of Ordovician corals housed at the Geology Department of the University of North Dakota, Grand Forks. These were collected by myself, by Dr. F. D. Holland, Jr., and Dr. Alan M. Cyancara and their students from exposures of Ordovician strata in southern Manitoba and in northern Wyoming on the eastern and western flanks of the Bighorn Mountains. Two species described by previous workers: <u>Praginella arborescens</u> Leith (1952, p. 795) from the Gunn Member, and <u>Lyella</u> sp. from the type section of the Stonewall Formation were not available for study.

The coral faunas consist of 55 species in 20 genera. Twelve species are new and are described with species diagnoses. Four additional species that are unassigned are thought to be new but insufficient material prevented confident diagnosis of a species. Thirtythree species in 11 genera are distributed in four families of the Order Tabulata, and 22 species in nine genera from three families are distributed in three suborders of the Order Rugosa. The generic taxa in the Order Tabulata are listed in the same manner as was used by Hill and Stumm (1956). Those in the Order Rugosa are listed in the same order used by Hill (1956). Species within each genus are placed so that the most primitive species are described first and the most advanced ones are last.

Phylum COELENTERATA Class ANTHOZOA Order TABULATA Family SYRINGOPHYLLIDAE Subfamily BILLINGSARIINAE Genus Trabeculites T. maculatus Flower T. manitobensis n. sp. Genus Nyctopora N. fissisepta n. sp. Genus Manipora M. garsonensis n. sp. M. amicarum Sinclair M. bighornensis n. sp. Subfamily SYRINGOPHYLLINAE Genus Calapoecia C. anticostiensis Billings Calapoecia sp. cf. C. anticostiensis Billings C. arctica Troedsson C. ungava Cox Family HELIOLITIDAE Subfamily COCCOSERIDINAE Genus Protarea Protarea sp. cf. P. cutleri Leith Genus Coccoseris C. astomata Flower Coccoseris sp. Subfamily PALAEOPORITINAE Genus Protrochischolithus P. magnus (Whiteaves) Family FAVOSITIDAE Subfamily FAVOSITINAE Genus Paleofavosites P. kuellmeri Flower Paleofavosites sp. cf. P. kuellmeri Flower P. mccullochae Flower Paleofavosites sp. cf. P. prayi P. prolificus (Billings) Paleofavosites sp. A cf. P. prolificus (Billings) Paleofavosites sp. B. cf. P. prolificus (Billings) P. okulitchi Stearn Paleofavosites sp. cf. P. okulitchi Stearn Paleofayosites sp. cf. P. capax (Billings) Paleofavosites sp. A Paleofavosites sp. B Genus Angopora Angopora manitobensis Stearn Angopora wyomingensis n. sp. [?] Angopora sp. Genus Favosites Fayosites manitobensis n. sp.

Family HALYSITIDAE

Genus Catenipora

C. robusta (Wilson)

C. rubra Sinclair and Bolton Catenipora sp.

Order RUGOSA

Suborder STREPTELASMATINA

Superfamily ZAPHRENTICIAE Family STREPTELASMATIDAE Subfamily STREPTELASMATINAE

Genus Streptelasma

S. kelpinae n. sp.

S. poulseni Cox

S. sheridanensis n. sp.

Streptelasma sp.

Genus Palaeophyllum

P. argus Sinclair

P. pasense Stearn

P. sinclairi n. sp.

Genus Grewingkia

<u>Grewingkia</u> robusta (Whiteaves) Grewingkia goniophylloides

(Teichert)

Grewingkia sp.

Genus Lobocorallium

L. trilobatum (Whiteaves)

Genus Dieracorallium

Dieracorallium manitobense Nelson

Dieracorallium sp.

Genus Bighornia

B. tyndallensis n. sp.

B. cvancari n. sp.

B. patella (Wilson)

B. parya Duncan

B. bottei Nelson

Suborder COLUMNARIINA Family STAURIIDAE Genus <u>Crenulites</u> <u>C</u>. <u>rigidus</u> Flower <u>C</u>. <u>duncanae</u> Flower Genus <u>Cyathophylloides</u> <u>C</u>. <u>hollandi</u> n. sp. Suborder CYSTIPHYLLINA Family TRYPLASMATIDAE Genus <u>Tryplasma</u> <u>T</u>. gracilis (Whiteaves)

SYSTEMATIC DESCRIPTION

Phylum COELENTERATA

Class ANTHOZOA

Order TABULATA

Family SYRINGOPHYLLIDAE

Subfamily BILLINGSARIINAE

Genus Trabeculites Flower, 1961

Type species (by original designation).--<u>Trabeculites keithae</u> Flower, 1961, New Mexico Bur. Mines and Mineral Resources, Mem. 7, p. 61, plates 26, 27.

<u>Diagnosis</u>.--Thin wall, cerioid; walls composed of laterally abutting, longitudinal wall trabeculae composed of sclerenchymal fibers arranged in V-shaped fashion around a central axial rod or plate; tabulae complete and incomplete, predominantly oriented normal to corallite axis or distal corallum surface.

Discussion.--Generic assignment of cerioid tabulate corals to the genus <u>Trabeculites</u> is based primarily upon microstructure of the corallite wall. Flower's original diagnosis of the genus (1961, p. 62) is based upon cerioid tabulates with corallite walls composed of sets of obliquely sloping calcite fibers forming inverted cones about rodlike or short planar axial structures. Each of the axial wall structures forms the center of a longitudinal trabecula. Corallite walls are constructed of sets of these parallel trabeculae in lateral contact with each other along a longitudinal plane. Contact between

pairs of adjacent wall trabeculae is manifested as a faint, thin line where sets of trabecular fibers abut.

Identification of <u>Trabeculites</u> to the generic or specific level cannot be done without the use of polished or thin section microscopy. Only under cross polarized light does the border between adjacent wall trabeculae become discernible. Two prime species diagnostic characters are corallite diameter and the shape of the wall trabeculae.

In the Flower Model (Figure 6), <u>Trabeculites</u> represents an early stage of evolution in the generic lineage <u>Lichenaria</u> — <u>Trabeculites</u> — <u>Nyctopora</u> — <u>Calapoecia</u>. Flower (1961), in proposing his Model, traced the development of the <u>Lichenaria</u>-type to the "<u>Calapoecia</u>"-type wall. This process originated with <u>Lichenaria</u> where a simple, planar wall of two sets of sclerenchymal fibers in V-shaped orientation separated into a wall of closely packed, individual trabeculae as in <u>Trabeculites</u>; to individually distinct, adjacent trabeculae characteristic of <u>Nyctopora</u>; and culminated in separate, parallel trabeculae characteristic of <u>Calapoecia</u>.

Trabeculites maculatus Flower, 1961

Plate 1, Figures 1, 2, 4, 7

Trabeculites masculatus Flower, 1961, New Mexico Bur. Mines Mineral Resources, Mem. 7, p. 62, pl. 28; pl. 31, figs. 5, 6; pl. 45, figs. 10-12.

<u>Diagnosis</u>.--Cerioid, polygonal corallites 1.8 to 2.45 mm in diameter; centers of individual wall trabeculae developed as short axial plates; trabecular walls commonly of nearly uniform thickness at trabecular centers and regions of intertrabecular contact; septa

developed as spines varying in length, major and minor types present, averaging 16 per corallite; tabulae complete, concave, or plane, segregated into closely and widely spaced zones; tabular spines in closely spaced zones usually longer and more numerous than those in widely spaced zones.

Description of material .-- Fragments of the massive ceroid hypotype corallum (UND Cat. No. 13560) have polygonal corallites aligned vertically in mature corallum portions, which open normal to the corallum surface. Corallites are about 2.1 mm mean diameter, with walls composed of parallel, longitudinal trabecular rods, each in lateral contact with adjacent ones on either side. Calcite fibers within each trabecula form a V-shaped divergent pattern in longitudinal section in which fibers originate from a central plate and are oriented upward and outward from the point of origin toward the lumen of each corallite. The wall junction between three adjacent corallites is formed by a single, three-armed trabecula with three convergent axial plates meeting at the point of corallite intersection (Figure 10). Fibers in these "junction" trabeculae contain sclerenchymal fibers oriented in three sets. Each set consists of a fibrous sclerenchymal layer in which constituent fibers are oriented with their long axes directed toward the axis of each corallite. Spine bearing trabeculae have skeletal fibers with their long axes arranged in three or four sets. Each spine has a central midline from which fibers diverge toward the two lateral spine surfaces. The two fiber sets in each spine show that the fibers within each trabecula bearing ^a spine are in the same orientation as those in the spine. Trabecular

fibers within the spines are oriented in V-shaped sets with the spine fiber orientation the same as that for the remainder of the wall (Figure 10).

Septa average 16 per corallite and are developed as major and minor forms of differing length. These are developed as individual spines of varying length (Appendix B, Table 6) or as short septal blades parallel to the corallite axis. Major septa consist of denticulate, longitudinal blades composed of septal spines merged longitudinally within a corallite and contain two or more large spines. Minor septa are developed as individual denticulations along a wall trabecula. No mural pores were present.

Tabulae are all complete and transverse to the corallite axis, varying in curvature from concave through planar. Few convex tabulae occur. Tabulae are zoned with respect to spacing. Zones are laterally continuous, and parallel the distal corallum surface. Zones of closely spaced tabulae exhibit distal tabular surfaces with well-developed, triangular, tabular spines, most of which are oriented normal to the tabular surface. Spines are also present on tabulae in zones where they are more distantly spaced but in these zones spines are shorter, narrower, and less frequent than those in zones of closely spaced tabulae (Appendix B, Table 6).

Type.--Hypotype. UND Cat. No. 13560.

<u>Occurrence</u>.--The hypotype (UND Cat. No. 13560) assignable to <u>Trabeculites maculatus</u> Flower was collected from the Selkirk Member of the Red River Formation in a quarry at Garson, Manitoba (locality A884, Appendix A). Flower 1961, p. 62) described the species from

examples collected from a horizon within Ordovician strata 99 meters (325 ft) above sea level on Akpatok Island, northern Quebec.

<u>Discussion</u>.--The hypotype from the Selkirk of southern Manitoba assigned to <u>Trabeculites maculatus</u> Flower is comparable to the original description of the species (Flower, 1961). Corallite diameters and spacing of tabulae are similar (Appendix B, Table 6); also little variation is observed between the width of wall along the trabecular centers and the width on each side of a trabecula in contact with adjacent trabeculae.

The hypotype does not exhibit the sharp distinction between adjacent trabeculae as shown by Flower's illustrations (1961, plate 28, figures 4, 6; plate 31, figures 5, 6; plate 45, figures 10, 11). However, transverse thin sections of this specimen viewed under plane polarized light and crossed nicols, reveal faint trabecular boundaries. In addition, fiber orientation within individual trabeculae and septa are discernible as very faint lineations within these skeletal elements (Figure 10).

The width of lateral margins in contact with adjacent wall trabeculae is 0.92 times the mean width of the trabecular centers (Appendix B, Table 6), negating the possibility that the hypotype is <u>T. kiethae</u> Flower, the type species. <u>Trabeculites kiethae</u> (Flower, 1961, p. 61) possesses corallite walls in which trabeculae are wider at their centers than at their lateral margins (Flower, 1961, plate 27, figures 4, 10).

Tabular spines in zones of closely and widely spaced tabulae show that closely spaced tabulae have spines that are longer and more numerous than those on widely spaced tabulae. This suggests a possible

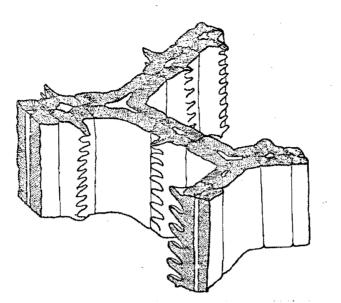


Fig. 10.--Corallite wall of <u>Trabeculites maculatus</u>. Fibrous structure of walls and septa shown by patterned stippling. Axial plates and rods shown by clear areas, approx. X13.

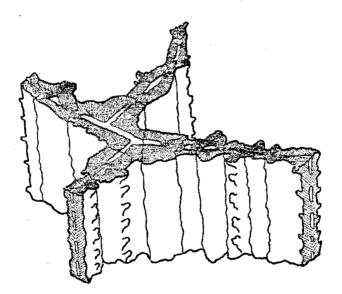


Fig. 11.--Corallite wall of <u>Trabeculites manitobensis</u> n. sp. Fibrous structure of walls and septa shown by patterned stippling. Axial plates and rods shown by clear areas, approx. X25. physiological relationship between rates of upward growth of the colony and development of spines but the exact relationship is not clear.

The occurrence of <u>T</u>. <u>maculatus</u> Flower in the Selkirk Member of the Red River Formation in southern Manitoba extends the geographic range of the species far southwestward from Akpatok Island, Ungava Peninsula of northern Quebec (Flower, 1961, p. 62).

Trabeculites manitobensis n. sp.

Plate 1, Figures 3, 5, 8; Plate 2, Figure 1

Diagnosis.--Corallite walls of trabeculae swollen at center, narrow at lateral margins, forming wall with swollen and constricted portions; septal spines short, 16-25 per corallite, averaging 22; tabulae predominantly complete, crenulate near corallite margin, often upturned at corallite wall, oriented normal to corallite axis, varying in curvature from concave, through planar, to convex; incomplete tabulae occurring in zones parallel to upper surface of corallum, oblique to corallite axis, varying in curvature from concave to convex; tabular spines uncommon, occurring most frequently on incomplete tabulae; tabular spacing near uniform.

Description of material.--The corallites in the massive, cerioid holotype corallum (UND Cat. No. 13561) are polygonal to sub-polygonal in cross section and are oriented parallel to each other, opening normal to the nearly planar corallum surface in mature portions of the corallum. The holotype is fragmental, with an observed maximum corallum heights of 55 mm and an estimated width of at least 90 mm. Lateral margins of the corallum show that lateral corallum expansion occurs by the lateral budding of peripheral polyps, and simultaneous secretion of new corallites over the sediment surface.

Corallite cross section varies from polygonal to subpolygonal. This variance is controlled by corallite wall thicknesses at the junctions of three or more adjacent corallites. Thick walls of these junctions result in a rounding of corallite lumina whereas thin walls result in sharply defined, polygonal lumina. The corallite wall is composed of longitudinally directed, parallel, monacanthine trabeculae composed of calcite fibers arranged in cone-fashion about a rod or a narrow, thick, axial plate at the center of each trabecula. The resulting cone sets of upwardly inclined fibers with their bases at the axial plate or rod of each wall trabecula, have their apices directed toward the corallum base (Figure 11). Most trabeculae in the holotype are markedly thicker at the trabecular center than at the lateral margins. Measured swollen wall trabeculae in the holotype show that the mean width of the trabecular margin is 0.62 times the width of the trabecular center (Appendix B, Table 7). Fiber orientation in transverse section exhibits a radial pattern of divergence from both the trabecular axial plates and rods. This forms indistinct but observable intertrabecular boundaries by the abutting of the peripheral ends of one trabecular set against those of adjacent trabeculae (Figure 11).

Septal spines occur as axial projections of elongate trabecular fibers from the corallite wall. In transverse section, spines show sets of fibers in two orientations (Figure 11) with a central line of divergence marking the septal midline. Septa per corallite range from 16 to 25 and mural pores are absent.

Tabulae show no zonation of tabular spacing; complete and incomplete tabulae occur. Complete forms are most oriented normal to the corallite axis, and are most frequently planar, or planar with upturned

margins. Concave forms are less frequent, and convex forms are rare. Incomplete tabulae are predominantly oriented oblique to the axis. Convex curvature is predominant; concave forms are less frequent. Complete and incomplete forms are in zones parallel to the upper corallum surface. The marginal edges of tabulae show a crenulate or undulatory aspect close to the line of attachment with the corallite wall. Short, triangular, tabular spines are rare, but are most common on incomplete tabulae. Since incomplete and complete tabulae are segregated into separate zones paralleling the corallum growth surface, spine occurrence is also zoned since spines are most common on incomplete tabulae. Some of these spines rarely show a very faint pattern of calcite fibers arranged in a manner similar to those in corallite walls.

Type.--Holotype, UND Cat. No. 13561.

Occurrence.--Quarry exposures in the immediate vicinity of Garson, Manitoba, Canada (locality A884, Appendix A).

<u>Discussion</u>.--The corallum described above is assigned to <u>Trabeculites</u> due to its possession of features shared by the species <u>T. keithae</u> and <u>T. maculatus</u>. <u>Trabeculites manitobensis</u> shares similar corallite diameters with T. maculatus.

Comparison of <u>T</u>. <u>manitobensis</u> with three species of <u>Trabeculites</u> described by Flower (1961, p. 61-62) results in the designation of a new species named for its occurrence in the southern portion of the province of Manitoba. This designation is based on (1) trabecular counts per corallite comparable to those in <u>T</u>. <u>keithae</u>, (2) expanded trabeculae wider at their centers than at their margins similar to those of <u>T</u>. <u>keithae</u>, (3) crenulate tabular peripheral margins similar to

<u>T. keithae</u> (Flower, 1961, p. 61, plate 26, figure 7), and (4) corallite diameters comparable to those of <u>T. maculatus</u>.

Comparison of wall outline and thickness, trabecular width at center and margin, septal counts, septal length, tabulae type, and tabular spine development with <u>T. maculatus</u> show the following: <u>Trabeculites maculatus</u> Flower has a nearly straight corallite wall with trabeculae having nearly the same width at the margin and center whereas the holotype of <u>Trabeculites manitobensis</u> has a wall with undulatory thickness, a result of wall trabeculae being thicker at the center than at the margin.

Septa in <u>Trabeculites maculatus</u> are fewer and longer than those of <u>Trabeculites manitobensis</u> (cf. Appendix B, Tables 6, 7). Tabulae in <u>T. maculatus</u> are complete, and segregated into zones of narrow and widely spaced types, whereas those in the holotype of <u>T. manitobensis</u> are both complete and incomplete, showing no tendency for grouping into zones. Tabular spines in the hypotype of <u>T. maculatus</u> are relatively abundant, especially on closely spaced tabulae, whereas the holotype of <u>Trabeculites manitobensis</u> has septal spines occurring very infrequently, usually only on incomplete tabulae.

Flower (1961) described the holotype of <u>T</u>. <u>keithae</u> from the Second Value Formation of the Montoya Group, western Texas. <u>T</u>. <u>maculatus</u> occurs in Ordovician strata of late Red River or early Richmond age on Akpatok Island. The holotype of <u>T</u>. <u>manitobensis</u> appears to be intermediate between the two, both in terms of morphology and geographic location. All occur in Ordovician strata containing

faunas similar to those in the Red River Formation, or in the Red River Formation itself.

Genus Nyctopora Nicholson, 1879

Type species (by monotypy).--Nyctopora billingsi Nicholson, 1879, tabulate corals of the Palaeozoic period, p. 184, pl. 9, figs. 3, 3a-c.

Emended generic diagnosis. -- Thick corallite walls composed of distinct, monacanthine trabeculae commonly extending as 8 to 16 septal ridges per corallite, present as longitudinal rows of separate septal spines or merged to form thick septal blades with denticulate axial ends; tabular commonly transverse to corallite axes.

<u>Discussion</u>.--The wall construction, number of septa, and nature of septa are markedly different from that of <u>Paleofavosites</u>. Based upon the most basic skeletal character, the corallite wall microstructure, the <u>Nyctopora</u> appears to be descendant from <u>Trabeculites</u>. Both possess corallite walls constructed of adjacent parallel trabecular rods, but <u>Nyctopora</u> differs from <u>Trabeculites</u> by its transversely crenulate wall, pronounced sutures between adjacent trabeculae, and 8 or 16 very thick septa.

Flower (1961) considered <u>Nyctopora</u> to be descendant from <u>Trabeculites</u> because of the greater separation between wall trabeculae; the two are within an evolutionary trend from the most primitive <u>Lichenaria-type</u> wall to the <u>Calapoecia</u> type. The trend extends from a two-layered, fibrous corallite wall typified by <u>Lichenaria</u>, through a breaking up of the wall into short trabecular planes as in <u>Trabec-</u> ulites, consolidation of the trabeculae into distinct, closely appressed, monacanthine trabecular rods as in <u>Nyctopora</u>, and finally into separated trabecular rods as occurs in <u>Calapoecia</u>.

Flower (1961, p. 63) updated a list of occurrence of <u>Nyctopora</u> and related forms given by Bassler (1950). Flower listed eight species from <u>Nyctopora</u>, two of which were new, resulting in an age range from Chuzyan (Marmorian of Cooper, 1956) to Richmondian. Of six species which are present in Ordovician rocks of eastern North America, five are in strata that are older than Richmondian. Thus <u>Nyctopora</u>, in addition to being "primitive," is an early genus and seems to be generally indicative of pre-Richmondian strata.

Nyctopora fissisepta n. sp.

Plate 1, Figure 6; Plate 2, Figures 2, 4, 5

Species diagnosis.--Lamellar cerioid coralla with parallel, prismatic corallites normal to the distal corallum surface; diameter range 1.0 to 1.8 mm; corallite wall 0.08 to 0.18 mm thick; septa developed in two orders; major septa long, extending nearly to corallite axis, axial ends often bifurcated near distal tabular surface, with denticulate margins inclined upward; minor septa approximately half as long as major septa. Tabulae all complete, slightly concave to planar, to slightly convex; tabulae normal to corallite axis.

Description of material. -- The holotype corallum (UND Cat. No. 13703) is a fragment of a larger corallum estimated to be at least 20 cm in diameter. The maximum diameter of the fragment is 7.0 cm and it is 1.5 cm in maximum thickness. The corallum is lamellar with all contained corallites parallel to each other and normal to the distal corallum surface.

The corallites are cerioid, subpolygonal in transverse profile, rectangular to hexagonal, and 1.0 to 1.8 mm in diameter (mean diameter, 1.36 mm). The corallite wall exhibits no amalgamation or layering. Wall structure is that of parallel, longitudinal bundles of monacanthine, trabecular rods with constituent fibers set in a series of cone-like patterns; trabecular fibers are inclined upward toward the trabecular center (Figure 12). Longitudinal sections through trabeculae show a vertical series of chevron-like fiber patterns. Rare wall perforations, possibly mural pores, occur in transverse rows between septa and above the distal surfaces of tabulae. Sixteen septal rows occur in each corallite, eight major and eight minor septa. Mean maximum extension of major septa into the lumen is 0.52 times the mean corallite radius whereas mean minor septal length of 0.37 times that of the major septa (Appendix B, Table 8).

Septal development varies from a minimum where both the major and minor septa are of equal length to a maximum where major septa extend more than halfway to the corallite axis. The length of the minor septa remain relatively constant in both developmental stages. Major septal development is variable along the length of a corallite and from corallite to corallite, and is best developed in regions of the corallum where tabulae are closely spaced. The major septa, at their intersection with the distal tabular surface are often bifurcated at their axial margins (Figure 12), and vary from longitudinal rows of upwardly inclined, axially projecting individual spines to blade-like structures with spinose margins.

Tabulae are complete and vary in curvature from slightly concave, through planar, to slightly convex. Tabular spacing is zoned, varies from 0.2 to 0.8 mm, and parallels the corallum growth surface.

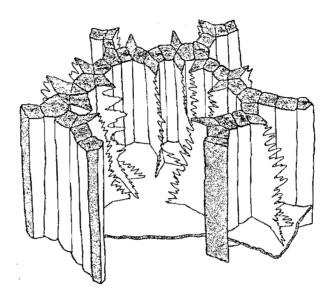


Fig. 12.--Cut-away of a corallite of <u>Nyctopora fissisepta</u> n. sp. Fibrous wall and septal structures shown by patterned stippling, approx. X40.

Type.--Holotype, UND Cat. No. 13703.

Occurrence. -- The holotype corallum (UND Cat. No. 13703) was collected from the Selkirk Member of the Red River Formation at the Garson quarry on the eastern edge of Garson, Manitoba (Appendix A, locality A897).

Discussion. -- The presence of axially bifurcating major septa has not been previously recorded in <u>Nyctopora</u>; <u>N. fissisepta</u> n. sp. is named for this septal quality.

Septal spines viewed in tangential sections of corallites appear as series of longitudinal rows of truncated, obliquely oriented spine tips. The development of individual spines or acanthine septal blades was controlled by the width and degree of merging of obliquely oriented fibrous trabeculae, which, in turn, may have been affected by the variations of longitudinal growth rates of the corallites as reflected by tabular spacing. Relatively rapid rates of growth resulted in longitudinally separated, short septal spines. Slower growth rates, as reflected by closely spaced tabulae, resulted in the merging of longitudinally adjacent septal spines to form a septal blade with denticulate axial ends.

Transverse sections of the holotype (UND Cat. No. 13703) examined under crossed nicols showed extensive replacement of the original skeletal material, obliterating much of the fibrous microstructure. Sufficient remnants of the original structure were observed and Figure 12 illustrates the probable skeletal structure. Septal spines appear as skeletal units not in direct fibrous continuity with the monacanthine wall trabeculae. This is based on observations of very faint,

poorly preserved skeletal features and may not be truly representative of original septal-trabecular relationships.

The only other species of Nyctopora with structures at the axial ends of the septa was described by Bassler (1950, p. 263): <u>Nyctopora</u> (<u>?Billingsaria</u>) <u>parvituba</u> (Troedsson) which has eight major septa which extend more than halfway to the corallite axis, and terminate in a thick, rounded structure. <u>Nyctopora fissisepta</u> n. sp. may be related to <u>N</u>. (<u>?Billingsaria</u>) <u>parvituba</u> due to both having structures on the axial septal margins, but <u>N</u>. <u>fissisepta</u> differs from the other species by its bifurcate septal margins.

Genus Manipora Sinclair, 1955

<u>Type species</u> (by original designation).--<u>Manipora amicarum</u> Sinclair, 1955, Trans. Roy. Soc. Canada, 3rd serv. v. 49, sec. 4, p. 97, plate 1, figures 1, 4, 10.

<u>Diagnosis</u>.--"A <u>Saffordophyllum</u>-like coral of halysitoid habit, the subquadrate corallites forming single or multiple ranks, tabulae complete, the inner walls of the corallites sporadically wrinkled to form discontinuous longitudinal 'septa'" (Sinclair, 1955, p. 97).

<u>Discussion</u>.--As Flower (1961, p. 45) noted, the common walls of <u>Manipora</u> are structural entities separate from the lateral wall surrounding the exteriors of the cateniform ranks and cerioid or agglutinative patches. The common wall is of the <u>Lichenaria</u>-type, with a microstructure of chevron-shaped fiber sets which abut at their inner ends along an axial plane. The lateral wall is similar to that in <u>Catenipora</u> in that it consists of a set of fibers sloping upward and inwardly from an external holothecal layer. Unlike <u>Catenipora</u>, no breakup of the common wall into trabeculae and no textural variation in the fibrous layer of the lateral wall is seen in <u>Manipora</u>. Structural differences between the common and lateral walls is also seen in the embedding of the peripheral ends of the common wall into recesses in the lateral wall. In addition, all three species of <u>Manipora</u> encountered in this work show that the fiber orientation in the lateral walls have greater angles of deviation from the wall plane than do the fibers in the common walls.

The genus, as is presently known, ranges from New Mexico to southern Manitoba and covers a range of from Selkirk to Gunn time. <u>Manipora wyomingensis</u> is the first recorded occurrence of the genus outside of beds of Red River age.

Manipora amicarum Sinclair, 1955.

Plate 2, Figure 3; Plate 3, Figures 1, 2, 5 Halysites catenularia var. gracilis (Hall), Lambe, 1899 [partim], Geol.

> Survey Canada, Contrib. Canadian Paleontology, v. 4, pt. 1, p. 69, 70, pl. 3, figs. 6, 7.

Halysites gracilis (Hall), Leith, 1944 [partim], Jour. Paleontology,

v. 18, no. 3, p. 268, 269, pls. 42, 43, figs. 1 (?), 2-4. Manipora amicarum Sinclair, 1955, Trans. Roy. Soc. Canada, v. 49, ser.

> 3, p. 97-99, pl. 1, figs. 1, 4, 10; Flower, 1961, p. 46, 47, pl. 2, figs. 1-5, pl. 3; Nelson, 1963, p. 60, pl. 15, figs. la, 1b, 2, 3.

<u>Diagnosis</u>.--Large, massive cateniform and agglutinative corallum with parallel and subparallel medium sized corallites 1.25 to 2.1 mm long in ranks oriented normal to slightly convex corallum growth surfaces; corallites commonly uniserial in cateniform ranks; agglutinative patches commonly formed by corallites arranged in alternate biserial fashion; corallite outline in cateniform ranks quadratic in straight ranks, trapezoidal in curved ranks with common wall normal to oblique to rank direction; approximately one-half to two-thirds of all corallites in agglutinative patches varying from 1.45 to 2.3 mm diameter; tabulae predominantly complete, oriented normal to corallite axes with curvature varying from concave through planar, to slightly convex; straight forms most common, convex forms least common; tabular spines rare, occurring only in zones of closely spaced tabulae; incomplete tabulae occurring only in same zones.

Description of material .-- The hypotype (UND Cat. No. 13765) is a fragment of a corallum much larger than the 275 mm width recorded (Appendix B, Table 9) for the fragment. Shape of the fragment and slight convexity of the corallum growth surface suggest a depressed hemispherical or shallow convex corallum. Corallites in the hypotype are oriented parallel to subparallel to each other, indicating that corallite increase occurred at or near the base of the corallum, with the resultant offset produced from its parent corallite soon after the increase of that parent from its predecessor. This method of increase ensured that most lateral expansion may have occurred before appreciable upward growth was initiated. Nearly one-third of all corallites in the hypotype (Appendix B, Table 9) are in uniserial, cateniform ranks, with the remainder present in agglutinative patches composed mainly of alternate biserial corallite aggregations. Corallites in cateniform ranks are most frequently quadratic to subquadratic in cross section with common walls normal to rank direction.

Trapezoidal corallites in straight, uniserial ranks are not common. Their common walls are oblique to the direction of the rank and these types are usually not associated with subquadrate forms within the same straight rank. Curved, cateniform ranks contain both subquadrate and trapezoidal forms with trapezoidal forms present in the arc of the rank.

Common walls within curved ranks are usually subparallel to the radius of the curve, forming trapezoidal corallites with their apices directed toward the radius center. Corallites in the agglutinative portions of the corallite are trapezoidal, pentagonal, and hexagonal in cross profile, with those in alternate biserial patches most commonly trapezoidal, or pentagonal. Common and lateral corallite walls are thin (Appendix B, Table 9), 0.04 and 0.07 times the mean cateniform corallite diameter. In the agglutinative portions, common and lateral wall thicknesses are respectively 0.05 and 0.08 times the mean corallite diameter. All lateral walls are convex and two-layered, with an outer prismatic layer corresponding to a holotheca and an inner fibrous stereozone with component fibers sloping upward toward the corallite axis. Holothecal prisms are oriented with their long axes normal to the lateral wall surface. Inner stereozone fibers are oriented in like manner when viewed in transverse section, and diverge from the area of insertion of the common wall (Figure 13). Common walls are strongly crenulate and consist of two layers of fibers sloping toward a common plane of intersection at the center of each wall, resulting in chevron-like fiber orientation.

Septa on the lateral wall consist of longitudinal rows of spines, structurally distinct from the stereozone with fibers diverging from an axial line (Figure 13). Longitudinal spine rows are not continuous through the length of the corallite, but are concentrated in and near zones of closely spaced tabulae. Septa on the common walls are continuous between tabulae, terminating axially in septal spines in zones of closely packed tabulae, but are not developed in zones of widely spaced tabulae. Septa arise from convex surfaces of the crenulate common wall, with one to three septa projecting from each wall segment of a polygonal corallite. Fiber orientations in the common and lateral walls differ, with respective mean values of 51 and 58 degrees (Appendix B, Table 9) from the wall planes. Lateral wall fibers are closer to a horizontal orientation than those in the common walls.

Tabulae are predominantly complete and oriented normal to the corallite axes. Incomplete tabulae are rare and occur only where tabulae are closely spaced. Incomplete types are oblique to the corallite axes and convex. Complete tabulae are predominantly planar in zones where tabulae are widely spaced. In zones where they are more closely spaced, concave tabulae are present with straight types. Tabulae are grouped into alternating zones of closely and widely spaced tabulae, parallel to the corallum growth surface. Spacing of alternation of zones varies from 4 and 19 mm. Zones of densely packed tabulae (Appendix B, Table 9) have a mean height of 6 mm whereas zones of widely spaced tabulae have a mean height of about 9.2 mm. Tabulae are nearly uniform in thickness and abut against the lateral and common walls. Tabular spines are rare, short, and occur only in zones where tabulae are densely packed.

Type.--Hypotype, UND Cat. No. 13765.

Occurrence. --- The species is widespread in the equatorial faunal realm, from New Mexico to the Hudson Bay region. Sinclair (1955) described the holotype (GSC No. 12382) from the Selkirk Member near Garson, Manitoba. Flower (1961) described a specimen (NMEM No. 622) from the Second Value Formation of the Montoya Group near El Paso, Texas. Nelson (1963) described three hypotypes (GSC Nos. 10373-10375) from Member Number 2 of the Portage Chute Formation and Member Number 3 of the Chasm Creek Formation, in the Hudson Bay region. The hypotype studied came from collecting locality A530 (Appendix A) in the Selkirk Member.

Discussion.--Biometric data from the southern Manitoba hypotype show that (1) about one-third of the corallites are in uniserial ranks, (2) the cateniform corallites are about 1.1 times as wide as they are long (parallel to rank direction), and have a mean width at the lateral margin of 0.83 times the mean width at the corallite center; (3) the lateral walls have a mean thickness of about 0.07 times the mean cateniform corallite width at the center; and (4) the common walls have a mean thickness of about 0.04 times the mean width stated above.

Plate figures of the Second Value specimen (NMBM No. 622) of <u>M. amicarum</u> (Flower, 1961, plate 2, figures 1-4) show that 36 percent of all corallites are in cateniform ranks. This agrees closely with the amount in the southern Manitoba hypotype. Sinclair's plate figures (1955, plate 1, figures 1, 10) of the species holotype show by count that 56 percent of the corallites are in uniserial ranks. Thus one apparent diagnostic character of the species is a cateniform

corallite content of approximately one-third to one-half of all corallites in the colony.

Sinclair (1955) gave no data on corallite wall thickness for the holotype. Flower (1961, p.93) mentioned that <u>M. amicarum</u> had thicker walls than <u>M. magna</u> Flower, however no comparable data was given to illustrate the difference between the two species. Flower's plate illustrations of transverse sections of the two species show little marked difference in wall thickness. The mean wall thicknesses of the southern Manitoba hypotype show that the walls are relatively thin in proportion to corallite width.

The hypotype under discussion has well developed lateral wall convexity in both the cateniform and agglutinative portions of the southern Manitoba example. Biometric data for the hypotype indicates that lateral wall convexity in the cateniform corallites is responsible for differences in the mean corallite widths at the lateral margin of the common wall and corallite center, indicating that the corallite at its center is 17 percent wider than at its margin due to wall convexity. Sinclair's illustrations of the holotype show corallites with definite convexity in the lateral walls.

Tabular spacing and the presence or absence of zones of widely and closely packed tabulae may not be a suitable diagnostic character. Zonation seems to be a variable quality, not being present in the holotype (Sinclair, 1955, p. 99; plate 1, figure 4) where tabulae are equidistant. Subsequent descriptions by Flower (1961, p. 93) and Nelson (1963, p. 60) show zonation to be indistinct. This feature Was probably controlled by variation in rates of upward growth, reflecting varying metabolic rates within the colony. Upward growth

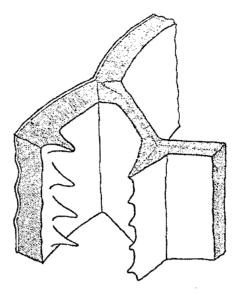


Fig. 13.--Lateral and common walls of <u>Manipora amicarum</u> showing the sutural surface between them and septal outgrowths from the walls. Holotheca of lateral wall shown by clear areas. Fiber orientation in walls and septa shown by patterned stippling, approx. X50.

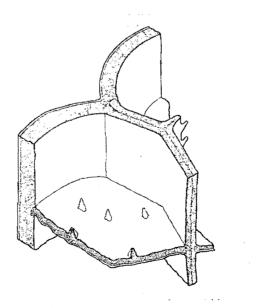


Fig. 14.—Portions of the lateral and common walls and tabulae of <u>Manipora garsonensis</u> n. sp. Fibrous structure of walls, septa, and tabular spines shown by patterned stippling. Tabular stereoplasm shown by patternless stippling. Tabulae and holotheca shown by clear areas, approx. X20.

rates may have controlled the occurrence of skeletal features other than tabulae. Septal spines on lateral walls, septa on common walls, tabular spines, and incomplete tabulae are not present in zones where tabulae are widely spaced. This reflects non-deposition of longitudinal skeletal structures during periods of maximum upward growth. These structures are best developed and most common in zones of closely spaced tabulae, indicating that sufficient calcitic material was available for septa and tabular spines only when rates of upward growth were near or at a minimum. This variation in development of these structures suggests that (1) calcitic material could be diverted from sites of septal and septal spine deposition to sites of wall construction, or (2) that the amount of calcitic material secreted was constant. Excess material may have been diverted to septal construction when not used for wall construction during periods of slow metabolic activity and commensurate moderate or slow upward growth. In the second alternative, periods of rapid upward growth caused all available secreted calcareous material to be used in wall and tabular construction.

Manipora garsonensis n. sp.

Plate 3, Figures 3, 4, 6

<u>Diagnosis</u>.--Small, tabular corallum with nearly all corallites inclined outwardly from point of origin; cateniform ranks short, small lacunae with profile varying from elongate, through kidney-shaped, to triangular; approximately half of total corallites located in cateniform ranks; corallites large, about 2.3 mm mean diameter, nearly equidimensional in mostly uniserial ranks, polygonal in agglutinative

patches, about 2.4 mm mean diameter, subrectangular to moniliform outline with convex lateral walls in ranks; common walls undulatory, oriented normal to rank direction; septa isolated to undulatory common walls, terminating axially in spines, one to two per wall segment; tabulae predominantly complete, incomplete forms rare, orientation predominantly horizontal, curvature varying from slightly concave through planar, to slightly convex, commonly thickened.

Description of material .-- The small cateniform and cerioid holotype is approximately four to five times as long and wide, as it is high (Appendix B, Table 10). Corallites at the corallum periphery are inclined outward from the colony point of origin whereas only those at the corallum center are oriented vertically. Inclined corallites are predominantly oblique to the corallum growth surface, and perpendicular corallites are normal to it. Cateniform ranks are predominantly uniserial, with a mean length of 9.5 mm, enclosing small lacunae averaging 13 mm long by 5 mm width, which vary in outline from elongate, through kidney-shaped, to triangular. Cateniform corallites are large, with mean length of 2.3 mm and width of about 2.4 mm, within a nearly equidimensional form, subrectangular to moniliform in outline with convex lateral walls. Marginal width of the cateniform corallites averages 0.8 times the mean width at their center. Cerioid corallites average about 2.4 mm diameter, and are polygonal with hexagonal and pentagonal forms predominating, and comprise 44 percent of all corallites. The lateral corallite wall enclosing the lateral portions of the corallum has a mean thickness of approximately 0.12 times the cateniform corallite diameter, retaining a relatively uniform thickness along the lateral surface

of the corallite. The two-layered lateral wall has an outer dark layer of coarse blunt prismatic crystals oriented parallel to the fibers in the inner layer (Figure 14).

Fibers in the inner layer are inclined upward toward the corallite center and are normal to the external surface of the lateral wall when viewed in transverse section. The common wall is oriented normal to the direction of the cateniform rank, and its mean width averages 0.14 of its length (Appendix B, Table 10). It shows a transverse undulatory habit, often with a septum positioned on the convex fold. Longitudinal sections of the common wall show chevron-like orientation of two fiber sets, each diverging upward and outward from the axial plane formed by the proximal ends of abutting sets of fibers (Figure 14).

Transverse sections of the common wall show fibers oriented normal to the common wall surface and axial plane. Lateral margins of the wall are embedded within the fibrous inner layer of the lateral wall, resulting in a sharp structural boundary between the two wall types separating contrasting fiber orientations (Figure 14).

Fiber orientation angles differ between the lateral and common corallite wall. Fibers in the latter have a mean orientation of 63 degrees from the corallite axis whereas those in the former have a mean of 46 degrees from the axis. Mural pores are rare, and appear to be restricted to cerioid corallites within the agglutinative patches.

Septa are not present on the inner surface of the lateral wall. Only an occasional cone-shaped protrusion, structurally continuous with the fibrous inner layer, is present. Septa with spines on their axial

margins occur only on the common wall. The number of septa per corallite is controlled by whether the corallite is in a rank or in a patch. The location determines the number of polygonal sides formed by the common wall since common wall sides have one or two septa per wall. Therefore the cateniform corallites would have from one to four septa and the cerioid types in the patches would have more, up to nine septa in a pentagonal corallite. Mean longitudinal spine spacing is 0.45 mm, with one to two spines present in each intertabular space (Appendix B, Table 10), and mean spine length os 0.07 times the mean cerioid corallite diameter.

Tabulae are predominantly complete, and incomplete types are rare. Orientation is predominantly normal to the corallite axes, with tabular curvature varying from slightly concave, through predominant planar types, to slightly convex.

Tabular thickness varies from a minimum of 0.04 mm to a maximum of 0.15 mm with a mean of 0.07 mm. No clear structural delineation between the tabula and the thickening steroplasm is seen, nor can structural features of either one be readily observed. The thickened tabular plate appears to be granular under high magnification. Broad spines embedded in the distal portion of the tabular material (Figure 14) appear to have a microstructure unlike that of the tabula. Very faint lineations on the surface of and within spines indicate a fibrous microstructure, similar to that of the cormon wall. Tabulae are not clearly segregated into zones of close and wide spacing. Tabular placement between corallites is continuous, occurring at similar levels within adjacent forms.

Type.--Hypotype, UND Cat. No. 13766.

Occurrence.--The holotype of <u>Manipora garsonensis</u> came from a bedding plane exposure of the Selkirk Member 0.3 meters (0.9 ft) below the top of the exposed section east of Garson, Manitoba, locality A889 (Appendix A).

<u>Discussion</u>.--The combination of large corallites and common walls normal to the cateniform rank direction preclude the assignment of the holotype to a previously described species of <u>Manipora</u>. <u>Manipora trapezoidalis</u> Flower is the only species having corallites of sufficient size, but the occurrence of common corallite wall oblique to the rank direction, also characteristic of the species, prevents assignment of the Manitoba holotype to that species. The diagnostic species characters within <u>Manipora</u> provide no corresponding match for the holotype. Hence a new species, <u>Manipora garsonensis</u> is designated, named for the village near the quarry where the holotype was collected.

Agglutinative patches in the holotype most frequently occur as short, alternate biserial groupings of cerioid corallites formed by the merging of four or more uniserial ranks. No agglutinative patch more than two corallites in width was present in the holotype.

Long, narrow common walls within the cerioid and cateniform portions of the corallum contain fibers in chevron-like sets (Figure 14). No structurally or crystallographically distinct axial plate, characteristic of more advanced anthozoan genera, is present. Mean fiber orientation of the lateral and common corallite walls shows an interesting contrast. Lateral wall fibers have a mean orientation of 63 degrees from the corallite axis whereas those in the common wall have a mean orientation of 46 degrees (Appendix B, Table 10).

This difference in orientation between all fiber types reflects a significant variation in type and mode of skeletal deposition of the two wall types, peculiar to the cateniform genera <u>Catenipora</u> and <u>Manipora</u>.

Common walls of both genera were deposited by interpolypid calicoblast layers underlying the interconnecting tissue. In <u>Manipora</u>, no discrete centers of wall deposition were present, and sites of common wall construction were distributed uniformly along the length of the layer. In <u>Catenipora</u>, common wall construction took place at discrete sites under the calicoblast layer, resulting in a common wall composed of one or more trabeculae, as in <u>C. rubra</u> and C. robusta.

Differences in common wall microstructure between the two genera lend support to Sinclair's statement of affinity (1955, p. 97) of <u>Manipora</u> to <u>Saffordophyllum</u>. Both <u>Saffordophyllum</u> and <u>Manipora</u> have similar common walls, which are transversely crenulate and nontrabecular with no axial plate.

Tabulae in <u>Manipora garsonensis</u> are of variable thickness (Appendix B, Table 10), and no striking structural contrast occurs between the tabular plate and the overlying stereoplasm. Only a thin, clear layer was observed to be at the base of some tabulae. The overlying layer of stereoplasm is essentially structureless as is the clear layer, possibly due to recrystallization. The former microstructure of tabulae and stereome is shown by the presence of secondary needles and prisms of calcite, on the upper and lower tabular surfaces, oriented with their long axes normal to the tabular surface. Orientation of the needles and prisms may be due to secondary crystallization in crystallographic continuity with the original

Spines embedded in the tabular stereoplasm occur at discrete continuous levels within adjacent corallites. Very faint lineations within some spines hint that spine microstructure is divergent, with spines radiating from a central axis (Figure 14). This structure contrasts with vertical fibers within the tabulae and resembles the microstructure of septal spines.

Tabulae thickened by stereome do not appear to be related to occurrences of the tabular spines. The spines are on tabulae with and without stereome. Thickened tabulae are not related to tabular spacing, but are present where tabulae are both closely and widely spaced. Tabular spacing did not seem to exercise any control over the placement of tabular spines, since they are present throughout the range of tabular spacing. Therefore it appears that rates of upward growth did not control spine placement or the volume of stereome deposited on tabulae.

Manipora bighornensis n. sp.

Plate 4, Figures 1-3, 5

Diagnosis.--Small corallum composed of interconnected patches of cerioid corallites with interconnection by narrow extension of cerioid patches with corallites in triserial arrangement; no cateniform corallites, corallites predominantly polygonal, mean diameter approximately 1.8 mm; nine to 14 septal ridges per corallite where developed; tabulae complete, normal to corallite axes, predominantly plane; no zonation of tabular spacing.

<u>Description of material</u>.--The small, fragmental holotype has a higher degree of amalgamation than that of other cateniform species

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of <u>Manipora</u>. Corallites are arranged in agglutinative patches interconnected by patches of corallites in biserial or triserial arrangement. All corallites are cerioid, with those on the corallum periphery bounded on their peripheral side by a lateral wall continuous around patches of cerioid corallites. Corallites average 1.8 mm, range from about 1.4 to 2.3 mm in diameter, and have a polygonal outline. Those on the corallum periphery often have their polygonal outline modified by a convex lateral wall.

The common wall is transversely crenulate with septal spines projecting from convex crenulate surfaces into the corallite lumen. The common wall has two sets of fibers, each sloping toward the wall's axial plane where the inner ends of fibers in one set abut against those in the other. Mean common wall thickness is 0.16 mm, with a mean fiber orientation of 54 degrees (Appendix B, Table 10) from the axial plane. Terminal ends of the common walls are embedded in the sclerenchymal layer of the lateral wall bordering the exterior corallum on all but the growth surface. The lateral wall averages 0.17 mm in thickness with a mean fiber orientation of 66 degrees from the wall plane. No holothecal layer is present.

Septal spines are poorly developed and occur sporadically on the convex portion of the common wall crenulations, forming a longitudinal series of low septal ridges. Two to three crenulations commonly occur on each transverse segment of the common wall. The number of ridges per corallite is controlled by the number of sides on the polygonal corallite. Nine to 14 ridges per corallite occur where ridges can be discerned. Tabulae are complete, transverse to the corallite axes, and are predominantly planar. There is no clear-cut

segregation of tabulae into zones of closely and widely spaced types. Spacing varies from 0.3 to 1.1 mm with a mean spacing of about 0.7 mm.

The corallum exterior is covered by an encrusting corallum composed of fibrous, monacanthine trabecular rods oriented normal to the host corallum surface, varying from 0.4 to 3.8 mm in thickness. The encrusting form has no well preserved distal surface, but seems to be a representative of the genus Coccoseris Eichwald.

Type.--Holotype, UND Cat. No. 13768.

<u>Occurrence</u>.--The small and fragmental holotype occurred as a float specimen from the Hunt Mountain beds from collecting locality A542, on the western flank of the Bighorn Range (Appendix A).

<u>Discussion</u>.--The holotype presents a problem of generic placement. As summarized by Flower (1961, p. 45) the genus <u>Manipora</u> Sinclair is characterized by: (1) corallites in cateniform ranks and cerioid patches; (2) crenulate common walls with no axial plate set into the outer wall; (3) septal ridges formed by longitudinal convex common wall flexures; and (4) plane and transverse tabulae. The fragmental northern Wyoming holotype corresponds to the generic description of <u>Manipora</u> with the exception of overall corallum form. No cateniform ranks occur and any observed interconnection between cerioid patches was accomplished by elongate cerioid extensions of the larger patches.

The northern Wyoming holotype is placed in the genus <u>Manipora</u> Sinclair since it has the internal features of the genus. It is ^{regarded} in this study as an example of the genus showing a genetic ^{ability} for the corallum to assume an increasingly pure cerioid ^{arrangement} within strung-out agglutinative patches. The possible

genetic response that this colony of Manipora possessed may be the sole evolutionary advancement over the cateniform Red River species of Mani-Leith (1944, plate 42, figures 1,2) illustrated a halysitoid pora. coral later assigned to Manipora amicarum by Sinclair (1955). Leith's illustrations show that this species also has well developed agglutinative patches of cerioid corallites interconnected by cateniform ranks in which corallites are arranged in uniserial, parallel biserial, and alternate biserial fashion. No such elongate ranks occur in the fragmental specimen from the Hunt Mountain beds, but this may be due to a lack of sufficient corallum material as well as due to genetic restriction of corallum form. This holotype is higher in the stratigraphic section and existed later in time than the Red River species of Manipora, and may represent an evolutionary advancement over the earlier forms. This is based on Manipora-like characters superimposed on a corallum form in which all corallites are cerioid, indicating a greater degree of intercorallite continuity than in all earlier forms of Catenipora. Whether this greater degree of intercorallite communication represents an evolutionary advancement and is a genetically controlled trait or represents an environmentally influenced response within genetically imposed limits of polymorphism cannot be determined. If genetic controls are responsible, then this holotype represents an evolutionary advancement.

The possibility of environmental or other external controls affecting the corallum form is raised by the presence of an encrusting <u>Coccoseris</u> corallum on the holotype exterior. Insufficient material is available to determine whether the encrusting form is an exocommensal or a parasitic organism restricting lateral growth of

the host corallum, or if it simply utilized an already dead colonial corallum for a substrate. Although I suspect that the exocommensal or parasitic relationship prevailed, it is difficult to prove whether that or the one in which the host colony was already dead was the case. Comparison of the holotype with other species of <u>Manipora</u> shows that it is more similar to <u>M. amicarum</u> in respect to cerioid corallite diameter and lateral wall thickness than to other species.

One significant contrast to <u>M</u>. <u>amicarum</u>, other than corallum form, is the poor development of septal spines and the number of septal ridges per ceroid corallite. Spines in the holotype are indeterminable as to longitudinal spacing and spine length because of their rarity and the small amount of material for study.

Despite the lack of greater amounts of available material, the well preserved portions in thin sections yield sufficient data for comparison to other species of <u>Manipora</u>. The unique corallum form and size, stratigraphic position, and unique interior morphology warrant designation of a new species, <u>Manipora bighornensis</u> n. sp., named after the northern Wyoming mountain range where it was collected. Flower (1961, p. 45) stated that the genus is restricted to faunas that are equivalent in age to those of the Red River Formation, but the occurrence in the Hunt Mountain beds in Manitoba extends the stratigraphic and time range of the genus in North America. Unique too is the occurrence of an encrusting form of <u>Coccoseris</u> Eichwald on the holotype of <u>M. bighornensis</u>. It was previously reported twice in Ordoyician strata of North America, once by Flower (1961, p. 56) from the Second Value Formation of the Montoya Group and once in this

study from the Selkirk Member. This genus also appears to be more typical of faunas with Red River characteristics than it is of Stony Mountain faunas.

Subfamily SYRINGOPHYLLINAE

Genus Calapoecia Billings, 1865

<u>Type species</u> (by subsequent designation of Lindstrom, 1883).--<u>Calapoecia anticostiensis</u> Billings, 1865, Canadian Naturalist and Geologist, new ser., v. 2, p. 426.

<u>Emended Generic Diagnosis</u>.--"Corallum massive hemispherical, irregularly spherical or encrusting. Corallites polygonal or circular"; corallite walls composed of parallel, longitudinal, monacanthine trabeculae; with spinose septa developed as axial projections of trabeculae; mural pores situated in longitudinal and transverse rows alternating with wall trabeculae; "septa typically twenty, wedge-shaped, radiating, of equal length, short, usually extending one-fifth or less of the diameter into the corallite, inclined slightly upward. Tabulae well developed, complete and incomplete. No dissepiments. A coenchyme may or may not be present; if it is, twenty costae radiate from the corallites. Buds arise from between corallites" (Cox, 1936, p. 2).

Discussion. --Flower (1961, p. 65) first noted the fibrous corallite wall of the genus. He regarded the corallite wall as a structural entity, composed of longitudinal, monacanthine trabeculae with septa developed as longitudinal rows of spines.

In <u>Calapoecia</u> the resulting corallite wall characteristic of the genus is the result of the multiple intersecting of subplanar, coenosteal plates and narrow, longitudinal spinose wall trabeculae expanded at the level of each plate to form continuous wall rings bearing 20 septal spines. Between plate levels, the trabeculae divide the interplate spaces into a series of circular or rectangular cavities (mural pores) bordered laterally by the trabeculae. Due to this, the number of mural pores, at any transverse level is directly controlled by the number of wall trabeculae in each corallite.

<u>Evolution and Inferred Relationships</u>.-Of the three species of <u>Calapoecia</u> in this study, all are coenenchymal and all bear circular corallites. Both <u>Calapoecia anticostiensis</u> and <u>C. arctica</u> existed during Red River time. Both occur in the Selkirk Member and a form comparable to C. <u>anticostiensis</u> was present in the Fort Garry Member. The third, <u>C. ungava</u>, existed at a later time and occurs higher in the Ordovician stratigraphic section---in the Hunt Mountain beds in the upper part of the Bighorn Formation.

<u>Calapoecia anticostiensis</u> appears to be the earliest representative of the two Red River species; it has smaller corallites and a narrower coenenchyme than does <u>C. arctica</u>. This latter species, in addition to having larger corallites and a wider coenenchyme than <u>C. anticostiensis</u>, also possesses the evaginated tabulae extending peripherally through the corallite mural pores into the coenenchymal spaces between adjacent levels of coenosteal plates. This character was probably acquired simultaneously with those of large corallites and wide coenenchyme and indicates a genetic lineage separate from that of <u>C. anticostiensis</u>.

<u>Calapoecía ungava</u>, a later species, underwent a dimunition in corallite size and coenenchymal width but retained the character of tabular plates extending through the mural pores into the intercorallite region of <u>C</u>. <u>arctica</u>, its probable precursor. However, the manner in which the tabulae protrude or extend into the intercorallite region differs in these two species. In <u>C</u>. <u>arctica</u> the tabulae are evaginated or folded out through a mural pore into the coenenchymal region whereas in <u>C</u>. <u>ungava</u> the peripheral margins of tabulae extending through pores are commonly grounded or attached to a coenosteal plate.

The inferred development and relationship among the three species can be summarized as follows (Figure 15): the genetic lineage of <u>Calapoecia</u> developed the coenenchymal character and the resulting change from cerioid to coenenchymal habit produced the laterally separated circular corallites. This resulted in <u>C. anticostiensis</u>. The genetic change from this species to one where corallites are larger and more widely spaced, and the ability to evaginate the basal plate of the polyp through the mural pores (Figure 16) characterized <u>C. arctica</u>. <u>Calapoecia anticostiensis</u>, or a form similar to it, (<u>Calapoecia</u> sp. cf. <u>C. anticostiensis</u>) survived at least into Fort Garry time.

The ancestor to <u>C</u>. <u>ungava</u> is not definitely known. It has corallite diameters similar to and coenenchymal widths less than those of <u>C</u>. <u>anticostiensis</u> but the presence of tabulae extending through the mural pores into the coenenchymal regions hint at a relationship to <u>C</u>. <u>arctica</u>.

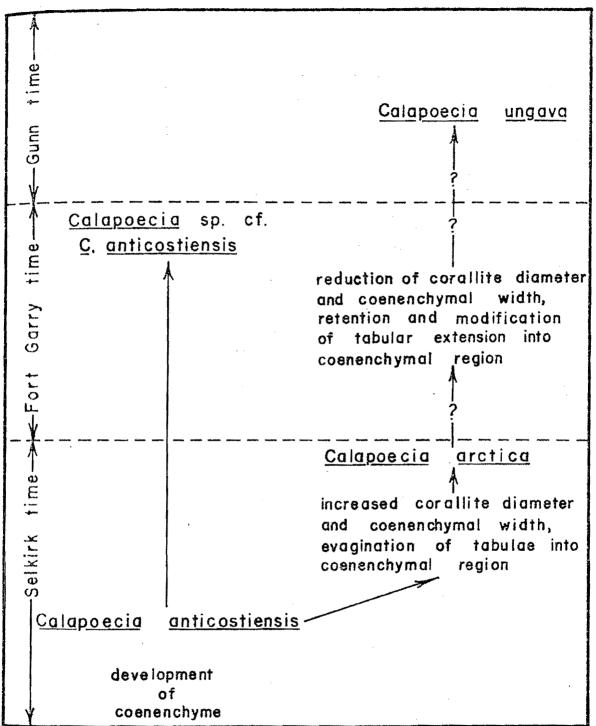


Fig. 15.--Suggested relationships among the coenenchymal species of Calapoecia, based on coenenchymal widths and character of tabulae.

Calapoecia anticostiensis Billings, 1865

Plate 4, Figures 4, 6. 7

<u>Calapoecia anticostiénsis</u> Billings, 1865, Canadian Naturalist and Geologist, new ser., v. 2, p. 426; Nicholson, 1879, Tabulate corals of the Palaeozoic period, Wm. Blackwood & Sons, Edinburgh & London, p. 163; Bassler, 1950, Geol. Soc. America, Mem. 44, p. 275, pl. 20, figs. 9, 10; Flower, 1961, New Mexico Bur. Mines Mineral Resources, Mem. 7, pl. 67, pl. 34, fig. 1-6, 10, 14, 15; Nelson, 1963, Geol. Soc. America, Mem. 90, p. 48, pl. 8, fig. 5, pl. 10, fig. 4.

Calapoecia canadensis var. anticostiensis (Billings) Cox, 1936, National Mus. Canada, Bull. 80, Geol. ser. 53, p. 12, pl. 1, fig. 6, pl. 3, figs. la-c, 3d, 5a-c, 6, 7; Roy, 1941, Field Mus. Natural History, Geol. Mem., v. 2, p. 74, figs. 38a-d.

Diagnosis.---Small, globose corallum with circular corallites separated by coenosteal material having mean widths approximately onehalf the mean corallite diameter; coenenchyme composed of transverse coenosteal plates interconnected by costae extending outward from septum; septa with upwardly inclined spines at levels coincident with coenenchymal plates; mural pore cross sections ranging from oval, through square, to rectangular with width greater than height; tabulae complete and incomplete, with complete forms suspended from axial ends of septal spines and incomplete forms suspended from undersides of spines and adhering to distal surfaces of complete tabulae.

<u>Description</u>.--The single hypotype corallum available for study (UND Cat. No. 13565) is small (41 mm wide, 26 mm high) with a globose shape, and exhibits an encrusting habit on a skeletal fragment. Corallites are 2.7 mm in mean diameter; center-to-center corallite spacing is approximately 1.5 times the mean corallite diameter and coenenchymal widths between adjacent corallites are approximately 0.5 times the corallum width (Appendix B, Table 11). Coenosteal plates are oriented generally parallel to the corallum surface, approximately equally spaced longitudinally. At a corallite, each plate is manifested in the corallite interior by a ring of 19 to 21 septal spines.

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Between corallites, the plates are interconnected by costae (Flower, 1961, p. 65) that radiate outward from wall trabeculae which are bordered axially by longitudinal rows of septal spines. At each level of a coenosteal plate, the trabeculae are expanded laterally to such a degree that some trabecular margins are in lateral contact, forming a ring of fused wall material. The intersection of coenosteal plates and trabeculae form a latticework of corallite and coenosteal elements, normal to each other, resulting in a corallite wall enclosing mural pores formed by cavities between these intersecting elements. Thickening trabeculae near plates and septa at and near points of intersection results in mural pores with outlines varying from oval, through square, to rectangular with width greater than height.

Tabulae within the hypotype are 56 percent complete and 44 percent incomplete. Tabulae vary in curvature from concave, through planar, to convex with orientation varying from transverse to oblique to the corallite axis. Most complete tabulae are attached to the ends of septal spines whereas most incomplete forms attach to the undersides of

septal spines. No tabulae protrude through mural pores into the coenenchyme. Small (approximately 0.5 mm diameter), circular tubules penetrate the coenosteal plates. These are oriented normal to the plates and possess wall material deposited by the colony coenosarc.

Type.--UND Cat. No. 13565.

<u>Occurrence</u>.--The species is widespread throughout the Ordovician equatorial faunal realm. Listed by geographic regions and Ordovician stratigraphic units it occurs at the following localities:

Arctic North America and Greenland (Bassler, 1950, p. 23-24): Baffin Land, Grinnell Land, Norman Lockyer Island, Sillimans Fossil Mount, Frobisher Bay, southern Baffin Land.

Eastern Canada (Bassler, 1950, p. 20, 23, 24): Perče, Quebec; Whitehead Limestone, Akpatok Island; Ungava Bay, northeastern Quebec, Richmond Head; Vauréal and Ellis Bay Formations, Anticosti Island, Quebec.

Northern Hudson Bay Lowlands, northern Manitoba (Nelson, 1963, p. 49): Portage Chute, Caution Creek, and Chasm Creek Formations, Churchill River; Caution Creek Formation, Nelson River and South Knife River.

Southeastern British Columbia, southern Manitoba (Nelson, 1963, p. 21, 22): Beaverfoot Formation, Beaverfoot Range, in region of Mons and Narrowgate, British Columbia; Stony Mountain (?) and Red River Formations, southern Manitoba (Flower, 1961, p. 67).

From the southwestern United States, Flower (1961, p. 67) reported a <u>Calapoecia</u> comparable to <u>C. anticostiensis</u> Billings. It was collected from the Second Value Formation of the Montoya Group in the San Andres Mountains, New Mexico. The hypotype (UND Cat. No. 13565) was collected from quarry exposures of the Selkirk Member of the Red River Formation east of Garson, Manitoba (Appendix A, locality A530). Okulitch (1943, p. 63) listed <u>C</u>. <u>anticostiensis</u> as an element in the fauna of the Gunton Member of the Stony Mountain Formation in southern Manitoba. I observed an external mold of a corallum of <u>Calapoecia</u> on a massive float block of dolomite from the same member in a quarry at Stony Mountain, Manitoba. Since it occurred in such a massive block, collection and subsequent species designation was not possible. Hence I cannot substantiate Okulitch's (1943) citation of C. anticostiensis in the Stony Mountain Formation.

<u>Discussion</u>.--Appendix B, Table 1, illustrates that mean corallite diameter of the hypotype (UND Cat. No. 13565) from the Selkirk Member of the Red River Formation corresponds to diameters stated for other examples of <u>Calapoecia anticostiensis</u>. Only Flower's (1961) <u>Calapoecia</u> cf. <u>C. anticostiensis</u> (NMBM No. 806) shows a marked departure significantly greater than those stated for the species.

Walled tubules penetrating the coenosteum of the hypotype (UND Cat. No. 13565) of <u>C</u>. <u>anticostiensis</u> show that the wall material is continuous with coenenchymal material of the colony and appears to have been deposited by the colony coenosarc. In the immediate region of the tubule the coenosteal plate increases in thickness toward the area of merging with the tubule wall. Inspection of the wall and plate under plane and cross polarized light reveals no marked dissimilarities in the calcareous material of the two structures; therefore the tubule is constructed by the colony coenosarc.

The tubules do not correspond to Nicholson's (1879, p. 160, plate 7, figure 2b) "intramural vacuities" which apparently are

restricted to the angles of junction of or within the corallite wall between two or three adjacent corallites. Cox (1936, p. 9) examined thin sections of <u>Calapoecia canadensis</u> and found that the vacuities occur in the corallite wall or near the wall in the coenosteum. He suggested that a polychaete organism may have been responsible for the vacuities. Cox proposed that the vacuities in <u>C. canadensis</u> be termed "disruptive canals," indicating that the perforations are controlled by an organism not integral to the colony flesh.

Tubules in the southern Manitoba hypotype (UND Cat. No. 13565) of <u>Calapoecia anticostiensis</u> have walls that appear to have been formed by the coral during construction of coenenchymal skeletal structures. The apparent uniformity of composition of coenenchymal and tubular material, plus the manner of fusion of coenenchymal plates to the tube wall, indicate that both elements were secreted by coenosarc. Wall formation may, however, have been a protective measure necessitated by the presence of an endocommensal organism penetrating both the colony coenosteum and coenosarc.

<u>Calapoecia</u> sp. cf. <u>C. anticostiensis</u> Billings, 1865 Plate 5, Figure 1

Description of material. --- The two corallum fragments available for study show a maximum size range of 8.0 by 3.0 cm (width and height). Corallites are circular in cross section with a diameter range of 1.9 to 2.8 cm and means of 2.23 and 2.34 mm for UND Cat. Nos. 13566 and 13567 (Appendix B, Table 12). A wide coenenchyme averaging 0.36 of the mean corallite diameter separates adjacent corallites whereas mean center-to-center corallite spacing averages 1.53 times the mean

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diameter. Nineteen to 20 septate, fibrous trabeculae occur in each corallite and are peripherally extended into well-defined costae projecting radially into coenenchymal spaces between corallites. Coenosteal plates between corallites vary in spacing from 0.4 to 0.75 mm with means of 0.56 and 0.51 mm for UND Cat. Nos. 13566 and 13567. Reliable observations of mural pores cannot be made due to replacement of the calcareous skeletal material by quartz. Septal spines are not preserved. Tabulae are complete and incomplete. Complete forms are transverse to the corallite axis and vary in curvature from deeply concave to planar. Incomplete forms are predominantly oblique to the axis, varying in curvature from concave to planar.

Types.--Hypotypes, UND Cat. Nos. 13566, 13567.

<u>Occurrence</u>.---Poorly preserved corallum fragments were collected from a stratigraphic interval 1.3 to 2.3 meters (4.2 to 7.4 ft) below the top of the section at the type locality of the Fort Garry Member of the Red River Formation (Appendix A, locality A853).

Discussion. -- The fragmental coralla have been extensively, if not completely, replaced by quartz and determinations to species are at best tenuous. One fragment (UND Cat. No. 13566) appears to be the basal portion of a larger corallum as it adheres to a shell fragment. The occurrence of the basal part of the corallum suggests that only immature individuals are present in the 1.0 cm-high fragment. Despite poor preservation, structures such as coenosteal plates, costae, and mural pores are discernible. In addition, one small corallite in that corallum, only 1.4 mm in diameter, appears to lack costae and septa

and may be representative of the juvenille stage of development. If this is truly an immature corallite, then the larger corallites in the fragment may be adults. If adults are represented in the biometric data for the two fragmental specimens (Appendix B, Table 12), then these fragments exhibit significant differences from other species in the Red River Formation. Corallites are much smaller than those in other species of <u>Calapoecia</u> in the study. Only two examples of <u>Calapoecia</u>, one designed <u>Calapoecia</u> canadensis var. <u>ungava</u> (Nelson, 1963) and the other <u>Calapoecia</u> sp. cf. <u>C</u>. <u>ungava</u> (Flower, 1961) have comparable corallite diameters.

Center-to-center corallite spacing with respect to corallite diameter is comparable to that given for Calapoecia anticostiensis Billings and C. arctica Troedsson in the Selkirk Member of the Red River Formation. Coenenchymal width in proportion to diameter is slightly less than that for the two species from the Red River Formation (cf. Appendix B, Tables 11-13) whereas coenenchymal plate spacing is nearly as great as that given for Calapoecia arctica. As observed in other species of Calapoecia in this study, mean plate spacing is commonly nearly equal to mean septal spine and mean tabular spacing. However, one fragmental specimen (UND Cat. No. 13566) from the Fort Garry Member has a mean tabular spacing of 0.42 mm. A remarkable feature not previously observed in Calapoecia is the type of curvature observed in both complete and incomplete. tabulae. It varies from deeply concave to planar. No convex tabular forms were observed.

If the Fort Garry specimens are adult forms, then they appear to represent a transition between a group consisting of <u>Calapoecia</u>

anticostiensis and <u>C</u>. arctica, both of which occur lower in the stratigraphic section in the underlying Selkirk Member, and <u>C</u>. <u>ungava</u> reported by Bassler (1950) from the overlying Stony Mountain Formation. Both <u>C</u>. <u>anticostiensis</u> and <u>C</u>. <u>arctica</u> are characterized by large corallites and wide coenenchyme. <u>Calapoecia ungava</u>, on the other hand, is characterized by small corallites and narrow coenenchyme. The Fort Garry hypotypes, occurring stratigraphically between the Selkirk and Stony Mountain species, have features common to those species above and below. They have corallite diameters more characteristic of <u>C</u>. <u>ungava</u>, whereas center-to-center corallite spacing and coenenchymal widths proportional to corallite diameter are more comparable to those of <u>Calapoecia anti</u>costiensis and C. arctica.

Poor preservation, fragmental coralla, and the possibility of immature corallites prevent assignment of the Fort Garry specimens to a new species, despite the presence of uniquely curved tabulae. They are placed in comparison to <u>Calapoecia anticostiensis</u> Billings due to the presence of the relatively wide coenenchyme. Maximum corallum dimensions occur in a fragment (UND Cat. No. 13567) in which few biometric data other than corallum size and form, corallite profile, and coenosteal plate spacing could be derived.

Calapoecia arctica Troedsson, 1929

Plate 5, Figures 2, 4, 5

<u>Calapoecia arctica</u> Troedsson, 1929, Medd. om Gronland, v. 72, p. 127, pl. 39, pl. 40, figs. 1a, 1b; Bassler, 1950, Geol. Soc. Amer. Mem. 44, p. 276, pl. 20, figs. 7, 8.

Calapoecia canadensis var. anticostiensis forma arctica Cox, 1936, Nat. Mus. Canada, Bull. 80, Geol. Ser. 53, p. 16, pl. 14, figs. la,

2a, 2b, 3.

Calapoecia arctica Troedsson, Nelson, 1963, Geol. Soc. Amer. Mem. 90,

p. 49.

Diagnosis.--Small hemispherical coralla with large circular corallites from 2.2 to 6 mm diameter, calyx rims raised above coenosteal surface; coenenchymal width between adjacent corallites averaging 0.5 times the mean corallite diameter; mean center-to-center corallite spacing 1.5 times the mean diameter; mural pore outline varying from circular, through square, to rectangular with height greater than width; tabulae complete and incomplete, ranging in curvature from concave, through planar, to convex, normal to oblique to corallite axis; tabulae evaginated through mural pores into coenenchymal region. Peripheral margins of tabulae suspended from septal spines.

Description of material. --- The hypotypes (UND Cat. No. 13569, 13570) exhibit an encrusting habit similar to that observed in the southern Manitoba hypotype of <u>Calapoecia anticostiensis</u> Billings. Corallites on the mature corallum surface open normal to that surface with each corallum separated from adjacent ones by a coenenchymal region. Preserved portions of the corallum surface show the coenenchymal surface immediately adjacent to the calicinal pit to be slightly elevated above the surface more distant from the corallites. All corallites are circular as a result of separation of adjacent forms by coenenchyme. Calicinal pits are very deep, averaging 0.9 times the mean corallite diameter. Coenosteal plates in mature portions of the coralla are frequently deflected downward close to the corallites, resulting in septal spine orientation approximately normal to the corallite axis. Coenenchymal areas, in addition to containing transverse, parallel plates and radial extension of trabecular rods, have extracorallite evaginations of tabular structures. These are restricted to spaces between adjacent levels of adjacent coenosteal plates and are generally subparallel to them (Figure 16). These tabular extensions protrude through mural pores formed between points where transverse coenenchymal plates and longitudinal, septate, trabecular rods intersect.

Spinose septa are mounted on 20 longitudinal, wall trabeculae which are dilated laterally at the level of each coenenchymal plate, extending axially at each plate level to form a ring of wedge-shaped wall trabeculae in contact with each other. Between plates, trabeculae are thin, with their peripheral margins extending radially into the coenenchyme as short costae.

Tabulae are complete and incomplete with both types varying in curvature from concave through planar to convex and are normal to oblique to the corallite axis. Peripheral ends of tabulae are suspended from septal spines or trabeculae but between septa and coenosteal plates they are evaginated into the coenenchymal intercorallite region, leaving little unoccupied coenenchymal space between plates. Peripheral ends of tabulae often terminate within the coenenchyme and are attached to a plate surface, or much of the tabula is evaginated through a mural pore into the coenenchymal spaces between plates with their peripheral end attached within or close to the corallite lumen (Figure 16). Mural pores surrounding the evaginated tabulae frequently

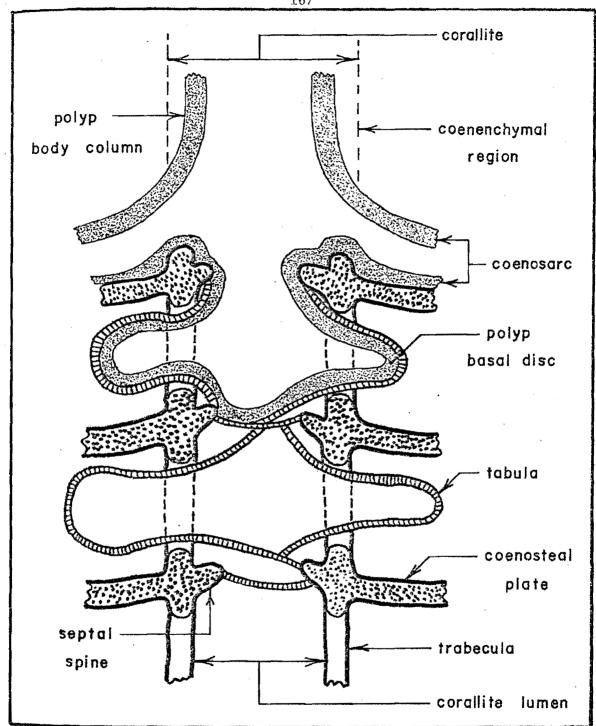


Fig. 16.—Portion of a corallite, basal portion of a polyp, coenosarc, and coenosteum of <u>Calapoecia arctica</u>. Cut by longitudinal section, soft parts shown by fine stippling. Sectioned skeletal structures shown by coarse stippling. Solid lines show skeletal outlines. Dashed lines show structures hidden by tabulae, approx. X15. exhibit a circle of tabular surface in the pore interior. Pores, varying in outline from square to rectangular, are determined by coenenchymal plate spacing whereas pores possessing a circular or nearly circular outline are formed from square pores modified by thick wall trabecular material at the level of coenosteal plates. This thickening material rounds out the corner of intersection between trabeculae and plates resulting in the modification of a square opening to a circular or rounded one.

Types.--Hypotypes, UND Cat. Nos. 13569, 13570.

<u>Occurrence</u>.--Troedsson (1929, p. 127) initially described <u>Calapoecia arctica</u> from the type section of the Cape Calhoun Formation at Cape Calhoun, Washington Land, northwestern Greenland. Cox (1936, p. 17) noted the occurrence of the species in Ordovician strata at Cape Hilgard, Ellesmere Island. Nelson (1963, p. 49) found examples of the genus <u>Calapoecia</u> in the Portage Chute Formation in the northern Hudson Bay lowland northern Manitoba, which he questionably assigned to <u>C. arctica</u>. The hypotypes referred to in this study (UND Cat. Nos. 13569, 13570) were collected from quarry exposures of the Selkirk Member of the Red River Formation (Appendix A, localities A530, A884).

<u>Discussion</u>.--Troedsson (1929, p. 127) initially described <u>C</u>. <u>arctica</u> as having coenenchymal coralla with large (Appendix B, Table 13), circular corallites with raised calicinal rings, corallites distant from each other, and sacklike processes projecting through the mural pores into interspaces between coenosteal plates.

Cox (1936, p. 17), in redefining Troedsson's species as a form of a variety of Calapoecia canadensis, stated that his <u>C</u>. <u>canadensis</u>

var. <u>anticostiensis</u> forma <u>arctica</u> is no more than a larger form of <u>Calapoecia canadensis</u> var. <u>anticostiensis</u>. Bassler (1950, p. 276) considered <u>C</u>. <u>arctica</u> to be a giant <u>C</u>. <u>anticostiensis</u> with coenenchymal interspaces filled with tabulae, and Nelson's (1963, p. 49) questioning assignment of examples of <u>Calapoecia</u> to <u>Calapoecia</u> <u>arctica</u> Troedsson was based on corallite diameters and coenenchymal widths greater than those of <u>Calapoecia anticostiensis</u> Billings. The southern Manitoba examples of <u>C</u>. <u>arctica</u> Troedsson are similar to Troedsson's species in that corallum dimensions, corallite diameters, coenenchymal widths, septal spine spacing, coenenchymal plate spacing, and tabular spacing are all greater than the southern Manitoba hypotype of <u>C</u>. <u>anticostiensis</u> Billings.

<u>Calapoecia arctica</u> appears to be closely related to <u>Calapoecia</u> <u>anticostiensis</u> but has consistently larger corallites, and intercorallite spaces averaging one-half the mean corallite diameter. The most important diagnostic feature for the species, however, is the prominent evagination of tabulae--Troedsson's (1929) "sack-like processes." Subsequent authors (Cox, 1936; Nelson, 1963) considered <u>C. arctica</u> to be little more than a giant form of <u>C. anticostiensis</u>. Only Bassler (1950) recognized the significance of the evaginated tabulae as a species diagnostic character.

The evagination of tabulae through mural pores is the reflection of a specialized activity of the basal disc of the polyps in this species. Since deposition of transverse corallite structures is accomplished by portions of the basal ectoderm not engaged in the construction of fibrous trabeculae and septal spines, the evaginated condition

of the tabulae indicates that portions of the basal disc were extruded through already formed mural pores. Figure 16 illustrates the probable relationship of the polyp basal disc to the corallite and coenenchyme. Extrusion of the basal polyp body wall into the coenenchymal interspaces probably occurred after the coenosarc had constructed the immediately overlying coenosteal plate. One possible function is that it may have increased the absorptive area of the polyp gastrovascular cavity without increasing the size of the polyp exposed above the corallum surface. The presence of raised calicinal rims may have served a protective function. Withdrawal of the polyp into the calyx and below the rim was facilitated by a relatively small polyp even though an increase in digestive or respiratory area had occurred.

Calapoecia ungava Cox, 1936

Plate 5, Figures 3, 6; Plate 6, Figures 1, 6

Calapoecia canadensis var. ungava Cox, 1936, Natural Mus. Canada, Bull. 80, Geol. ser. 53, p. 12, pl. 3, fig. 2; Nelson, 1963, Geol. Soc. Amer., Mem. 90, p.50, pl. 10, fig. 3.

Calapoecia canadensis ungava Cox, Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 276.

- Calapoecia ungava Cox, Flower, 1961, New Mexico Bur. Mines Mineral Resources, Mem. 7, p. 67; Nelson, 1963, Geol.Soc. America, Mem. 90, p. 48.
- [?]Calapoecia cf. ungava Cox, Flower, 1961, New Mexico Bur. Mines Mineral Resources, Mem. 7, p. 68, pl. 33, fig. 6.

Diagnosis. --- Small, circular corallites with elevated calicinal margins, diameter ranging from approximately 2 to 3 mm, calicinal depth

0.6 times the mean diameter; coenenchyme narrow, with center-to-center corallite spacing approximately 1.1 times the mean diameter, mean coenenchymal width 0.12 times the mean diameter; nineteen to 20 longitudinal, septate trabeculae radiating from each corallite perimeter into the coenenchyme and expanding laterally at each plate level to form a solid ring with spinose septal projections directed toward the corallite axis; tabulae both complete and incomplete; complete forms both normal and oblique to corallite axis, varying in curvature from concave through convex; incomplete forms predominantly oblique to axis and convex; tabular margins commonly extended into spaces between coenosteal plates; coenosteal plates, septal spines, and tabulae all with approximately equal mean spacing.

Description of material.--The single corallum (UND Cat. No. 13571) is an elongate, tabular form with rounded peripheral margins. Corallites are oriented normal to the curved, distal, corallum surface. Although the colony point of origin adhered to fragmental invertebrate skeletal material where the fragments served as an attachment substrate, subsequent lateral expansion of the colony occurred by lateral budding of polyp material out onto the unconsolidated sedimentary substrate. The proximal ends of the budded corallites appear to have rested directly on the sediment surface. Corallites are small, with a mean diameter of 2.6 mm and have calicinal rims elevated above the coenenchymal surface. Calicinal pits are 1.3 to 1.7 mm deep with a mean depth of 0.6 times the mean corallite diameter (Appendix B, Table 14). Center-to-center corallite spacing averages 1.1 times the mean corallite diameter whereas

mean coenenchymal width averages 0.12 times that diameter. The coenenchyme is constructed of subparallel, subplanar, coenosteal plates terminating at each corallite in an upwardly inclined septal spine projecting into the corallite lumen. The intercorallite spaces between coenosteal plates, in some instances, are partially occupied by lateral extensions of the tabular surfaces into the coenenchymal area. Nineteen to 20 longitudinal septate trabeculae form the perimeter of each corallite. Between adjacent levels of coenenchymal plates they are narrow and radiate outward as costae into the coenenchyme. At plate level trabeculae are expanded laterally to such a degree that adjacent ones merge at each plate level to form a septal ring of broad, deltashaped spines with their apices directed axially.

Tabulae are complete and incomplete. Complete forms may be normal or oblique to the corallite axis; they are suspended from septal spines and vary in curvature from concave, through planar, to convex. Incomplete tabulae are usually oblique with respect to the corallite axis, and are predominantly convex. Peripheral margins of tabulae are often grounded on the distal surface of a coenosteal plate within the intercorallite region.

Types.--Hypotypes, G.S.C. No. 10503; UND Cat. No. 13571; Figured specimen, NMBM No. 791.

Occurrence. -- The single hypotype of <u>Calapoecia ungava</u> (UND Cat. No. 13571) was collected as float more than 4 meters (13 ft) above the Hunt Mountain beds (Appendix A, locality A545) in the Bighorn Mountains, Wyoming.

Other examples of the species occur in the Upper Ordovician of Akpatok Island (Nelson, 1963, p.50), in the Stony Mountain

Formation in southern Manitoba (Bassler, 1950, p. 22), and in the upper member of the Caution Creek Formation in the South Knife River region of the northern Hudson Bay lowland in northern Manitoba (Nelson, 1963, p. 50). Flower (1961, p. 68) described a fragmental, extensively silicified corallum with small corallites and narrow coenenchyme that he stated was comparable to <u>Calapoecia ungava</u> Cox from the Aleman Formation, Montoya Group, New Mexico. No examples of <u>C. ungava</u> have been collected by the writer from the Stony Mountain Formation.

<u>Discussion</u>.--The hypotype (UND Cat. No. 13571) of <u>Calapoecia</u> <u>ungava</u> compares favorably with other descriptions of the species (Appendix B, Table 14) in terms of corallite diameter, center-tocenter corallite spacing, and resulting coenenchymal width.

If the northern Wyoming hypotype of <u>C</u>. <u>ungava</u> is compared (Appendix B, Table 14) to the hypotypes of <u>Calapoecia anticostiensis</u> (UND Cat. No. 13565) and <u>C</u>. <u>arctica</u> (UND Cat. Nos. 13566, 13567), several diagnostic contrasts become apparent (Appendix B, Tables 11-14):

1. Corallite diameters of the northern Wyoming hypotype of <u>C. ungava</u> are less than those for the hypotypes of <u>C. anticostiensis</u> and <u>C. arctica from the Selkirk Member of southern Manitoba.</u>

2. Center-to-center corallite spacing of <u>C</u>. <u>ungava</u> is less than that of the southern Manitoba hypotypes of <u>C</u>. <u>anticostiensis</u> and <u>C</u>. <u>arctica</u>.

3. Coenenchymal width is 0.12 times the mean corallite diameter for the hypotype of <u>C</u>. <u>ungava</u> whereas widths for the hypotypes of <u>C</u>. <u>anticosti</u> <u>nsis</u> and <u>C</u>. <u>arctica</u> are 0.49 and 0.53.

4. The degree of lateral fusion of septate trabeculae at the coenosteal plate tends to form spinose, transverse rings of fused septal and wall material at each plate level in the hypotype of
C. ungava.

5. Coenosteal plate, septal spine, and tabular spacing are approximately equal in the hypotype of <u>C</u>. <u>ungava</u>. These spacing values are less than those expressed for the studied hypotypes of <u>C</u>. anticostiensis and <u>C</u>. arctica.

6. Extension of the tabular peripheral margins into the coenenchymal regions between coenosteal plates apparently represents a continuation of the character of extrusion of the polypid basal plate through the mural pores into the intercorallite region. This characteristic was first noted by Troedsson (1929) in <u>C. arctica</u>, a species which developed earlier in Ordovician time than <u>C. ungava</u> and was the earliest to develop the characteristic.

It is possible that the occurrence of tabular material in the intercorallite region of <u>C</u>. <u>ungava</u> indicates that the species may be a descendant of <u>C</u>. <u>arctica</u>.

Nelson (1963, p. 48) summarized Bassler's (1950, p. 275-276) classification of species within the genus <u>Calapoecia</u>, which is based on the proximity of adjacent corallites and corallite separation by coenenchyme. Nelson stated that examples of the genus with the smallest corallites and a narrow coenenchyme are characteristic of <u>Calapoecia ungava</u>. Of the six species assigned to the genus at the time of Nelson's writing (1963), only three are characterized by the possession of a coenenchyme. The two other coenenchymal species, if

placed in order of increasingly large corallites and wide coenenchymebearing species described in this study, the hypotype of <u>C</u>. <u>ungava</u> has the narrowest well-defined coenenchyme and the smallest corallites.

Family HELIOLITIDAE

Subfamily COCCOSERIDINAE

Genus Protarea Milne-Edwards and Haime, 1851

<u>Type species</u> (by subsequent designation, Miller, 1899, p. 201).--<u>Protarea vetusta</u> (Hall), 1847, Nat. Hist. New York, pt. 6: Palaeontology of New York, v. 1, p. 71.

<u>Diagnosis</u>.--Small, thin, encrusting coralla composed of stout, closely packed, parallel or nearly parallel trabeculae. Stellate corallites lacking walls. Coenenchyme and septa manifested only on corallum surface as ridges elevated above the calyx. Baculae occupying all of corallum interior; no internal cavities present (modified from Hill and Stumm, p. F468).

<u>Remarks.--Protarea</u> differs from <u>Coccoseris</u> Eichwald in that the corallum is usually thin and small, and is restricted in lateral dimensions by the size of the fossil fragment. The corallum of <u>Coccoseris</u> is much thicker, attaining a greater corallum size. This genus appears to have been a form in which colony life was significantly longer than that of the colonies of <u>Protarea</u> whose apparently short life is reflected by the small, thin corallum.

Protarea coralla are too thin to determine whether septal trabeculae are upwardly inclined toward the columella as in Coccoseris.

Protarea sp. cf. Scutleri Leith, 1952

Plate 6, Figure 3

Description of material .-- Two encrusting coralla occur on articulate brachiopod valves; the corallum breadth appears to be controlled by the area of the host substrate. One specimen (UND Cat. No. 13651) has a maximum thickness of 0.7 mm. The corallum is composed of subparallel, fibrous, trabecular baculae with most of these oriented normal or nearly normal to the substrate surface. Corallites are manifested on the corallum surface by differing relief of rounded, conical, distal ends of the baculae. Calices are localized depressions on the corallum surface with a central elevated columellar platform with a tubercular surface representing the conical, distal ends of columellar trabeculae. Calyx diameter averages 0.9 mm and center-to-center corallite spacing averages 1.2 times the mean calicinal diameter (Appendix B, Table 15). Columellar width on the single colony example measured is 0.66 times the calyx diameter. The calicinal area between the columella and wall forms a depressed ring around the calyx periphery with 10 observed septal elevations radiating from the columella rim to the calvx wall. Interseptal spaces occur as small, radiating depressions between septa. No corallum cavities occur and all skeletal volume is occupied by closely packed trabeculae. The intercorallite regions are occupied by a trabecular coenenchyme occurring as an elevated platform capped by tuberculate or rounded, conical projections formed by the distal ends of coenenchymal baculae. Mean coenenchymal width is approximately 0.3 times the mean calicinal diameter. Trabecular baculae in both the corallite and coenenchymal regions of the

corallum are composed of skeletal fibers, radiating and upwardly inclined from the bacular axis. Mean bacular diameter is 0.22 mm and mean fiber orientation is 43 degrees from the bacular axis. No wall structure or internal boundary occurs between corallite and coenenchymal baculae.

Types.--Hypotypes, UND Cat. No. 13651, 13652.

Occurrence.--The two coralla (UND Cat. Nos. 13650, 13651) were collected from the Gunn Member of the Stony Mountain Formation at the western quarry of the Winnipeg Municipality aggregate plant at collecting locality A584. Leith (1952, p. 794) recorded occurrences of the species from the Gunn and Penitentiary Members of the Stony Mountain Formation in the vicinity of the town of Stony Mountain.

<u>Discussion</u>.--Only two specimens (UND Cat. Nos. 13650, 13651) of the encrusting bacular coralla were observed and collected. Only a small portion of one corallum has sufficiently preserved detail to reveal the surficial character of the corallites and coenenchyme. Only one corallite exhibits sufficient detail for a septal count. Ten interseptal pits were observed. This conflicts with Leith's (1952, p. 793) original description of <u>Protarea cutleri</u> for which he recorded 12 septa. This apparent difference may result from a variation of septa per corallite, since Leith (1952) stated that 12 did occur in corallites where all were visible. However, he added that in the majority of the calices the septal structures could not be distinguished from the tubercular ends of the remaining corallite baculae (termed "papilli" by Leith, 1952, p. 794).

The examples under discussion are not assigned to <u>Protarea</u> <u>cut</u>-<u>leri</u> Leith due to the lack of sufficient surficial detail and the

resulting lack of septal counts, and to slight differences in center-tocenter corallite spacing.

Genus Coccoseris, Eichwald, 1855

<u>Type species</u> (by monotypy) Lang, Smith, and Thomas, 1940, p. 39.--<u>Coccoseris ungerni</u> Eichwald, 1855, Lethaea Rossica ov Paléontologie de la Russie pt. [?], p. 2.

Diagnosis.--Encrusting coenenchymal coralla with corallum interior completely occupied by polygonal, coenenchymal, trabeculae (modified from Hill and Stumm, 1956, p. F458).

<u>Remarks.--Coccoseris</u> is very similar to <u>Protrochischolithus</u> Troedsson in external form. However, transverse polished sections of coralla of both genera show that <u>Protrochischolithus</u> contains 12 conspicuous, interseptal spaces arranged in stellate pattern whereas <u>Coccoseris</u> has none due to the lack of voids in the corallum. These are the second and third reported occurrences of the genus <u>Coccoseris</u> in North America. The first was noted by Flower (1961, p. 56) from a corallum occurring in the Second Value Formation in western Texas. Previous to this, all species of <u>Coccoseris</u> were reported from northern Europe and Australia (Flower, 1961, p. 56).

Coccoseris astomata Flower, 1961

Coccoseris astomata Flower, 1961, New Mexico Bureau Mines and Mineral Resources, Mem. 7, p. 56-57, pls. 16, 17, 18.

<u>Diagnosis</u>.--Small, rounded to subrounded corallites with stellate margins and coenenchymal tissue between corallites raised above ^{calyx} floor; width 0.26 times the mean corallite diameter; calicinal pits U-shaped; columella mean width 0.56 times the mean corallite diameter; columellar trabeculae projecting above calicinal floor as conical pustules; mean interseptal depression length 0.35 times the mean corallite radius; diameter of corallum trabeculae not equal, with widest trabeculae approximately four times the diameter of narrowest forms.

Description of material. -- Eight hypotypes were collected (UND Cat. Nos. 13653, 13655-13661). These range in corallum form from sheet-like (UND Cat. No. 13659) to thick, globose masses nearly as thick as they are wide (UND Cat. No. 13658). Hemispherical coralla, such as UND Cat. Nos. 13653, 13655, and 13661, are encrusting forms which conform to the hemispherical shape of the utilized substrate, usually a stromatoporoid colony. Where individual layers of the corallum are observed, none appears to exceed 20 mm in thickness. Each thick corallum is composed of successive concentric layers of skeletal material, often with layers of sediment between them.

The coralla are composed of closely packed, polygonal baculae, 0.37 mm in mean diameter, each a monacanthine trabecula composed of calcareous fibers arranged in chevron-like sets when viewed in longitudinal section. Transverse sections show the upwardly inclined fibers to be arranged radially around the trabecular center.

Coralla of the genus <u>Coccoseris</u> contain no interior spaces. The entire corallum is filled with closely packed, trabecular baculae. Therefore, they differ from those of the closely related genus <u>Protrochischolithus by lacking interseptal space and tabulae</u>.

Corallites of <u>Coccoseris astomata</u> are exhibited most clearly on unabraded, distal, corallum surfaces. These have a rounded or

subrounded outline modified to a stellate appearance by the pustulose, bacular projections in the peripheral ends of the septa and coenenchyme. Corallites observed on the preserved distal surfaces of three hypotypes (UND Cat. Nos. 13653, 13655, 13660) have mean diameters ranging from 1.63 to 1.69 mm. Adjacent corallites in the three hypotypes have mean center-to-center spacing values ranging from 1.92 to 1.97 mm (Appendix B, Table 16). Corallites are separated from each other by a coenenchyme composed of trabecular baculae oriented normal to the proximal and distal corallum surfaces. In one hypotype (UND Cat. No. 13653) mean coenenchymal width is 0.15 times the mean corallite diameter.

No true corallite wall occurs. The only demarcation between adjacent corallites and coenenchyme is shown by a change in bacular orientation. Baculae in the corallite region between the corallite periphery and columella, where the septa are located, are upwardly inclined toward the columella. Thus the boundary between the coenenchyme and corallite, as seen in longitudinal section, is a narrow zone where the vertical coenenchymal baculae and the inclined ones of the septal abut against each other. The coenosteal baculae occur at the distal corallum surface as a raised ridge or platform of tubercles elevated above the corallite calyx.

Within the calyx, 12 septa occupy the region between the calyx periphery and the columella. These show up at the corallum surface as 12 wide ridges extending axially from the periphery. Adjacent septal ridges are separated by oval, radially elongate interseptal spaces which form depressions. Length of these depressions averages 0.37

times the mean corallite radius in the hypotype studied (UND Cat. No. 13653).

No differentiation between the septal ridges and interseptal depressions occurs in the corallum interior. In the hypotype mentioned above, all trabecular baculae in this region of the corallite are inclined upward to merge with the periphery of the columella, turning to become oriented parallel to the columellar axis. At the distal corallum surface the columella forms a pustulose platform. The mean columellar width is 0.56 times the mean corallite diameter. Mean pustule count per columella is 13 but transverse sections show that each pustule may be composed of more than one bacula.

Types.--Hypotypes UND Cat. Nos. 13653, 13655-13661.

Occurrence.--Flower (1961, p. 57) stated that the holotype (NMBM No. 670) of <u>Coccoseris astomata</u> came from an exposure of the Second Value Formation of the Montoya Group near the crest of Scenic Drive, El Paso, Texas. The eight hypotypes of the species listed above came from quarry exposures of the Selkirk Member of the Red River Formation at and near Garson, Manitoba, at collecting localities A530, A884, and A893.

Discussion.--Flower (1961, p. 57), in describing the holotype, stated that the corallum surface was weathered and he was not able to identify individual corallites. Only internal features such as bacular diameter, bacular orientation, and fiber orientation were observed in the holotype. The unique North American occurrence of a corallum of <u>Coccoseris</u> caused Flower to construct the species. The eight hypotypes from the Selkirk Member constitute a confirmation of the occurrence of Coccoseris on the North American continent. The presence of

well-preserved corallum surfaces on three of the hypotypes allow characters of the corallites to be observed and surficial biometric data to be obtained (Appendix B, Table 16).

The hypotypes are assigned to <u>C</u>. <u>astomata</u> since few significant differences in internal features occur between these specimens and the holotype. However, Flower (1961, p. 57) noted that the baculae in the holotype are of relatively uniform diameter but gave no dimensions. The hypotype best displaying baculae (UND Cat. No. 13653) has them ranging in diameter from 0.14 to 0.55 mm as viewed in transverse section.

All the hypotypes are assigned to <u>Coccoseris astomata</u> because (1) three which have the corallum surfaces preserved show very close agreement for mean corallite diameters and mean center-to-center corallite spacing (Appendix B, Table 16), (2) the remainder of the hypotypes are very similar in corallum habit, laminar thickness, and bacular orientation, (3) weathering and field characters of all the hypotypes are similar, and (4) all occur within the same stratigraphic interval at two adjacent collecting localities.

<u>Coccoseris astomata</u> has probably been mistaken in the field for a stromatoporoid as has <u>Protrochischolithus magnus</u>. In the field, coralla of <u>C</u>. <u>astomata</u> are bright cream-white in fresh exposures and are distinct from colonial coralla of other coenenchymal and cerioid taxa due to their lack of visible corallites.

Coccoseris sp.

Plate 4, Figures 1-3, 5

Description of material. -- A single, thin, encrusting corallum (UND Cat. No. 13662) occurs on a substrate formed by <u>Manipora</u>

bighornensis and varies from a minimum thickness of 0.2 mm at the periphery to a maximum thickness of 1.5 mm. Shape of the encrusting corallum was determined by the shape of the host corallum exterior.

The surface of the <u>Coccoseris</u> corallum is abraded but irregularly distributed surficial pustules do occur. There is no regular pattern of these pustules which would delineate corallites or other features.

Diameters of these surficial pustules range from 0.12 to 0.25 mm. The corallum interior is completely filled by parallel and nearly parallel monacanthine, trabecular baculae oriented normal or nearly normal to the distal corallum surface. Bacular diameter ranges from 0.14 to 0.25 mm. Means of pustular and bacular diameters are the same (Appendix B, Table 16), indicating that each pustule caps a single bacula. Skeletal fibers within the trabecular baculae, when viewed in transverse section, are oriented radially about the bacular axis. Longitudinal sections of baculae show that the fibers are arranged in chevron-fashion and they are inclined upward from the axis toward the bacular periphery. Fibers vary in orientation from 16 to 52 degrees from the axis, with a mean of 31 degrees. No baculae are oblique to the corallum surface and no voids in the corallum are present.

Type.--Hypotype UND Cat. No. 13662.

<u>Occurrence</u>.--The specimen was collected as a float from the Hunt Mountain beds in the upper part of the Bighorn Formation on the western side of the Bighorn Range (Appendix A, locality A542).

<u>Discussion</u>.--The single fragmental specimen (UND Cat. No. 13662) cannot be assigned to a species. Only the occurrence of well-preserved, Parallel, monacanthine, trabecular baculae and no internal cavities show

that the specimen is the coral <u>Coccoseris</u> Eichwald. As mentioned previously, Flower (1961, p. 56) reported the first occurrence of the genus in North America. The second occurrence, hypotypes of <u>Coccoseris</u> <u>astomata</u> from the Selkirk Member in southern Manitoba is reported in this study. This is the third noted occurrence but it is the first report of the genus in North America in Ordovician strata overlying those with Red River-like faunas. <u>Coccoseris</u> sp. occurs in beds that are faunal and lithologic equivalents of the Gunn Member of the Stony Mountain Formation.

Comparison of the northern Wyoming specimen of <u>Coccoseris</u> sp. (UND Cat. No. 13662) with one of the hypotypes of <u>Coccoseris astomata</u> (UND Cat. No. 13653; Appendix B, Table 16) shows several contrasting features. Trabecular baculae in the hypotype of <u>C. astomata</u> are of consistently greater diameter than those of the northern Wyoming specimen of <u>Coccoseris</u> sp. Trabecular fibers in baculae of the hypotype are inclined from the bacular axis (mean orientation; 52 degrees from the axis) to a greater degree than those of the specimen (mean orientation; 31 degrees).

Subfamily PALAEOPORITINAE

Genus Protrochischolithus Troedsson, 1929

Type species (by original designation).--Protrochischolithus kiaeri Troedsson, 1929, Meddelelser om Gronland, v. 72, pt. 2, p. 116.

Diagnosis.--Commonly thick, encrusting coralla composed of polygonal, trabecular baculae within corallites and narrow coenenchymal regions; stellate corallites with 12 septa and perforate or dense columella. Inclined baculae restricted to septa; septa

separated by interseptal spaces containing tabulae (adapted from Flower, 1961, p. 53).

<u>Remarks.--Protrochischolithus</u> is very similar to <u>Coccoseris</u> in corallum shape, size, habit, and it is difficult to separate the genera in the field. In addition to the interseptal spaces and accompanying tabulae this genus is further differentiated from <u>Coccoseris</u> by the possession of circular pores within the septa and columella.

Species of <u>Protrochischolithus</u> are differentiated from each other by corallite diameter, width of septa, width of interseptal spaces as compared to that of septa, and width and density of the columella.

Protrochischolithus magnus (Whiteaves), 1897

Plate 6, Figure 7; Plate 7, Figures 2, 5, 6 Protarea (vetusta? var.) magna Whiteaves, 1897, Geol. Survey Canada,

Palaeozoic Fossils, v. 3, pt. 3, p. 155, pl. 18, figs. 2, 3

(?), 3a(?).

Protarea vetusta var. magna Whiteaves, Lambe, 1899, Geol. Survey

Canada, Contrib. Canadian Palaeontology, v. 4, pt. 1, p. 91. Protarea magna Whiteaves, Kiaer, 1904, Vidensk. selsk. Christiana Skr.,

Math-naturu, Kl. 1903, n. 10, p. 50 (fide, Flower, 1961, p. 55).
<u>Protrochischolithus kiaeri</u> Troedsson, Leith, 1952, Jour. Paleontology,
v. 26, no. 5, p. 792, pl. 114, figs. 1 (?) 2-5, 6-9 (?), pl.
115, figs. 1-3, 4-6 (?); Nelson, 1963, Geol. Soc. America, Mem.
90, p. 50, pl. 7, figs. 7, 8 (?).

Protrochischolithus magnus (Whiteaves), Flower, 1961, New Mexico Bureau Mines and Mineral Resources, Mem. 7, p. 55, pl. 13, pl. 14, figs. 2-5, pl. 15, fig. 14.

<u>Diagnosis</u>.--Small stellate corallites from 1.0 to 2 mm diameter; mean center-to-center corallite spacing in hypotypes studied 1.1 times the mean corallite diameter; mean wall thickness 0.11 times the mean corallite diameter; columella wide, about one half the corallite diameter; columella dense, composed of closely packed prismatic baculae oriented parallel to columellar axis; few columellar canals; septa thick, tapered toward columella as wide as or wider than parallelsided interseptal spaces; tabulae complete convex, planar, and concave with tabular spacing variable in zones of closely and loosely packed tabulae; zonation continuous between adjacent corallites, paralleling distal corallum surface.

Description of material. ---Three hypotypes, UND Cat. Nos. 13663, 13664, 13665, are variable in corallum size and form (Appendix B, Table 17); complete corallum development where maximum size is attained is accompanied by a hemispherical form. Thickness on the smallest hypotype (UND Cat. No. 13664) is 2 mm and maximum thickness of the largest (UND Cat. No. 13663) is 39 mm. Most encrust on skeletal fragments and the largest hemispherical form (UND Cat. No. 13663) probably utilized a hemispherical stromatoporoid skeleton. The smallest coralla are laminar forms adhering to a solitary rugose coral or to a nautiloid shell.

Coralla are constructed entirely of closely packed, polygonal, fibrous, monacanthine, trabecular baculae capped by conical, distal terminations at the corallum surface. Coralla of <u>Protrochischolithus</u>, unlike those of <u>Coccoseris</u>, have longitudinal, radial cavities, suboval with parallel or subparallel sides when viewed in transverse

section. These cavities, termed interseptal spaces by Flower (1961, p. 53), are between pairs of adjacent septa. They generally have parallel or subparallel sides, reflecting septal thickening toward the corallite periphery. Each bacula is a monacanthine trabecula consisting of fibers oriented in chevron-fashion when viewed in longitudinal section. When viewed in transverse section, the fibers radiate from the point of origin of each fiber at the trabecular axis.

Corallites of all three hypotypes have approximately equal mean diameters, 1.43 mm. Corallite outlines at the corallum surface are stellate due to the peripheral ends of the 12 thick septa. The region between corallites is occupied by a wall with a mean thickness on one hypotype (UND Cat. No. 13663) of 0.11 times the mean corallite diameter. The wall is expressed at the distal corallum surface by a narrow ridge between adjacent corallites and is composed of closely packed baculae oriented normal to the distal corallum surface. These baculae, as viewed in transverse section, are closely appressed against those of the septa. No compositional or textural difference exists between the wall and septal baculae. No skeletal structure that could be termed a corallite wall occurs in coralla of the genus Protrochischolithus. The 12 thick septa per corallite are composed of prismatic baculae that are inclined upwardly and axially toward the columella. Baculae at the axial septal edge turn and merge with those of the columella or terminate obliquely against the columella (Figure 17). The septa are pierced by infrequent, circular mural pores that are directed transversely through the plane of a septum, interconnecting adjacent interseptal spaces.

The columella is composed of closely packed baculae that are oriented with their long axes parallel to the columella axis. The columella is distally terminated at the calyx by a pustulose platform. Mean columellar widths for the three hypotypes range from 0.42 (UND Cat. No. 13663) to 0.53 (UND Cat. No. 13665) times the mean corallite diameter (Appendix B, Table 17). The columella interior contains rare circular tubules that are distally inclined toward the columellar axis.

Tabulae are restricted to interseptal spaces and vary in curvature from concave through convex.

Types.--Hypotypes UND Cat. Nos. 13663-13665.

Occurrence.--Leith (1952, p. 792) reported specimens (U. of Manitoba 111-116) here assigned to <u>Protrochischolithus magnus</u> from exposures of the Selkirk Member of the Red River Formation at Lockport, Manitoba. The remaining hypotypes (MMBM No. 733; Flower, 1961, p. 55; and UND Cat. Nos. 13663-13665) occurred in exposures of the Selkirk Member in quarries at Garson, Manitoba, at localities A883 and A884 (Appendix A).

Discussion.--Bacular skeletal elements, viewed under crossed nicols, show their points of origin within the thin wall. Septa of two adjacent corallites frequently originate within the wall and are directed upward toward the respective corallite axes. This results, in longitudinal sections, in a chevron-like pattern of septal baculae with each half of the chevron representing a septum of one corallite. Other septal baculae appear to abut at their peripheral ends against the flanks of the wall baculae. At the axial margin of the septum, few of the septal baculae terminate at the columella. Other baculae merge with the columella, changing direction so that each is subparallel

or parallel to the columella, becoming one of the columellar structural elements (Figure 17). Baculae within the columella appear to be directed upward toward the center of the columella, and are replaced at the columella periphery by succeeding baculae within higher portions of the septa.

The wall region shows two characters. (1) The wall between septa of adjacent corallites is the point of origin for the septal baculae. These baculae abut the basal portions of those of the adjacent septum (Figure 17). (2) Wall portions not between septa of adjacent corallites show a V-shaped orientation of fibers within the wall baculae. There is continuity of bacular elements from the point of origin in the corallite wall, across the length of the septa, into the columella where they are terminated within that structure, possibly near the columella center. This continuity demonstrates that the depositional sites for baculae within a polyp migrate with time from the polyp periphery to or near the polyp center.

The V-shaped fiber sets within wall baculae which do not directly lead to a septum exhibit a different character. As mentioned by Flower (1961, p. 53), baculae restricted to the wall show that the fibers meet at the center of the V. The center represents the site of initiation of deposition of each fiber. Following this initiation of fiber formation the axes of the fibers are directed upward and toward the corallite axis. This oblique orientation parallels the chevron-like aspect of basal portions of septa baculae.

The assignment of the three hypotypes studied (UND Cat. Nos. 13663-13665) to <u>Protrochischolithus magnus</u> is based on corallite diameter, wide, axially tapering septa, interseptal spaces with parallel

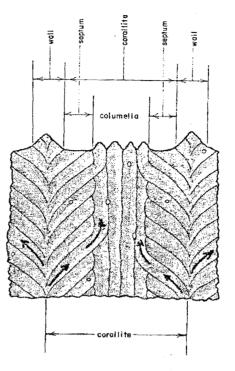


Fig. 17.--Corallite of <u>Protrochischolithus magnus</u> cut by longitudinal section. Fibrous structure of trabecular baculae shown by patterned stippling. Arrows show migration direction of trabecular secretory centers, approx. X20.

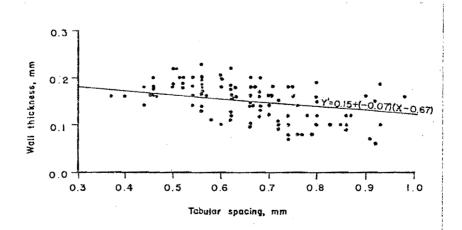


Fig. 18.--Scatter diagram and regression line of wall thickness plotted against tabular spacing for <u>Paleofavosites kuellmeri</u>.

or subparallel sides, thin walls, and wide, dense columellae (Appendix B. Table 17). This agrees with Flower's (1961, p. 55) description of a hypotype (NMBM No. 733) which he assigned to Protrochischolithus magnus. Leith's (1952, p. 792) assignment of the southern Manitoba hypotypes (U. of Manitoba 111-116) to P. kiaeri was changed by Flower (1961, p. 54). This writer found no coralla of Protrochischolithus in the Selkirk Member of southern Manitoba which resemble P. kiaeri Troedsson's figure (1929, plate 30, figure 1c) of a Troedsson, transverse section of the holotype of P. kiaeri shows a relatively thin wall, long, thin septa, interseptal spaces wider than the septa, and a small, porus columella. Leith's illustrations (1952, plate 115, figures 3, 4) of a single hypotype (U. of Manitoba 116) on the other hand, show thicker wall, thicker septa, narrower interseptal spaces, and a wider, more dense columella than those of the holotype of P. kiaeri. Therefore, all previously and presently described specimens of Protrochischolithus from the Selkirk of southern Manitoba are assignable to P. magnus.

Family FAVOSITIDAE

Subfamily FAVOSITINAE

Genus Paleofavosites Twenhofel, 1914

<u>Type species</u> (by original designation of Twenhofel, 1914, p. 24).--<u>Favosites asper D'Orbigny, 1850.</u>

<u>Diagnosis</u>.--Favositines with "mural pores predominantly at angles of walls. . . ." (Hill and Stumm, 1956, p. F461).

Etymology.--Oekentorp (1971) has applied to the International Commission of Zoological Nomenclature to suppress the generic name

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Calamopora Goldfuss, 1829 and to retain the name Palaeofavosites [sic] Twenhofel. He summarized the nomenclatorial history of the genera Calamopora, Favosites, and Paleofavosites, stating that Paleofavosites must be regarded as a junior synonym of Calamopora (type species C. alveolaris Goldfuss, 1829, by subsequent designation of King, 1850), which has pores located at the corners of the corallites. Calamopora has not been used for many years whereas Paleofavosites is a well known and accepted name in paleontology. Oekentorp is of the opinion that reintroduction of the name Calamopora for legalistic purposes would cause confusion. He requested (1) that the generic name Calamopora Goldfuss, 1829 be suppressed and be placed on the Official Index of Rejected and Invalid Generic Names in Zoology; (2) placement of the generic name Paleofavosites Twenhofel, 1914 with the type species Favosites asper d'Orbigny, 1850 on the Official List of Generic Names in Zoology; and (3) that the specific names asper d'Orbigny, 1850 and alveolaris Goldfuss, 1829 be placed on the Official List of Specific Names in Zoology. At the time of this writing, the Commission has not issued an opinion on this case.

The spelling of the generic name deserves comment. Twenhofel (1914, p. 24), in his original description of the genus (and elsewhere throughout this work), spelled it <u>Paleofavosites</u>. However, some subsequent workers, such as Lang, Smith, and Thomas (1940, p. 95), Bassler (1950), Hill and Stumm (1956, p. F461), Nelson (1963), Oekentorp (1971), and Yochelson (1972, p. 788) to name a few, have spelled it <u>Palaeo-</u> <u>favosites</u>. Oekentorp's application to the International Commission on Zoological Nomenclature included the improper spelling, <u>Palaeofavosites</u>.

This spelling is not that of Twenhofel (1914) and it would be unfortunate if this improper spelling was placed on the Official List of Generic Names in Zoology.

<u>Discussion</u>.--Flower (1961, p. 71) in his discussion of <u>Paleo-</u> <u>favosites</u>, stated that the genus probably arose from <u>Foerstephyllum</u> since both share the rugosan type of wall (Flower, 1961). His opinion was that <u>Paleofavosites</u> arose from a group he termed (p. 70) the <u>F</u>. <u>vacuum</u> group, named for <u>F</u>. <u>vacuum</u> (Foerste), a species occurring in the Liberty Formation in the Richmond Group in the Ohio Valley (Browne, 1964, p. 390). This group of species of <u>Foerstephyllum</u> is characterized by a three-layered rugosan wall, a curved corallite wall, short septal ridges or rows of spines, mural pores at the corallite corners, and irregularly spaced and variably curved tabulae.

Some species of <u>Paleofavosites</u> are similar to the <u>F</u>. <u>vacuum</u> group of species since they have the same wall types, pores, spines and tabulae in common. One species, <u>P</u>. <u>sparsus</u> Flower, is very suggestive, according to Flower (1961, p. 73), of <u>Foerstephyllum</u> of the <u>F</u>. <u>vacuum</u> group. According to Flower this species of <u>Paleofavosites</u> may be the best indication of a <u>Foerstephyllum</u> ancestor for <u>Paleo-</u> favosites.

Review of relatively recent literature on Ordovician and Silurian <u>Paleofavosites</u> (Stearn, 1956; Flower, 1961; Nelson, 1963) shows several evolutionary trends within the genus:

- There is a progression from distinctly curved walls and corners to straight walls and angular corners.
- 2. Pores located exclusively in corallite corners gave way to increasing proportions of pores in the walls indi-

- Septal development in <u>Paleofavosites</u> progressed from a complete absence in early species toward long spines arranged in longitudinal rows.
- Tabular margins lost the crenulate and downturned character occurring in early species.

Thus a conceptual primitive species of <u>Paleofavosites</u> would be characterized by curved corallite walls and corners, mural pores located only in the corners, no septal spines, and crenulate, downturned tabulae. In contrast, advanced species would have straight walls and angulate corners, mural pores located in the corners with a subordinate amount in the walls, septal spines, and planar tabulae.

Species of <u>Paleofavosites</u> are distinguished from each other by corallum type, corallite orientation, corallite diameter, mural pore diameter, and the presence and degree of development wall curvature, wall crenulation at the corallite corners, septal spines, and crenulation of the tabular margins.

Paleofavosites kuellmeri Flower, 1961

Plate 7, Figure 4; Plate 8, Figures 1-3 <u>Paleofavosites kuellmeri</u> Flower, 1961, New Mexico Bur. Mines and Mineral Resources, Mem. 7, p. 74, 75, pl. 36.

Diagnosis.--Large, elongate, massive cerioid corallum with moderate to large diameter corallites oriented parallel to each other; corallites on corallum periphery oriented oblique to corallum growth surface; mural pores closely spaced, circular to suboval, located only at corallite angles, between either consecutive or alternate corallite wall crenulations which are strong, closely spaced, located at corallite angles; sclerenchymal layers on both sides of axial plate variable in thickness and fiber orientation, commonly thicker in regions of closely spaced tabulae than in regions of widely spaced types; walls in transverse sections straight to gently curved; aseptate; tabulae all complete, predominantly normal to corallite axis, commonly crenulate and downturned at peripheral margins, segregated into poorly defined regions of closely and widely spaced tabulae, each zone subparallel to corallum growth surface.

Description of material .-- The northern Wyoming hypotype of Paleofavosites kuellmeri Flower (UND Cat. No. 13729) is a fragmental cerioid corallum, showing maximum width and height, but broken normal to the corallum long axis so that the full length is indeterminable (Appendix B, Table 18). The general corallum form is flattened cylindrical or elongate tabular. Corallites are nearly parallel with a total corallite divergence of about 37 degrees across the width of the corallum. Corallite axes are nearly normal or normal to the probable sedimentary surface. Corallites at the corallum periphery are oblique to the growth surface. Corallite diameters vary widely, from 1 mm to 2.9 mm. Mean corallite width is about 2 mm but a number of large corallites, 2.2 to 2.7 mm diameter, surrounded by smaller corallites of diameters less than 2.1 mm. Corallites are subpolygonal in cross section, with slightly curved or straight walls.

Corallite corners are commonly rounded, and some curved corallite walls are continuous across the sides of several corallites. Most curved, continuous walls appear to be transverse to the direction of lateral expansion of the corallum, whereas straight

walls are predominantly oriented with the plane of the straight wall parallel to the expansion direction. The presence of parallel mature corallites which are continuous throughout the height of the corallum near its center indicates that budding occurred during the early stages of colony development. Budding rarely occurred during the mature portion of the colony's life. The rare budding resulted in small (approximately 0.7 mm), triangular corallites which appear at the intersection of three mature corallites. Longitudinal sections which intersect corallite angles show the corallite wall at the angle to be contorted into a longitudinal series of strong, very closely spaced crenulations. Mean crenulation length is 0.6 mm, whereas mean maximum amplitude of the crenulation at the angle is 0.25 mm, 0.08 times the mean corallite diameter. Mural pores are located only in the corallite angles, and are variably spaced, with pores located between consecutive or alternate crenulations. Longitudinal pore spacing averages 0.37 and 0.65 mm for closely and widely spaced pores, respectively. Corallite walls are thin and three-layered, with a central, clear axial plate averaging 0.03 mm in thickness, flanked on both sides by fibrous sclerenchyme. Wall thickness is variable throughout the corallum, appearing to be thinnest at and near the corallum lateral periphery, and in regions where tabulae are widely spaced. Figure 18 illustrates a rough inverse relationship between wall thickness and tabular spacing, implying that walls are thickest in corallite regions where tabulae are closely spaced. Wall thickness is manifested predominantly by variations in fibrous stereozone thickness; the axial plate thickness is relatively constant (Appendix B, Table 18). Fiber orientation,

viewed in transverse section is normal to the axial plate and wall plane. In longitudinal section, fibers are seen to diverge upward from the plate at angles varying between 26 and 90 degrees from the corallite axis. Septa are totally lacking.

Tabulae are thin, with no tabular spines. Complete, horizontally oriented tabular are greatly predominant. Tabular curvature varies from concave (rare), through planar (more abundant), to planar types with downturned and crenulate peripheral margins. Tabulae are zoned into poorly defined groups of widely and closely spaced types, subparallel to the corallum growth surface. The transition between the zones appears to occur where the tabulae are spaced approximately 0.25 to 0.7 mm from each other. The total variation in spacing ranges from approximately 0.2 to 1.0 mm. In zones of closely spaced tabulae, mean spacing is approximately 0.5 mm whereas that of zones of widely spaced tabulae is about 0.77 mm.

Type .-- Hypotype UND Cat. No. 13729.

Occurrence. -- The holotype of <u>Paleofavosites kuellmeri</u> Flower was collected from the coral zone of the Aleman Formation of the Montoya Group, northern Franklin Mountains, Texas. The (UND Cat. No. 13729) was collected from the uppermost shale bed of the Hunt Mountain beds, in the upper portion of the Bighorn Formation, Bighorn Mountains, Wyoming east of Hunt Mountain (Appendix A, locality A538).

Discussion. -- The northern Wyoming hypotype is assigned to the species Paleofavosites kuellmeri Flower on the following basis:

> Growth habit of corallites in the holotype and hypotype are similar. Corallites in both specimens are subparallel,

and budding does not appear to have been prevalent in the mature portions of either.

- 2. Corallite diameters are similar.
- 3. Walls in both are straight and curved in transverse section.
- 4. Pores in both occur only at the corallite corners.
- 5. Mural pores of both are more closely spaced than in other Ordovician species of <u>Paleofavosites</u> where biometric data are available.
- Crenulations at the corallite corners of both are more closely spaced and of greater amplitude than in other species of Paleofavosites.
- Both the northern Wyoming hypotype and the holotype are aseptate.
- 8. Tabular form and spacing are somewhat similar.

Comparison of the hypotype and the holotype of <u>P</u>. <u>kuellmeri</u> does show some significant differences, especially in the area of corallite corners where wall features are dissimilar. Wall crenulation length of the hypotype is less (mean=0.63 mm) than the 1.0 to 1.5 mm length of the holotype whereas the crenulation amplitude of both is strong. Mural pore spacing of the hypotype is approximately equal to that of the holotype (Appendix B, Table 18). Tabulae with downturned, crenulate edges appear to be more prevalent in the hypotype than in the holotype.

Budding of the Wyoming hypotype appears to have occurred at the colony base, as most corallites in longitudinal section show continuity throughout the corallum thickness. Each new corallite appears to have been constructed directly on the sediment surface at nearly

the same level as the adjacent parent corallite. The newly budded polyp probably was emplaced on the clastic surface prior to corallite construction, which illustrates that budding and maximum lateral expansion had occurred before the corallum had reached half to total height. Thus the latter half of the colony's history was essentially without great amounts of asexual reproduction.

Wall curvature within the hypotype appears to be related to budding and subsequent lateral corallum expansion. Curved walls are predominant in directions normal and oblique to direction of budding and corallum expansion. These curved forms are continuous over the flanks of two or more corallites and are termed, multicorallite. Short, straight walls are continuous over one face of the corallite prism and serve to interconnect the multicorallite wall sets by closing the subpolygonal figure (Figure 19). The mechanism of lateral increase and lateral corallum expansion (Figure 20) seems to have consisted of the following processes:

- Lateral advance of newly budded polyps along a front away from the corallum margin onto the sediment surface,
- 2. Deposition of a curving, multicorallite wall at the newly stabilized polyp front with possibly simultaneous construction of basal tabulae; at the same time, short, straight walls were emplaced between the previous and new multicorallite wall, closing each polygonal corallite,

3. Repetition of steps one and two.

As lateral expansion and upward growth continued, skeletal mass increased and the resulting colony weight caused the corallum to subside gradually into the argillaceous substrate forcing the newly budded polyps to begin

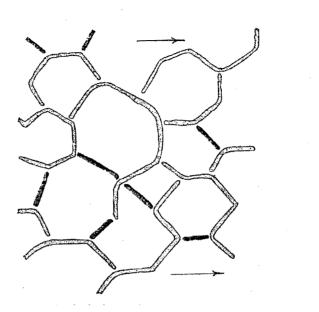


Fig. 19.--Transverse section of <u>Paleofavosites kuellmeri</u>. Multicorallite wall shown by stippling. Short, straight, discontinuous walls are solid. Direction of lateral expansion shown by arrow, approx. X12.

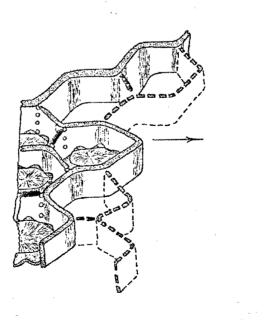


Fig. 20.--Corallum margin of <u>Paleofavosites kuellmeri</u>. Established corallites and multicorallite walls shown by stippling. Short, straight walls are solid. Future position of multicorallite wall dashed and stippled. Future position of short straight wall dashed and solid. Expansion direction shown by arrow, approx. X12.

corallite construction at the sediment surface higher relative to the corallum. As a result, the curved base of the colony reflects continued subsidence into the argillaceous substrate. An additional factor in the shaping of the corallum base may have been the deposition of argillaceous sediment, but this may have been a subsidiary or negligible factor considering the short time necessary for colony develop-Evidence rapid growth for corallum subsidence can be indirectly ment. derived by a review of rates of longitudinal coral growth. Ma (1960) cited annual growth values for Late Carboniferous corals. His data ranged from a minimum of 2.0 to a maximum of 39.0 mm per year. For Holocene corals, Ma attained a range of mean growth rates varying from 2.5 to 20 mm per year. Knutson, Buddemeier, and Smith (1972, Table 1) derived growth rates of from 4.6 to 13.5 mm per year for seven species of Holocene hermatypic scleractinian corals from Eniwetok Island on Bikini Atoll. Thus, for the hypotype corallum which is 50 mm high, using minimum and maximum growth values for Carboniferous and Holocene corals, a time of 1.25 to 25 years would have been required for the hypotype colony to attain its present thickness.

It is unlikely that a high rate of sedimentation could have determined the shape of the underside of the hypotype corallum by sediment buildup since massive colonial corals did not appear to fare well under conditions of rapid clastic sedimentation. So at least in part, the oval cross-sectional profile of the hypotype corallum may have been controlled more by subsidence due to skeletal mass than by rate of sedimentation.

Paleofavosites sp. cf. P. kuellmeri Flower, 1961

Plate 8, Figures 5, 6

Description of material .-- The hypotype corallum is extremely large, in excess of 1 meter wide and more than 17 centimeters high. Corallites parallel each other, with vertical or slightly inclined They are subpolygonal in transverse section, with gently axes. curved walls slightly predominating. These are frequently continnous between numbers of individual corallites and are accompanied by rounded corallite corners. Straight walls terminate in angular cor-Curved, multicorallite walls are laterally superimposed against ners. adjacent walls in the direction of lateral corallite expansion (Figure Mural pores are predominantly circular and occur only in coral-19). lite corners, with an average longitudinal spacing of 0.5 mm. In longitudinal section, corallite walls away from corners are straight whereas at corallite corners they are strongly crenulate with a mean maximum amplitude of 0.1 times the mean corallite diameter. Corallite wall thickness is determined by the length of sclerenchymal fibers, with the axial plate remaining uniformly thin. Walls tend to be thickest, with long fibers in corallum regions where tabulae are closely spaced, and thin in regions of widely spaced types (Figure 21). No septa and no spinose projections occur within observed corallites. Tabulae are grouped into zones according to spacing, With closely packed forms and widely spaced forms having mean spacing of 0.3 to 0.73 mm respectively (Appendix B, Table 18). All tabulae are oriented obliquely to the corallite axis in inclined corallites and transversely in vertical ones. Most are complete,

but incomplete ones occur. Grenulation is present at the tabular margins, appearing in tangential sections as a transverse undulatory line. Tabulae show a wide variation in curvature despite extensive crushing of corallites. Those still preserved indicate that widely spaced types are predominantly planar, often with downturned margins. Closely spaced tabular vary in curvature from planar to convex, and account for all incomplete forms present.

Type.--Hypotype, UND Cat. No. 13730.

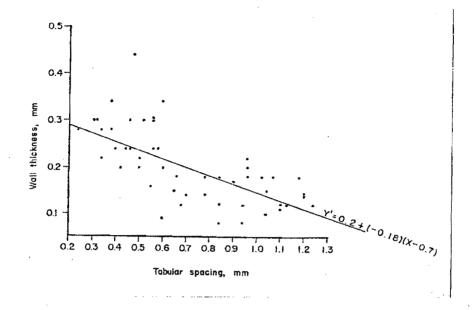
Occurrence. -- The hypotype of <u>Paleofavosites</u> sp. cf. <u>P. kuellmeri</u> was collected as a fragment of a complete corallum at the contact between the underlying Gunn and the Penitentiary Members of the Stony Mountain Formation at the Municipality of Winnipeg Aggregate Plant north of Stony Mountain, Manitoba, collecting locality A896 (Appendix A).

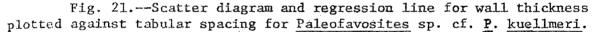
<u>Discussion</u>.--Extensive post-burial crushing has destroyed most of the interior structures of the corallum, but uncrushed portions are well preserved and permit comparison to known species of <u>Paleofavosites</u>. The specimen under discussion has the greatest affinity with <u>Paleofavosites kuellmeri</u> Flower since both this species and the specimen at hand share parallel corallite orientation, curved corallite walls and rounded corallite corners, pores only in corners, wall crenulations strong and closely spaced, restricted to corners, no septa, and relatively planar tabulae often with downturned or crenulate margins.

The hypotype specimen however, is sufficiently differ from \underline{P} . kuellmeri to prevent assignment to the species.

1. The corallum is much larger than other known specimens.

2. Corallite diameters are larger in the specimen than in





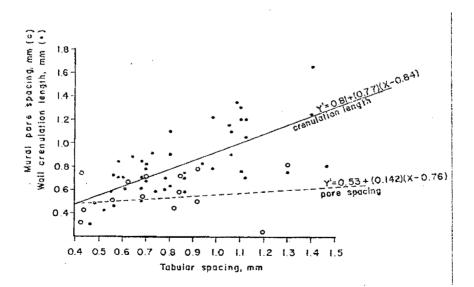


Fig. 22.--Scatter diagram and regression lines for mural pore spacing and wall crenulation length plotted against tabular spacing for <u>Paleofavosites mccullochae</u>.

3. Tabulae in the specimen are very closely spaced and are commonly oblique to the corallite axis whereas tabulae in the species holotype and hypotype are normal to the axis.

The only other species similar to the southern Manitoba specimen is <u>Paleofavosites prolificus</u> (Billings). Biometric data furnished by Stearn (1956, p. 60) and Hill (1959, p. 12) for this species gave a mean diameter of 2.34 mm for the corallites and a diameter of 5 cm for the corallum. Additional description by Stearn (1956) and Hill (1959) list rare mural pores in the corallite wall and the development of short septal spines, precluding assignment of the Manitoba specimen to this species. Affinity of <u>Paleofavosites</u> sp. cf. <u>P. kuellmeri</u> with the horthern Wyoming and New Mexico examples of the species indicates that a Montoya-like <u>Paleofavosites</u> extends northeastward from west Texas and New Mexico through Wyoming, to southern Manitoba.

Paleofavosites mccullochae Flower, 1961

Plate 8, Figures 4, 7; Plate 9, Figure 3 <u>aleofayosites mccullochae</u> Flower, 1961, New Mexico Bur. Mines and Mineral Resources, Mem. 7, p. 75, 76, pl. 37, figs. 2, 6-9.

Diagnosis.--Small hemispherical coralla, with corallites radiatng from corallum origin, corallites subpolygonal or polygonal with traight or gently curved walls, angular to rounded corallite corners; verage corallite diameter up to 3.2 mm; mural pores only in corallite orners, oval or circular; wall crenulations only in corners, closely paced, with strong amplitude; aseptate but with small spinose projecions of wall sclerenchyme in regions where tabulae closely spaced and

walls of maximum thickness; tabulae all complete, and normal to corallite axis, crenulate at peripheral margins, segregated into clearlydefined zones of closely and widely spaced types, with zones paralleling corallum growth surface.

Description of material.--Hypotypes the small, hemispherical hypotype coralla (UND Cat. Nos. 13731, 13732) have well-defined points of origin from which corallites radiate to form pronounced hemispherical growth surfaces. Corallites are polygonal or subpolygonal, ranging in prismatic form from triangular through octahedral. Diameter ranges from 0.9 mm for relatively immature form to 3.2 mm for mature corallites. Approximate mean diameter for both hypotypes is 1.9 mm (Appendix B, Table 19). Most corallites in transverse section are angular. Gently curved walls and rounded corners occur but are subordinate to straight walls and angular corners. Curved walls frequently lead into a corallite corner where deflection of the wall forms a curve leading into the adjacent corallite wall.

Mural pores occur only at the corallite corners and vary in outline from oyal to circular, with the elongate axis of the oyal paralleling the corallite axis. Oyal forms have an average width to length ratio of 0.9 and circular forms have an average diameter of 0.18 mm, whereas the mean spacing value is approximately 0.5 mm. Pores are located within the concave portion of the wall crenulation and are bordered on their periphery by a raised wall rim termed a poral process (Hill, 1959, p. 11). No systematic placement of pores within consecutive versus alternate crenulations was observed (Figure 22).

Crenulation is restricted to the corallite corners and is most strongly developed in corallite regions where tabulae are closely spaced.

The mean maximum observed crenulation amplitude is 0.14 times the mean corallite diameter. Crenulation length varies from 0.3 to 1.65 mm (Appendix B, Table 19), with closely spaced forms concentrated in zones of closely spaced tabulae and widely spaced forms predominating in zones of widely spaced tabulae (Figure 22), establishing a relationship between length and tabular spacing.

Corallite walls vary in thickness from 0.05 to 0.26 mm with the thinnest walls occurring in corallite regions where tabulae are widely spaced and thickest forms in zones of closely spaced tabulae (Figure 23). Wall fibers are oriented normal to the central axial plate in transverse section. Longitudinal sections show wall fibers oriented obliquely to the axial plate, forming chevron-like sets of fibers on both flanks of the corallite wall. Wall fiber orientation in longitudinal section varies from 40 degrees to 88 degrees with no apparent relationship existing between wall fiber orientation and tabular spacing (Figure 23).

No septa occur, but one hypotype (UND Cat. No. 13732) exhibits spinose projections of the sclerenchymal wall layer in which relatively long fibers within the layer project into the corallite lumen. Spine development occurs only in regions where the walls attain maximum thickness and is absent or not preserved in corallite regions where walls are thinner.

Tabulae are all complete, normal to the corallite axis, and are grouped into zones of widely and closely spaced forms that parallel the corallum growth surface. Tabulae in zones of closely spaced forms are predominantly plane, with fewer being slightly convex or concave. All appear to be crenulate on their periphery. Widely spaced tabulae are

predominantly plane with crenulate margins. One hypotype (UND Cat. No. 13731) shows that the transition between zones of closely and widely spaced types is relatively abrupt. At these transitions, tabulae have a spacing value ranging between 0.7 to 0.8 mm. Mean spacing values for the zones of closely spaced tabulae are nearly equal for both hypotypes. Both hypotypes also have nearly equal spacing values for zones of closely spaced types (Appendix B, Table 19).

One hypotype (UND Cat. No. 13732) possesses small intramural tubules, from 0.1 to 0.2 mm diameter occupying the central portions of the corallite wall. Viewed in longitudinal section, the tubules are of uniform diameter, filled with sparry calcite, and have no internal structures. The wall axial plate appears to line the tubule.

Types.--Hypotypes, UND Cat. Nos. 13731, 13732.

Occurrence.--Both hypotypes were collected from the same locality. One (UND Cat. No. 13731) came from 0.9 to 4.1 meters (3.1 to 13.2 ft) above the top of the Hunt Mountain beds, and the other (UND Cat. No. 13732) was a float specimen at least 6.1 meters (20 ft) above the top of the beds on the western side of the Bighorn Mountains, Wyoming at localities A544 and A546 respectively (Appendix A).

<u>Discussion</u>.--Both hypotypes are assigned to <u>Paleofavosites</u> <u>mccullochae</u> Flower because of the following similarities between them and the types cited by Flower (1961, p. 75) who did not designate a holotype.

1. All exhibit the same type of radiating corallite pattern.

 Corallite diameters are close to those of the types described by Flower.

- 3. Corallite walls are predominantly straight with angular corallite corners.
- 4. Tabulae of all specimens assigned to the species are are markedly crenulate along their margins.

Comparison of the Wyoming hypotypes of <u>P</u>. <u>mccullochae</u> and <u>P</u>. <u>kuellmeri</u> reveal the following points regarding the previously men-

- <u>P. mccullochae</u> shows the corallites arranged in radiating fashion, indicating that budding occurred during the entire growth history of the colony. <u>P. kuellmeri</u>, on the other hand, contains corallites arranged in parallel fashion, illustrating that nearly all budding and lateral growth of the colony occurred relatively early in the development of the colony.
- The hypotypes of <u>P. mccullochae</u> have predominantly straight walls and angular corallite corners. In contrast, <u>P.</u> <u>kuellmeri</u> is characterized by curved, multicorallite walls and rounded corners predominating.
- 3. The types of <u>P</u>. <u>mccullochae</u> contain rare pores in the wall (Flower, 1961, p. 75) but the Wyoming hypotypes do not. The holotype and Wyoming hypotypes of <u>P</u>. <u>kuellmeri</u> have all pores located at the corallite corners.
- 4. The Wyoming hypotypes of <u>P</u>. <u>mccullochae</u> contain tabulae in which those with downturned margins are approximately equal in number to those that are planar. Tabulae with downturned margins are most common where they are widely

spaced. In contrast, the holotype of <u>P</u>. <u>kuellmeri</u> has downturned tabulae being subordinate to planar types in the mature portions of the colony (Flower, 1961, p. 75). The Wyoming hypotype of <u>P</u>. <u>kuellmeri</u> (UND Cat. No. 13729) also contains subordinate downturned types.

Use of the trends cited in the generic discussion show that <u>Paleofavosites</u> <u>kuellmeri</u> is, by comparison, more primitive than <u>P. mccullochae</u>. This latter species has straighter walls and some pores in the walls, features which may be considered to be advances within the genus.

As in the hypotype of P. kuellmeri (UND Cat. No. 13729), the hypotypes of P. mccullochae show an inverse relationship between wall thickness and tabular spacing (Figure 23). This indicates that construction of thick fibrous sclerenchyme on both flanks of the axial plate was accomplished by secretion of long sclerenchymal fibers. In addition to thick sclerenchymal layers, spinose extensions of the sclerenchyme protrude into the corallite lumina on one of the northern Wyoming hypotypes (UND Cat. No. 13732). Spines are irregularly developed and occur in this hypotype only where walls are thickest and tabulae are closely spaced. Whether or not these spines represent true septa is not apparent. Their occurrence apparently was physiologically controlled, and they appeared only when certain skeletal structures attained or exceeded a given dimension. Secretion of short sclerenchymal fibers resulted in a thin corallite wall, most frequently associated with regions of widely spaced tabulae.

Wall crenulation length is associated with tabular spacing (Figure 22) where high values of length are associated with widely ^{spaced} tabulae and vice versa. The inverse relationship between

wall thickness in hypotypes of both <u>Paleofavosites kuellmeri</u> and <u>P</u>. <u>mccullochae</u> and tabular spacing suggests two possible phenomena related to rates of upward corallum growth.

- 1. Deposition of massive amounts of skeletal material in construction of long-fibered, thick walls with accompanying projecting spines shows that larger areas of the polyp basal plate may have been involved in skeletal secretion than when walls are thin and wall secretion is restricted to limited areas of the basal plate. Thick walled forms and concommitent spreading of secretory centers over large areas of the basal polyp surface may have resulted in a slower upward growth since skeletal material was being deposited over a wider area than when thin walls were constructed.
- 2. Variations in metabolic levels may have resulted in increased rates of upward growth wherein the amount of calcareous material allotted for the fibrous sclerenchymal walls may have been relatively constant per unit of time during the life of the colony. During periods of slow upward growth reflected by parallel or concentric zones of closely spaced tabulae, the constantly secreted amount of wall material was accommodated to the slow upward progression of the corallum surface by secretion of relatively long sclerenchymal fibers. Rapid upward growth, reflected by zones of widely spaced tabulae was accompanied by the concentration of secretory zones

within the basal plate close to the secretory centers of the axial plate. This may have resulted in secre-

tion of short fibers, causing a thin corallite wall. If tabular spacing reflects varying rates of upward colony rowth, then construction of tabular plates may have been at relaively regular time intervals. Corallite wall crenulation length nd mural pore spacing are related to tabular spacing in which acreases in tabular spacing are accompanied by increases in both. us indicates that individual pore placement and wall deflection av also have occurred at relatively regular intervals of time. Of he two previously discussed possibilities; (1) whether growth eflects massiveness of skeletal structure or (2) controls skeletal assiveness, neither can be stated absolutely on the sole basis of ssil evidence. That rates of calcium uptake and skeletal secreon can vary within a coral has been demonstrated by Goreau and reau (1959, p. 250) who showed that some Holocene hermatypic rals have the capacity to vary their rates of growth and skeletal nstruction under yarying environmental conditions. Whether this a be applied to an extinct group of anthozoans in the strictest ise cannot be said since the hermatypic corals are aided by sym-)tic zooxanthellae or chloranthellae for which no evidence remains the extinct Rugosa and Tabulata. In both Paleofavosites kuellmeri P. mccullochae it is possible that varying dimensions in skeletal uctures reflect changes in rates of colony metabolism controlled environmental factors such as levels of light (Goreau and Goreau, 9), water temperature, and available food.

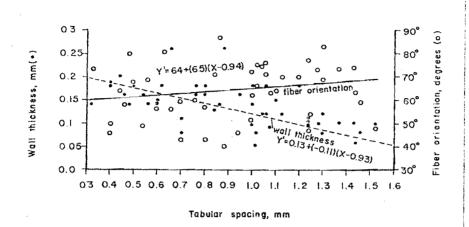


Fig. 23.--Scatter diagram and regression lines for wall thickness and wall fiber orientation plotted against tabular spacing for Paleofavosites mccullochae.

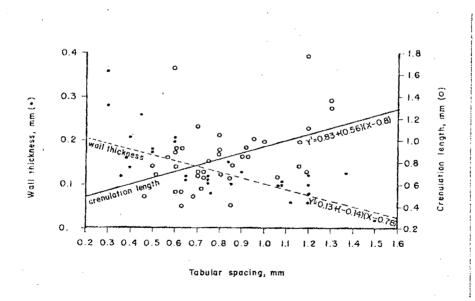


Fig. 24.--Scatter diagram and regression lines for wall thickness and crenulation length plotted against tabular spacing for <u>Paleofavosites</u> sp. cf. P. prayi (UND Cat. No. 13733). The intramural tubules noted in one hypotype (UND Cat. No. 13732) do not appear to have a wall lining composed of material other than that of the axial plate. The plate appears to divide in order to line each tubule. This suggests that there was a localized formation of a secretory region similar to an edge zone for secretion of a tube lining. The tubules, by their not having an inner sclerenchymal layer, are probably not representatives of an ontogenetic stage of a corallite since a corallite would have presumably deposited an inner sclerenchymal layer. Instead the tubules may have been constructed by the colony around an endocommensal organism.

Flower (1961, p. 75) attributed similar tubules in <u>P. mccullochae</u> from the Montoya Group to budding individual corallites. He stated that the tubules he saw occurred as rounded tubes 0.5 mm diameter which enlarged into the polygonal form of a corallite. One specimen (NMEM No. 802) which Flower illustrated (plate 37, figures 12, 13) shows the intramural tubules. No such transition from tubule to polygonal corallite however, was seen in the hypotype at hand.

Paleofavosites sp. cf. P. prayi Flower, 1961

Diagnosis.--Small, depressed hemispherical corallum, corallites at corallum center oriented normal to substrate surface; those at corallum periphery oblique to surface; corallites small, mature forms of relatively uniform diameter, alveolitid to subrounded in transverse profile with corallite walls straight to conspicously curved; curved walls commonly extending between two or more corallites or around a number of walls of corallites; corallite corners angular or rounded; mural pores only in corallite corners, predominantly circular, rarely

elongated parallel to corallite axis; wall crenulation length variable, increasing with increases in tabular spacing; crenulation amplitude strong; wall thickness variable, from extremely thin to thick; thin forms predominanting in zones of wide tabular spacing and vice versa; aseptate; tabulae all complete, oriented normal to corallite axes at corallum center and oblique to axes when corallites inclined; planar tabulae predominating, grouped into zones of closely and widely spaced types paralleling corallum growth surface.

Description of material .-- The extensively silicified, fragmental, cerioid hypotype (UND Cat. No. 13733) is subcircular in peripheral aspect and flattened hemispherical in profile. Corallites within the corallum vary in orientation from vertical at the corallum center to inclined at the periphery, resulting in an overall radiating aspect. Corallites are small, of uniform diameter, with maximum observed diameter not exceeding 1.8 mm and a mean diameter of 1.3 mm (Appendix B, Table 20). Offsets occur as tubules at the junction of three or more mature corallites. The smallest tubules are 0.1 mm diameter and occur at the junction of three convergent axial plates. These tubules appear to be the earliest observable stages of offset (budded) corallites. At this earliest stage they are subcircular but change with maturation to a subpolygonal corallite. Transverse corallite outlines vary with position within the corallum. Those at the corallum center which are vertically oriented are predominantly subpolygonal, with straight or slightly curved walls with angulate or rounded coral-Inclined corallites at or near the corallum periphery lite corners. approach a alveolitid transverse outline in which the arch of the upper wall is oriented with the convex surface in the direction of

lateral expansion. Corallite corners in this region of the corallum are rounded. Mural pores are restricted to corallite corners and pore outline is predominantly circular with variable pore diameter. Wall crenulation at the corallite corner varies in length and is loosely allied with tabular spacing (Figure 24) in which widely spaced crenulation convexities often occur in regions of the corallum where tabulae are widely spaced. Means of crenulation amplitude maxima are 0.13 times the mean corallite diameter and are "moderate" to "strong" where observed.

Corallite wall thickness is variable and inversely related to tabular spacing (Figure 24), whereby a decrease in wall thickness is accompanied in that region of the corallite by widely spaced tabulae. Extreme wall thinness is manifested by no sclerenchymal wall fiber development; the wall consisting only of a thin axial plate. Conversely, thick walls occur predominantly in corallite regions where tabulae are closely spaced (Figure 24). Wall fibers are here developed at their maximum length. A probable relationship between wall fiber orientation and tabular spacing occurs (Figure 25). This inexact relationship implies that wall fibers tend to be oriented at greater angles to the axial plate in regions of widely spaced tabulae and are more nearly parallel to the plate where tabulae are closely spaced. No septa were observed. All tabulae are complete and are oriented parallel or nearly parallel to the base of the colony. Inclined corallites contain tabulae oriented oblique to the corallite axis whereas vertical ones have them oriented normal to the axis. Tabulae in zones of wide spacing are predominantly straight with no curvature. Tabulae in zones of close spacing

tend to exhibit a greater range in curvature varying from slightly convex to slightly concave. Zones of tabular spacing are parallel or subparallel to the corallum growth surface.

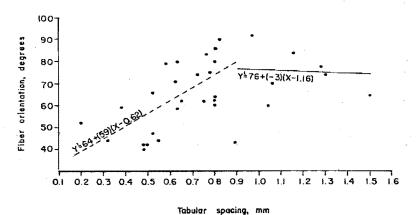
Hypotype.--UND Cat. No. 13733.

Occurrence.--Paleofavosites sp. cf. P. prayi was collected as a badly silicified float specimen, approximately 5.1 meters (20 ft) above the top of the Hunt Mountain beds, on the western flank of the Bighorn range, northern Wyoming (Appendix A, locality A546). This float hypotype indicates that its stratigraphic position is at least equal to or above the collecting level. The holotype of <u>Paleofavosites prayi</u> (NMEM No. 685) occurred in the coral zone of the Aleman Formation of the Montoya Group, in the north Franklin Mountains and was also observed in the southern end of the range near El Paso, Texas. Another form of <u>Paleofavosites</u> that Flower (1961, p. 74) compared to <u>P. prayi</u> occurs in the Cutler Formation of the Montoya Group in Tank Canyon in the Mud Spring Mountains and in the Hueco Mountains (NNEM Nos. 796, 797).

<u>Discussion</u>.--Most of the silicified portion of the hypotype corallum is not usable for identification and description. The remaining unsilicified portions represent the original morphology. Review of the literature on previously described species of North American <u>Paleofavosites</u> revealed no similar form. However, the hypotype contains some features which are like those of the holotype of <u>P. prayi</u> (NMEM No. 685) and the previously mentioned comparable form (Flower, 1961, p. 74). All have small corallites (Appendix B, Table 20). The holotype and the Wyoming hypotype (UND Cat. No. 13733) have curved corallite walls, pores only in the corallite corners, no septa, and planar tabulae. The holotype has parallel corallites whereas the hypotype has both parallel and radiating corallites. The holotype possesses walls which are crenulate away from the corallite corners whereas the hypotype has walls which are straight away from the corners. The hypotype is compared to <u>Paleofavosites prayi</u> Flower and also shows some similarity to <u>Paleofavosites</u> cf. <u>prayi</u> described by Flower (1961, p. 74).

Wall curvature in the Wyoming hypotype is unique in that the degree of curvature is in excess of that possessed by other species of <u>Paleofavosites</u>. Curvature is so strong that corallite wall segments form semicircular arcs. Like <u>P</u>. <u>kuellmeri</u>, curvature appears to be associated with lateral corallum growth. However, unlike that species, the arcuate wall does not connect margins of lateral corallum growth. Instead the arcuate wall encloses the periphery of a single corallite, demonstrating that corallite budding in this specimen occurs individually, and that corallite expansion with age occurs in the direction of the convex wall. Immature offsets show that after arising from an intramural tubule, the new corallite constructs a convex wall portion comprising only 25 to 40 percent of the total corallite perimiter.

In this hypotype, as well as previously discussed northern Wyoming examples of <u>Paleofavosites</u>, definite relationships between rates of vertical corallite growth reflected by tabular spacing and longitudinally placed morphological features occur. This suggests that dimensions of these features may have been directly controlled by the speed at which the corallum grew upward. Sclerenchymal fiber orientation was not previously noted to be controlled by growth. Figure 25 illustrates that fiber orientation tends to approach



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Fig. 25.--Scatter diagram and regression lines for wall fiber orientation plotted against tabular spacing for <u>Paleofavosites</u> sp. cf. <u>P. prayi</u>.

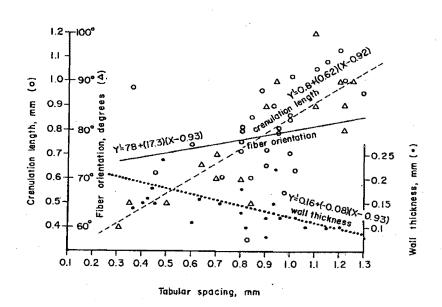


Fig. 26.--Scatter diagram and regression lines for crenulation length, wall fiber orientation, and wall thickness plotted against tabular spacing for <u>Paleofavosites prolificus</u> (UND Cat. No. 13734).

perpendicularity to the axial plate as tabular spacing increases. The significance of this is not understood, but a relationship between decreasing fiber length and progression toward fiber perpendicularity accompanies increased values of tabular spacing. In the reverse, longer fibers, increasing acuteness of fiber orientation, and closely spaced tabulae occur roughly simultaneously. The result of this is that long fibers, steeply inclined, during times of slow upward growth take up less lumen space than fibers of the same length oriented at less acute angles.

Paleofavosites prolificus (Billings), 1865

Plate 9, Figures 4-6; Plate 10, Figures 1, 6 Favosites prolificus Billings, 1865, Canadian Naturalist and Geologist,

New series, v. 2, p. 429; Whiteaves, 1895, Geol. Survey Canada, Palaeozoic Fossils, v. 3, pt. 2, p. 113.

Favosites aspera d'Orbigny Lambe, 1899 [partim] Geol. Survey Canada, Cont. Canadian Palaeontology, v. 4, pt. 1, pl. 1, fig. 2.

Paleofavosites prolificus (Billings), Twenhofel, 1914, Geol. Survey Canada, Mus. Bull. 3, p. 24; _____, 1928, Geol. Survey Canada, Mem. 154, p. 126; Stearn, 1956, Geol. Survey Canada, Mem. 281, p. 60, pl. 4, fig. 1, pl. 10, fig. 13; Nelson, 1963, Geol. Soc. America, Mem. 90, p. 52, pl. 7, fig. 5.

[?]Paleofavosites prolificus (Billings), Shimer and Shrock, 1944, Index fossils of North America, John Wiley and Sons, New York, p. 107, pl. 37, fig. 7.

[?]<u>Paleofavosites asper</u> (d'Orbigny), Shimer and Shrock, 1944, Index fossils of North America, John Wiley and Sons, New York, pl. 37, fig. 16. Diagnosis.--Small to large, flattened, hemispherical or discoidal coralla with radiating and parallel corallites ranging from 1.2 to 3.1 mm diameter, subpolygonal in transverse section frequently with conspicuously curved corallite walls and corners; mural pores exclusively at corners; thin corallite walls deflected at corners around pores, forming crenulate aspect at corners only; walls straight between corners; septal spines; tabulae complete, transverse to corallite axis, predominantly downturned at periphery and crenulate.

Description of material .-- One of the three hypotype coralla (UND Cat. No. 13734) is a flattened hemispherical type 3.5 cm in diam-Corallites on the basal corallum surface are oriented radially eter. and laterally. Those in the remainder of the corallum are arranged in radiating fashion. Another hypotype (UND Cat. No. 13735) is fragmental with corallites oriented parallel to each other. The third (UND Cat. No. 13735) is fragmental and is a portion of what appears to be a flattened hemispherical corallum. Adult corallites in the three hypotypes range in diameter from 1.2 to 3.1 mm with means of approximately 2.1 mm (Appendix B, Table 21). Immature types are as small as 0.6 mm and appear to arise at the junction of three or more corallites by peripheral, extratentacular budding. A portion of wall near a corner of the parent encloses a peripheral portion of the corallite, which develops with subsequent diameter increase and increase of polygonal wall faces into an adult. Mature corallites are subpolygonal in transverse outline, due to the presence of conspicuously rounded corallite walls and corners. The curved wall appears to curve around multiple faces of the subpolygonal corallite or migrate between two or more corallites, forming a

multicorallite wall. Corallite corners enclosed by this wall type are conspicuously curved in transverse section.

Subcircular to circular mural pores are only in the corners, mounted on a poral process and are spaced from 0.3 to 0.88 mm apart. They are closely spaced in regions of closely spaced tabulae and vice versa. Corallite wall crenulations are present only in the corners and are strong, averaging 0.1 times the mean corallite diameter. Crenulation length is variable and controlled by tabular spacing (Figure 26).

Wall thickness is apparently related to tabular spacing (Figure 26). It increases in corallite regions where tabulae are closely spaced. The axial plate is uniformly thin, and continuous throughout the observed wall, flanked on both sides by fibrous sclerenchyme with fibers oriented upward and away from the axial plate. Fiber orientation varies from 60 to 100 degrees from the plane of the wall and is related to tabular spacing. The amount of angular deviation from the plate increases as tabular spacing increases (Figure 26), indicating that as corallite walls become thin in regions of widely spaced tabulae, fiber orientation within the walls approaches or exceeds perpendicularity to the axial plate as increasingly short wall fibers were secreted.

Septa are not present, nor are spines arranged in any systematic pattern around the lumen periphery. Spines within the corallum interior appear to be extensions of sclerenchymal wall fibers, projecting into the corallite interior. Longitudinal sections of sediment-filled calices show spinose projections into the lumen.

Tabulae are all complete and transverse to the corallite axis, with planar central portions and deflected or crenulate peripheral margins. Tabular are grouped into zones of closely and widely spaced types with no sharp boundary between zones. Mean spacing in the former zones is 0.4 mm whereas that in the latter is 1.0 mm.

Types.--Hypotypes, UND Cat. Nos. 13734-13736.

Occurrence.--One hypotype (UND Cat. No. 13734) was collected 13 feet below the top of the Gunn Member of the Stony Mountain Formation. The second (UND Cat. No. 13735) came from near the top of the member, and the third (UND Cat. No. 13736) came from 0.2 to 1.4 meters (0.8 to 4.6 ft) above the base of the Penitentiary Member of the Stonewall Formation. All three hypotypes came from the quarry at the Municipality of Winnipeg Aggregate Plant near the town of Stony Mountain, Manitoba, collecting localities A969 and A574.

A well preserved, allbeit dolomitized, fragmental specimen (UND Cat. No. 13738) came from a quarry exposure of the Stonewall Formation on the eastern edge of Stonewall, Manitoba. Stearn (1956, p. 60) listed occurrences of the species from the Ordovician Stony Mountain and Stonewall Formations and from the Silurian Inwood and East Arm Formations of the Interlake Group in southern Manitoba. Nelson (1963, p. 52) described samples of the species from Members No. 1 and 2 of the Ordovician Chasm Creek Formation in the Churchill River region of the northern Hudson Bay lowland, northern Manitoba.

<u>Discussion</u>.--Okulitch (1943, p. 61) reported only two species of <u>Paleofavosites</u> from the Gunn Member, <u>P. prolificus</u> and <u>P. capax</u>; however, four species may be present in the member. The Gunn Member

hypotype (UND Cat. No. 13734) was compared to previously described species of Paleofavosites.

The hypotypes are assigned to P. prolificus. Stearn (1956, p. 60) gave the latest extensive description of the species in which he commented on the difficulty of using corallite diameter as a diagnostic character for the species. In his original description of the species, Billings (1865, p. 429) noted that the corallum formed large hemispheral or " . . . irregularly convex masses. Tubes about one line [approximately 2 mm] in diameter." Whiteaves (1895, p. 113) noted that the corallum he assigned to P. prolificus had polygonal corallites, 2 mm diameter, with sharp septal spines. Lambe's illustration (1899, plate 1, figure 2) shows a polygonal corallite with pores confined to the corallite corners, the spines, and planar tabulae normal to the corallite axis. Twenhofel (1914, p. 24) in describing the genus Paleofavosites stated that P. prolificus and P. capax are identical. Billings (1866, fide Stearn, 1956, p. 60) however, described P. capax as having corallites 4 mm in diameter. Stearn (1956) noted the confusion which exists over the relationship of P. prolificus to In order to establish a frame of reference he (p. 60) P. capax. designated as P. prolificus, coralla with pores only in the corners and corallite diameters near 2.3 mm, and termed P. capax (p. 61) those with pores only in corners and diameters near 3.8 mm. Moreover, Stearn said that the mural pores of P. prolificus have prominent poral processes which gives the wall a crenulate aspect in the corner, rudimentary, short septal spines and plane tabulae with deflected peripheral margins.

One hypotype of <u>P</u>. <u>prolificus</u> (UND Cat. No. 13734) resembles the Wyoming hypotype of <u>P</u>. <u>kuellmeri</u> (UND Cat. No. 13729). <u>P</u>. <u>kuellmeri</u> includes curved corallite walls, closely spaced and strongly developed wall crenulations restricted along with mural pores to the corallite corners, no septa, and crenulate tabulae (Flower, 1961). The hypotype of <u>P</u>. <u>kuellmeri</u> from Wyoming has slightly smaller corallites, stronger crenulations, no spines, and more closely spaced tabulae than the hypotype of <u>P</u>. <u>prolificus</u>. Both species have the curved, continuous multicorallite wall and rounded corners, both, plus the holotype of <u>P</u>. <u>kuellmeri</u>, have most features but spines in common, although dimensions vary. Only the spinal projections on the calicinal walls of the hypotype of <u>P</u>. <u>prolificus</u> prevents its inclusion in P. kuellmeri.

The foregoing discussion suggests that while the two species may not be conspecific, there is a very strong resemblance between them and they appear to be very closely related. Before any conclusions to this question can be drawn, a thorough restudy, based on thin sections and biometrical analysis must be made on the holotypes of <u>Paleofavosites prolificus</u> (Billings) and <u>Paleofavosites capax</u> (Billings), in order to determine the relationship between the two species. Only after a rigorous, numerically based diagnosis is constructed for <u>P</u>. <u>prolificus</u> and <u>P</u>. <u>capax</u> can the relationships between the examples from the Stony Mountain and Montoya group be precisely established.

Paleofavosites sp. A cf. P. prolificus

Description of material. -- The hypotype fragments contain nearly parallel, small corallites averaging 1.7 mm diameter which

are polygonal or subpolygonal in cross section, with mural pores in the corallite corners. No septa are visible. Tabulae are complete, plane with crenulate margins and oriented normal to the corallite axes. Mean observed tabular spacing is about 0.5 mm. No zonation of closely or widely spaced tabulae was observed.

Type.--Hypotype, UND Cat. No. 13739.

Occurrence. -- The hypotype was collected from 1.4 to 1.7 meters (4.7 to 5.5 ft) above the base of the Stonewall Formation at the Williams Quarry north of Stonewall, Manitoba (Appendix A, locality A554).

<u>Discussion</u>.--Only poorly preserved, dolomitized fragments were collected. Apparently extensive fragmentation occurred before burial. The small corallite diameter (Appendix B, Table 21) plus the single row of mural pores in the corners, no septa, and the plane, crenulate tabulae indicate that the hypotype is comparable to <u>Paleofavosites</u> prolificus which also is characterized by the same features.

Paleofavosites sp. B cf. P. prolificus

Description of material.--The very small hypotype coralla (UND Cat. Nos. 13740, 13746-13748) are all hemispherical and evidently represent an immature growth stage. Corallum length varies from 13 to 21 mm, width from 10 to 13 mm, and height from 9 to 11 mm. Corallites are subrounded to rounded in transverse section with very conspicuously curved walls, similar to the multicorallite wall observed in <u>Paleofavosites kuellmeri</u>, in which a wall can be traced between numbers of corallites or around much of a corallite perimiter. Mural pores are only in the corallite corners, circular or elliptical in outline, rimmed by a poral process, and located within the concave flexures of wall crenulations restricted to the corallite corners. Crenulation length ranges from 0.64 to 0.8 mm and the crenulation amplitude averages 0.11 times the mean corallite diameter (Appendix B, Table 21). Corallite walls are uniformly thin with a mean 0.15 mm and composed of a uniformly thin, continuous axial plate flanked on both sides by fibrous sclerenchyme, to form a rugosan wall (Hill, 1959). There are no septa or spines. Tabulae are predominantly complete and normal to the corallite axis. Rare incomplete tabulae occur in zones where they are closely spaced. Widely spaced types occur close to the corallum point of origin and may represent growth during the immature stage of the colony. Tabular margins are not crenulate.

Types.--Hypotypes, UND Cat. Nos. 13740, 13746-13748.

Occurrence. -- The small, possibly immature, hypotype coralla are from the Gunn Member of the Stony Mountain Formation at a quarry north of the town of Stony Mountain, Manitoba (Appendix A, locality A584).

Discussion.--Okulitch (1943, pl. 1, fig. 17) illustrated a small favositid corallum approximately 16 mm in diameter which he attributed to be a young form of <u>Paleofavosites capax</u> (Billings). This was collected from the Gunn Member of the Stony Mountain Formation in southern Manitoba and appears to be very similar in general form to the hypotypes under discussion. No biometrical data or description was given by Okulitch to substantiate his assignment. Biometrical description based on thin section material indicates that the hypotypes are more closely comparable to P. prolificus (Appendix B, Table 21) than to other species. Mean

corallite diameters correspond closely to those of <u>P</u>. prolificus. These diameters were most frequently measured on corallites after expansion to adult diameter had apparently occurred. Insufficient biometrical data is available on previously published hypotypes of <u>P</u>. prolificus to permit close comparison to the Gunn Member hypotypes under consideration but comparison with the hypotypes of <u>Paleofavosites</u> assigned to <u>P</u>. <u>prolificus</u> in this study show that many internal similarities occur. Length and amplitude of wall crenulation, wall thickness, and tabular spacing are generally similar (Appendix B, Table 21).

Only tabular form is noticeably different from that of the hypotypes assigned to the species. No peripheral tabular crenulation occurs on the plane tabulae whereas it is common in the hypotypes of P. prolificus.

The relative abundance of these small, favositid coralla of uniform size suggest that more than one line of approach should be used in considering the maturity of these. If these are all immature, then many young colonies assignable to this group were killed before reaching maturity, a phenomenon that occurred repeatedly during the time of deposition of the Gunn Member. The fact that no other small favositid colonies comparable or assignable to species of Paleofavosites appeared to have been involved in the repeated kill-off suggests that either these small colonies were exceptionally vulnerable to some unfavorable environmental factors or that they may have been genetically controlled, small, short-lived forms. The recurrence of these small forms in the same unit with other apparently mature benthonic invertebrates suggests the former. The apparent predominance of small solitary corals in the Gunn Member

tends to bear this out. It was suggested previously in this study that the colonial corals were less tolerant than the solitary types to environmental conditions prevailing during sedimentation of argillaceous clastics.

The small hypotype coralla represent the second group of <u>Paleo-favosites</u> sp. to be compared to <u>P. prolificus</u>, and are designed <u>Paleo-favosites</u> sp. B cf. <u>P. prolificus</u> to distinguish them from the first group. The possibility that these forms are immature, the presence of non-crenulate tabulae, and the possibility that other taxa may have been involved prevent confident assignment to <u>Paleofavosites prolificus</u> (Billings).

Paleofavosites okulitchi Stearn, 1956

Plate 10, Figures 2, 3, 5, 7, 8

[non]Favosites intermedius Stewart, 1938, Geol. Soc. America, Spec.

Paper 8, p. 62, pl. 13, figs. 4, 5.

- Favosites intermedius Okulitch, 1943, Trans. Roy. Soc. Canada, v. 37, sec. 4, p. 70, pl. 1, fig. 16.
- Paleofavosites okulitchi Stearn, 1956, Geol. Survey Canada, Mem. 281, p. 61, pl. 3, figs. 4, 6, pl. 8, fig. 3; Hill, 1959, New Mexico Bureau Mines and Min. Resources, Bull. 64, p. 13; Flower, 1961, New Mexico Bureau Mines and Min. Resources, Mem. 7, p. 72; Nelson, 1963, Geol. Soc. America, Mem. 90, p. 53, pl. 7, fig. 6.

Diagnosis. — Coralla varying from small hemispherical shape with radiating corallites to large tabular shape with parallel basal and growth surfaces and parallel corallites oriented normal to surfaces;

corallites ranging from 0.98 to 4 mm diameter, polygonal and subpolygonal transverse outline with straight or slightly curved corallite walls and angular or rounded corallite corners; mural pores closely spaced at corallite corners and widely spaced in single or double rows within corallite walls; walls crenulate in immediate region of corallite corners, no poral processes, pore spacing and crenulation length varying with tabular spacing; mean maximum crenulation 0.1 times the mean corallite diameter; axial plates uniformly thin and continuous, with fibrous sclerenchymal layers flanking the plate tending to thicken in regions of closely spaced tabulae and vice versa; septa consisting of longitudinal wall thickenings present in zones of maximum wall thickness, 13 to 23 septa per corallite with maximum axial extension of 0.14 times the mean corallite radius; all tabulae complete and normal to corallite axis, with strongly crenulate peripheral margins, segregated into sharply defined zones of closely and widely spaced types.

Description of material.--The hypotype from the Gunn Member (UND Cat. No. 13741) is fragmental, apparently a laminar type with parallel corallites. The other two hypotypes (UND Cat. Nos. 13742, 13743) have radiating corallites. Corallites in the three hypotypes are subpolygonal or polygonal in transverse outline with straight and slightly curved walls. The hypotype from the Stonewall Formation (UND Cat. No. 13743) is a fragmental, dolomitized remnant of an encrusting, hemispherical corallum estimated to have been approximately 3 cm diameter and more than 1 cm in height. It encrusts what appears to have been a trilobite genal spine with corallites radiating from the adhesion surface. Corallite contours are angular

or rounded depending on the position of the curved corallite wall. The curved wall is of the multicorallite type, seen in some other species of <u>Paleofavosites</u> encountered in this study, in which short straight walls interconnect the curved walls at angular corners. Corallite diameters in the three hypotypes range from 1 to 4 mm and mean diameters range from approximately 2.4 to 2.6 mm (Appendix B, Table 22).

Budded corallites arise at the junction of three or more adult corallites as subcircular tubules which change to a rectangular, then subpolygonal outline with increasing maturity. Mural pores are located in both the corallite corners and walls. Pore diameters range from 0.08 to 0.28 mm and longitudinal pore spacing in the corners ranges from 0.3 to 1.1 mm for the three hypotypes. Spacing varies with crenulation length and tabular spacing. Wall crenulation occurs only in the corallite corners with a length varying from 0.5 to 1.4 mm for two hypotypes (UND Cat. Nos. 13741, 13742). Length varies directly with tabular spacing in UND Cat. No. 13741 (Figure 27). Maximum crenulation amplitude, based on three counts in the same hypotype averages about 0.1 times the mean corallite diameter. Spacing of pores in the wall is indeterminable, but it appears to be greater than that of the pores in the corners. Pores in the wall are arranged in single or double rows, with those in single rows at the center of the wall, midway between adjacent corallite corners. Pores in double rows are arranged in an alternate pattern.

Corallite walls possess a well-defined, uniformly thin, axial plate positioned between a pair of fibrous sclerenchymal layers in which the fibers are oriented upward and away from the plate. Fiber orientation in one hypotype (UND Cat. No. 13741) varies with tabular

spacing (Figure 27), the fibers tending to approach perpendicularity to the wall as tabular spacing increases and vice versa.

Wall thickness, as exemplified by the same hypotype, is directly related to tabular spacing, being at a maximum in regions of closely spaced tabulae and at a minimum where tabulae are widely separated (Figure 27). Septa are well developed in regions where tabulae are closely spaced; thirteen to 23 occur in each corallite of UND Cat. No. 13741 with a mean length 0.14 times the mean corallite radius. Exposed lumen interiors of that hypotype reveal that septa are localized thickenings of the sclerenchymal layer (Figure 28). Corallite regions of widely spaced tabulae show very little or no septal extensions or spinose wall extensions, resulting in septal occurrences restricted to portions of the hypotype where walls are thick and tabulae are close. Tabulae are all complete, normal to the corallite axes, with a strongly crenulate margin. Zones of closely and widely spaced tabulae are sharply defined with little or no transition between the two. Closely packed tabulae are frequently covered with a thick deposit of stereozone, possibly fibrous on their upper surfaces.

Types.--Hypotypes, UND Cat. No. 13741-13743.

Occurrence.--Okulitch (1943) reported the holotype (GSC, no number stated) from the Gunton Member of the Stony Mountain Formation at a quarry 0.5 mile (0.8 km) south of Gunton Station, Manitoba. Stearn described two hypotypes (GSC Nos. 10404, 12685) from the Stonewall Formation near Flin Flon, Manitoba. Nelson (1963, p. 53) found and described one hypotype (GSC No. 10351) and five specimens from members 1, 2, and 3 of the Chasm Creek Formation of the Churchill River Group in the Hudson Bay lowlands on the Churchill River.

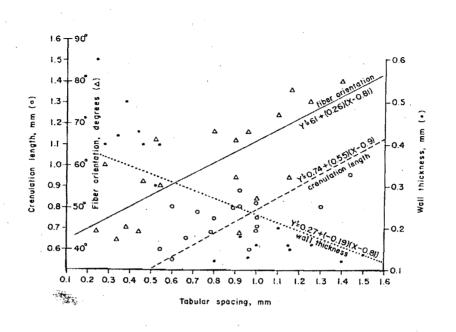


Fig. 27.--Scatter diagram and regression lines for crenulation length, wall fiber orientation, and wall thickness plotted against tabular spacing for <u>Paleofavosites okulitchi</u> (UND Cat. No. 13741).

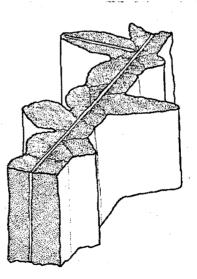


Fig. 28.--Portion of corallite wall of <u>Paleofavosites</u> <u>okulitchi</u>. Fibrous structure of wall and septa shown by patterned stippling, approx. X45. Hypotype UND Cat. No. 13741 came from 4 meters (13 ft) below the top of the Gunn Member at the quarries of the Municipality of Winnipeg Aggregate Plant, north of Stony Mountain, Manitoba (Appendix A, locality A969).

Hypotype UND Cat. No. 13742 was a float specimen from the Hunt Mountain beds in the upper portion of the Bighorn Formation (locality A542) on the western flank of the Bighorn Mountains in Sheridan County, Wyoming.

Hypotype UND Cat. No. 13743 was collected from the Stonewall Formation (locality A553), a quarry exposure of the unit on the eastern edge of Stonewall, Manitoba.

<u>Discussion</u>.-As Stearn (1956, p. 62) stated: "The change in the generic name of this species results from the redefinition of <u>Paleofavosites</u> and the change in the specific name from the homonymy of <u>F. intermedius</u> Okulitch with <u>F. intermedius</u> Stewart [a Devonian favositid]." Evidently Okulitch (1943) was not aware of Stewart's (1938) usage of the name.

The hypotype from the Gunn Member (UND Cat. No. 13741) is assigned to <u>P. okulitchi</u> Stearn because of similarities between it, the holotype, and previously described hypotypes. Okulitch (1943, p. 70), in describing the holotype, mentioned the presence of mural pores in the corallite corners and a single row in the middle of the corallite wall. In addition, he commented on the presence of longitudinal rows of blunt tubercules or spines in the corallite interiors. His tabular comparisons are similar to those of the Gunn hypotype, but they did not include evidence of tabular crenulation.

Stearn's (1956, p. 61) description of the hypotypes from the Flin Flon area (GSC Nos. 10404, 12685) mentioned, in addition to features noted by Okulitch, the lack of a raised rim around the pores at the corallite corners and downward deflection of the peripheral margins of the tabulae. The Gunn hypotype possesses no raised poral process as do hypotypes of <u>Paleofavosites prolificus</u> and <u>P. kuell-</u> <u>meri</u>. The Gunn hypotype possesses several features not mentioned in the holotype and subsequent hypotypes. These features appear to be related to varying rates of upward growth, but could be interpreted as species diagnostic features.

The development of septa or longitudinal ridges of dilated fibrous sclerenchyme occurs only in corallite regions where tabulae are closely spaced and walls are of maximum thickness. Exposed corallite interiors within the Gunn hypotype have longitudinal ridges occurring in zones of closely spaced tabulae near the corallum growth surface. In zones of widely spaced tabulae the reverse occurs. Walls are thin, no hint of septa or longitudinal sclerenchymal ridges are observed, and only a uniformly thin fibrous wall with few observable spinose projections occurs. Viewed with cross polarized transmitted light, transverse sections of the thickened corallite wall show that longitudinal "septal" ridges and associated sclerenchymal portions of the corallite wall are composed of what appears to be separate sclerenchymal fiber bundles or sets bordering on adjacent ones (trabeculae). Figure 28 illustrates the structural elements of the thickened wall and its associated septal ridges. With increasing axial extension, septa tend to become more structurally defined as entities distinct from the wall sclerenchyme.

The shortest ones consist of an axial bulge of radiating fibers, whereas the longest show hints of an axial plane where fiber sets abut against each other or there is an axial plate with a clear platelike core flanked by the septal fiber sets. Thus trabecular units appear to be related by parallel occurrences with closely spaced tabula, indicating control of septal occurrences by rates of upward growth. Minimum upward growth results in the formation of thick walls, steeply inclined fiber sets (Figure 27), trabecular differentiation of fibers; and septa. These may have been a response to a decrease in upward growth rates by an accommodation of wall material within decreased available vertical space.

Two processes may have operated: (1) thickened walls, oblique fibers, septa, and closely packed tabulae were a response to a decreasing rate of upward growth; since (2) decreased upward growth may have caused an increased lateral distribution of skeletal material with secretory centers more broadly distributed over the basal plate of each polyp. The cyclic occurrence of closely and widely spaced tabular zones shows that environmental factors may have controlled the distribution of secretory centers in the polyp basal plate and caused subsequent thickening of walls and septa.

An interesting taxonomic question can be posed regarding the thick and thin walled polymorphic stages of the Gunn hypotype of <u>P</u>. <u>okulitchi</u>. If fragments were available which contained only one of the two stages, each could possibly be placed in two separate specific or generic taxa. Stearn (1956, p. 67) gave the original description of <u>Angopora manitobensis</u>, a cerioid favosited with polygonal corallites, abundant pores in corallite corners, rare

pores in the walls, thick walls with septa and thinner walls with no septa, septal laminae projecting 0.2 mm into the corallite, and closely packed, plane tabulae (Appendix B, Table 26). This species is widespread in the Stonewall Formation in southern Manitoba and is known only from fragmental specimens. The apparent similarity between A. manitobensis Stearn and the thick walled, septate stage of P. okulitchi from the Gunn Member, suggests a possible relationship between the two. Angopora manitobensis is essentially a septate version of P. okulitchi and may represent a descendant form of P. okulitchi. Until the holotype of A. manitobensis is described by use of thin sections this relationship may be little more than speculation. This would additionally be complicated by dolomitization of the holotype. The fragmental hypotype corallum (UND Cat. No. 13743) from the Stonewall Formation at Stonewall, Manitoba, is also dolomitized and no thin sections were possible from the material at hand. Unlike the Gunn hypotype, the Stonewall hypotype exhibits no septate stages in the observed fragments.

No data on wall thickness is available nor is there sufficient material for delineating zones of tabular spacing and possible related variations in pore and crenulation spacing in the Stonewall hypotype. This hypotype of <u>P</u>. <u>okulitchi</u> does correspond to the species diagnosis in being a cerioid form, presumably with a rugosan-type wall (Flower, 1961), and pores in both corallite corners and walls, with greater abundance in the corners. Stearn (1956, p. 61) recorded two rows of mural pores in the hypotype of <u>P</u>. <u>okulitchi</u> (GSC Nos. 10404, 12865) from the Stonewall Formation. The Stonewall hypotype under discussion (UND Cat. No. 13743) corresponds to Stearn's (1956) description, illustrating that with the passage of time from the Gunn to the Stonewall the proportion of pores increased in corallite walls. This is consistent with the general evolutionary trend within <u>Paleofavosites</u> in which the approach to <u>Favosites</u> is made through the shift of the predominant number of pores from the corallite corners to the walls.

The variation of corallum types between the Gunn and Stonewall hypotypes demonstrates that P. okulitchi probably had the genetic capability to alter its corallum form in response to differing environmental conditions. The fragmental Gunn hypotype shows that the corallum was large and probably tabular. The predominant amount of corallum increase occurred at the basal portion of the corallum where most corallite budding occurred early in the developmental stages of the colony. The corallum had probably expanded to its maximum lateral size before appreciable upward growth occurred. This is shown by the corallites being continuous throughout the entire height of the corallum and the parallel, vertical orientation of all corallites. Corallum shape, corallite continuity and orientation, and probable method of lateral and vertical growth indicate that the substrate upon which the Gunn Member corallum grew may have been relatively firm. The Stonewall hypotype of P. okulitchi is much smaller than the Gunn hypotype (Appendix B, Table 22), and the method of corallum increase is different. The hemispherical corallum form, radiating pattern of corallite orientation, and the encrusting habit on a skeletal fragment hint at less favorable environmental conditions in Stonewall time. The larval stage encountered a favorable solid substrate on a skeletal fragment. After metamorphosis to the polyp form, upward growth equalled or exceeded lateral expansion, indicated by the hemispherical form and radiating corallites. Expansion

could not occur out over the substrate as with the Gunn hypotype. Instead, expansion occurred continuously during the life history of the corallum by budding of offsets among previously formed adult polyps. This insured the survival of the young individuals even though the adults on the basal periphery might have been killed by the soft carbonate substrate. The small corallum size implies that the colony lived a relatively short life, much shorter than that of the Gunn hypotype. Thus the species appears to have had the genetic capability to alter its colony shape in response to environmental conditions prevailing at the time a given colony of <u>P. okulitchi</u> existed.

Paleofavosites sp. cf. P. okulitchi

Description of material. --- A very small (4.5 by 3 cm) cerioid corallum (UND Cat. No. 13744) contains corallites radiating from the basal corallum surface. Corallites range in diameter from 0.8 mm for immature forms up to 2.6 mm for adults with mean diameter of 1.5 mm. Corallites are subpolygonal to subrounded with corallite walls rounded and crenulate in transverse section. Corallite corners are consistently angulate with little or no wall curvature at the wall intersection. Transverse crenulation is seen as an undulatory folding of the axial plane between corallite corners, each convexity being topped by a spine. The corallite wall exhibits a longitudinal crenulation along and restricted to the corallite corner. Its length varies from 0.8 to 0.88 mm (n=3). Mural pores are both in corallite corners and walls. Mean diameters are 0.13 and 0.18 mm respectively. The corallite wall has a well-defined, uniformly thin, continuous axial plate flanked on

both sides by fibrous sclerenchyme in which fibers are inclined upward and away from the plate. Wall thickness varies from 0.12 to 0.3 mm and appears to be related to tabular spacing. Walls contain spinose project tions of fibrous sclerenchyme, with a mean maximum axial extension of 0.4 times the mean corallite radius (Appendix B, Table 23), and a mean longitudinal spacing of 0.22 mm. Spines are arranged in poorly defined longitudinal and transverse rows (Figure 29). No uniform distribution of spinese around the corallite interior occurs but 13 to 20 longitudinal spine rows were observed.

Complete tabulae are predominant, oriented normal to the corallite axes, and are grouped into poorly defined zones paralleling the corallum surface in which tabulae are closely or widely spaced. Those in the zone of closely spaced types are predominantly plane or gently curved whereas those in the zone of widely spaced types are more variable in curvature, ranging from planar to deeply concave. Corallite walls commonly contain small, circular tabules centered at the axial plate, approximately 0.2 mm in diameter, paralleling the corallite axes, and filled with sparry calcite. No internal structures are present and tubule interiors are lined with axial plate material which bifurcates transversely to line the tube then merges again on the other side of the tube.

Type.--Hypotype, UND Cat. No. 13744.

<u>Occurrence</u>.--The hypotype of <u>Paleofavosites</u> sp. cf. <u>P</u>. <u>okulitchi</u> was collected 1.4 to 1.6 meters (4.6-5.2 ft) below the uppermost shale layer in the Hunt Mountain beds in the upper portion of the Bighorn Dolomite, at locality A539 (Appendix A) on the western flank of the Bighorn Range, northern Wyoming.

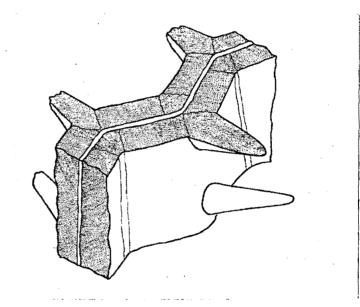


Fig. 29.--Portion of corallite wall of <u>Paleofavosites</u> sp. cf. <u>P. okulitchi</u>. Fibrous structure of walls and septal spines represented by patterned stippling. Clear region represents axial plate, approx. X75. <u>Discussion</u>.--Generic placement of this hypotype from the upper portion of the Bighorn Dolomite is an uncertain process. Flower (1961) recognized two species groups of the genus <u>Foerstephyllum</u> Bassler. The first, the <u>F. halli</u> (Nicholson) group is essentially of Blackriveran age. <u>Foerstephyllum halli</u> has been noted by Bassler (1950, p. 269) from the Trenton Limestone in Canada and from other Blackriveran and Trentonian age strata in North America. The <u>F. halli</u> group apparently ranges from Blackriveran to Trentonian in age and is characterized by; a two-layered, thick <u>Lichenaria</u>-type wall (Flower, 1961, figure 4), no mural pores, septa developed as longitudinal ridges with denticulate axial margins, regularly spaced transverse tabulae, and straight corallite walls.

Flower's second group consists of species centering about \underline{F} . <u>vacuum</u> (Foerste) from the Liberty Formation of the Richmond Group of the Ohio Valley (Browne, 1964, p. 390). This younger, advanced group of species is characterized by: the rugosan wall structure, a transversely curved corallite wall, short septal ridges or rows of descrete spines, mural pores at the corallite angles, and irregularly spaced and variably curved tabulae.

Flower's concept of this genus appears to encompass species with two types of wall structure--the <u>Lichenaria</u>-type and those with a rugosan wall type. Two varying wall types within the same genus is not consistent with the placement and definition of genera according to the Flower Model. If the model based partially on wall microstructure is consistently applied, this would result in the placement of the <u>F. vacuum</u> group in a new genus, restricting the scope of the genus to the <u>F. halli</u> where the Lichenaria-type wall is present.

If the generic diagnosis is based upon the type species F. halli, then Flower's F. vacuum group does not belong in Foerstephyllum on the basis of differing wall structure. Generic reassignment of the F. vacuum group should involve comparison of this group with genera contemporary with its occurrence. The genus Paleofavosites Twenhofel may provide insight to its generic assignment. The hypotype (UND Cat. No. 13744) has prominent septal spines, mural pores, and is a Paleofavosites with extreme development of spines. A hypotype of Paleofavosites okulitchi from the Gunn Member (UND Cat. No. 13741) had the genetic ability to develop or not develop septa. That the occurrence of septa was not a feature inherent only in a stage of development of the colony is shown by the cyclic repetition of the thick walled, septate stages alternating with aseptate, thin walled stages. This indicates a cyclic phenomenon, possibly a physiological response to an environmental factor and not an as to genetic stage.

A case is made herein for the correlation of the Hunt Mountain Rock Creek beds, with the "Stony Mountain shale" of the Williston Basin and the Gunn Member in southern Manitoba. Such equivalence indicates that the northern Wyoming hypotype (UND Cat. No. 13744) is contemporaneous with the hypotype of <u>P. okulitchi</u> in the Gunn Member of Manitoba. The question of the generic placement of the Wyoming hypotype in <u>Paleofavosites</u> or <u>Foerstephyllum</u> revolves around the following questions:

> Can the hypotype be assigned to <u>Foerstephyllum</u> when the <u>F. vacuum</u> group of Flower contains wall microstructures not occurring in the type species?

 Does Foerstephyllum, as defined by the type species, persist until Late Ordovician time when the <u>F</u>. <u>vacuum</u> group occurred?

Flower (1961, p. 70) considered the same questions when he discussed the relation of Paleofavosites sparsus of the Second Value Formation of the Montoya Group with Foerstephyllum vacuum. He suggested that Paleofavosites and the Favositidae may have descended from the genus Fourstephyllum rather than from Saffordophyllum. His argument suggested that Foerstephyllum, ancestral to the Favositidae, developed mural pores, the rugosan wall which characterized the early forms of the family Favositidae, and lost spines. The development of the Favositidae from the primitive Foerstephyllum involved a progression from Lichenariatype corallite walls with transverse crenulation of the septal wall, to the F. halli group, to the nearly aseptate condition of the early species of Paleofavosites. Septal spines and septa appear in later forms of the Favositidae as elements structurally distinct from a corallite wall which had the ability to form trabecular bundles (Figure 33) where walls are greatly thickened. Since the septal structures in the F. halli group and P. okulitchi are structurally different and arise from dissimilar areas within the polyp basal plate, differing genetic controls may have been responsible for the occurrence of septal structures in the two taxa.

Only reexamination of the holotype of <u>F</u>. vacuum would determine its generic assignment, but Flower's (1961) Akpatok Island examples <u>F</u>. porosum and <u>F</u>. minutum may more properly be assigned to <u>Paleofavosites</u> on the basis of abundant mural pores and the rugosan

type of corallite wall typical of the favositids. The extreme development of septa, smaller corallite diameter, and the very thick, crenulate walls prevent confident assignment of the hypotype (UND Cat. No. 13744) to <u>P. okulitchi</u> which is also septate and bears pores in the corallite walls and corners. For this reason, it is compared to <u>P. okulitchi</u> because only one collected corallum the size of a walnut and two thin sections are not, in my opinion, sufficient material for establishment of a new species.

Paleofavosites sp. cf. P. capax (Billings), 1866

Description of material .-- A fragmental hypotype (UND Cat. No. 13749) seems to be an immature colony with corallites radiating from the colony point of origin and expanding in diameter with increasing distance from the origin. Corallites are subpolygonal to polygonal in transverse profile with a mean diameter of 3.34 mm. Mural pores are restricted to the corallite walls, are circular to suboval in outline, with a mean diameter of 0.29 mm (Appendix B, Table 24). Broken corallite sections show epithecal surfaces with transverse growth annuli not seen in thin section or by other means of obser-Wall and corner curvature are unknown. Wall thickness is vation. not observable, and septal spines were not preserved in visible corallite interiors. Tabulae are complete, oriented normal to the corallite axes, and plane with crenulate margins having a mean spacing of 0.44 mm.

Type.--Hypotype, UND Cat. No. 13749.

Occurrence.--The hypotype came from a stratigraphic level 5.2 meters (17 ft) above the base of the Stonewall Formation in a quarry north of Stonewall, Manitoba (Appendix A, locality A555).

Discussion.---Because of the large diameter of the corallites near their distal margins, the restriction of mural pores to the corallite corners, the apparent absence of septa, and plane crenulate tabulae, this hypotype is compared to <u>Paleofavosites capax</u> (Billings). Insufficient material is available for definite assignment to the species, but the marked increase with age of the diameter of the corallites implies a form comparable to <u>P. capax</u>. Stearn (1956, p. 60) separated <u>P. capax</u> from <u>P. prolificus</u> almost solely on the basis of corallite diameter; the latter species is characterized by the smaller corallites. Whether or not this represents a valid basis for separating two species must depend on redescription of the holotypes of the two using thin sections and biometrical procedures to delineate species-diagnostic characters.

Paleofavosites sp. A

Plate 10, Figure 4

Description of material.--A silicified, fragmental hypotype comes from a corallum of indeterminable shape. Corallites range in diameter from 2.2 to 3.6 mm, increasing in diameter away from the point of origin of the colony. Corallites are polygonal or subpolygonal within the cerioid fragment and are arranged in radiating orientation. Mural pores are restricted to the corallite corners with a mean spacing of 0.55 mm (Appendix B, Table 25). Tabulae are complete, plane with crenulate margins, and are oriented normal to the corallite axes. Mean tabular spacing is 0.31 mm (Appendix B, Table 25).

Type.--Hypotype, UND Cat. No. 13750.

Occurrence. -- The hypotype occurred 1.3 to 2.3 meters (4.2 to 7.4 ft) below the top of the type section of the Fort Garry Member

east-northeast of the town of Stony Mountain, Manitoba (Appendix A, locality A853).

Discussion .-- Species assignment of such a poorly preserved corallum is impossible. The hypotype may be a fragment of a colony that did not survive beyond the juvenille or immature stage. If the corallum is not fragmental, then the time of its existence may have been unfavorable for coral development. This may have been the case since extensive searching of the quarry produced only three coral genera. All are fragmental, colonial, and in the Order Tabulata. Lack of preservation may have been a factor, but not the sole factor, in the sparseness of the coral fauna represented by fragmental specimens of Catenipora, Calapoecia, and Paleofavosites. All specimens are small and relatively susceptible to post-death destruction and transport. Thus the primary factors controlling the occurrence of the sparse fossil assemblage from the exposure of the Fort Garry Member type section may have been because the living coral fauna was sparse with small colonies, few taxa, few individual coralla, and post-death transportation from the habitat region. The possibility that the hypotype is an immature colony further prohibits an attempt to assign it to a species. Therefore its biometrics probably are not representative of mature individuals. The very closely spaced, mature, crenulate tabulae (Appendix B, Table 25) in such an apparently immature corallum implies that well-developed, mature tabulae are an indication of tabular neoteny within corallites whose diameters were still expanding, or the rate of upward growth for all corallites was very slow because of unfavorable environmental conditions, resulting in closely spaced tabulae.

Despite insufficient fossil material and resultant data for speciation, the hypotype appears to show affinities to <u>P</u>. <u>prolificus</u> or <u>P</u>. <u>capax</u> in the restriction of pores to the corners, no apparent septa, and the plane, crenulate tabulae normal to the corallite axes. Difficulty of assignment to species is especially unfortunate because this example represents the only documented occurrence of the genus in the Red River Formation.

Paleofavosites sp. B

Description of material.--Only fragments represent the hypotype. Corallites are parallel near the distal corallum surface. Corallite diameters range from 1 to 3.2 mm with a mean of 2.5 mm. Corallites are subpolygonal to subrounded in transverse section with elongation commonly normal to the probable direction of lateral corallum expansion. Corallite walls are conspicuously curved in forming distinctly curved corallite corners in which mural pores are restricted. Pores are circular or oval with a mean diameter of 0.23 mm (Appendix B, Table 25), and a mean longitudinal spacing of about 0.9 mm. No septa were observed. Tabulae are plane, normal to the corallite axes with crenulate margins. No zonation of tabular spacing is present. Tabular spacing ranges from 0.26-0.99 mm with a mean of about 0.5 mm.

Type.--Hypotype, UND Cat. No. 13769.

<u>Occurrence</u>.--The hypotype was collected as fragments from a stratigraphic horizon 1.4 to 1.7 meters (4.5 to 5.5 ft) above the base of the Stonewall Formation at a quarry exposure north of Stonewall, Manitoba (Appendix A, locality A554).

Discussion. ---Poor preservation and an insufficient amount of material prevent species assignment. The fragments are from the distal portion of the corallum where corallites are parallel to each other. Only corallite diameter, mural pore diameter and spacing, and spacing of a very few unbroken tabulae were available for data. Corallite outline and wall curvature are barely discernable due to dolomitization and crushing. Wall thickness, wall microstructure of septa, or tabular spacing were not preserved or are not observable. The presence of corallites with 2.5 mm mean diameter, parallel orientation of corallites in mature portions of the corallum, mural pores only in corallite corners, no apparent septa, and plane, crenulate tabulae imply similarity to more than one species. The hypotype is remotely comparable to either Paleofavosites prolificus or P. kuellmeri.

Genus Angopora Jones, 1936

<u>Type species</u> (by original designation).--<u>Angopora hisingeri</u> Jones, 1936 Ann. Mag. Nat. Histor, 10th ser., v. 17, no. 97, p. 18.

<u>Diagnosis</u>.--"Tabulate corals resembling <u>Favosites</u>, but with discontinuous lamellar septa which break up into spines along their axial edges" (Jones, 1936, p. 18).

<u>Discussion</u>.--Lang, Smith, and Thomas (1940, p. 17) stated that the type species of <u>Angopora</u> is <u>Agarica</u> <u>swinderniana</u> Goldfuss, and that <u>A. hisingeri</u> is a junior synonym. However Jones' figures (1936, plate 2, figures 4, 6), when compared to illustrations of <u>A</u>. <u>swinderniana</u> shown by Hill and Stumm (1956, Figure 351, 1a) show completely different characters. Jones' diagnosis and his figures show that the septa in <u>A</u>. hisingeri are discontinuous and are not

in lateral contact. <u>Thecia</u>, however, is characterized by wide septa in lateral contact. <u>Angopora</u> is not <u>Thecia</u> and it belongs in the family Favositidae.

Rates of upward growth are reflected in two morphological features in Angopora. The first is tabular spacing where zones of closely and widely spaced types are present. The second is the development of septal structures. In the holotype of A. wyomingensis n. sp. (UND Cat. No. 13754) septal structures vary from separate septal spines associated with widely spaced tabulae to lamellar septa composed of longitudinally apressed spines associated with closely spaced tabulae. Widely spaced tabulae, separate spines, and closely spaced tabulae with lamellar septa show that the formation of these associated septal and tabular structures occurred at regular intervals of time in discrete zones. In this, increasingly slow rates of upward growth resulted in the progressively closer spacing of these structures. Thus, based upon the growth function of the colony, the "discontinuous lamellar septa which break up into spines" (Jones, 1936, p. 18) should be considered as discrete septal spines which merge longitudinally to form lamellar septa.

All examples of <u>Angopora</u> encountered in this study appear to be closely related to <u>Paleofavosites</u>. If a separate Angopora lineage existed, it may have lasted from Gunn through Stonewall time since representatives of the genus occur in these and equivalent units. The similarity of these representatives to <u>Paleofavosites</u> raises the possibility that <u>Angopora</u> may be either an ecovariant of or a descendant from the <u>Paleofayosites</u> genetic lineage. <u>Angopora</u> was a result of

variably developed septal structures in which development was controlled by growth rates. Slow upward growth of a spinose Paleofavosites stock could conceivably have resulted in the formation of lamellar septa by the close longitudinal stacking of spines, forming Angopora-like septa.

The relationship to Paleofavosites is reflected in mural pore location, wall crenulation, rugosan wall microstructure, and complete tabulae normal to the corallite axes. This relationship is strengthened by the sporadic, slight development of marginal tabular crenulation. The genetic scope of Angopora contains that apparent tabular quality characteristic of some Ordovician species of Paleofavosites albeit less strongly developed in Angopora. Stearn (1956) envisioned Paleofayosites poulseni Teichert as having descended from A. manitobensis during Stonewall time since Stearn (p. 63) found forms which appear to be transitional between the two in the Stonewall Formation. Paleofavosites poulseni is distinguished from A. manitobensis by the breaking up of the septal laminae of the latter species into longitudinal rows of discrete spines in the former. Stearn's concept implies that Paleofavosites is polyphyletic and that it gave rise to Angopora which in turn gave rise to a representative genus. Either P. poulseni should be assigned to Angopora or it should be considered to have arisen from the main Paleofavosites stock, its arisal from Angopora is contrary to the concept of a single lineage for a genus (Figure 30). Angopora may actually turn out to be a subgeneric stock of Paleofavosites but such a question needs more study than the scope of this project allows. Hence Angopora is here treated as a genus descendant from Paleofavosites.

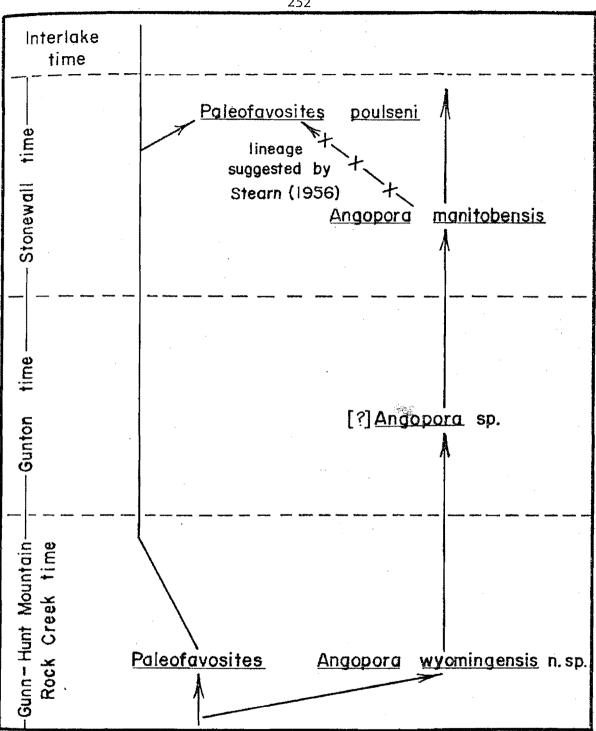


Fig. 30.--Suggested lineage of Angopora showing probable relationship to Paleofavosites. Adapted in part from Stearn (1956).

Angopora manitobensis Stearn, 1956

Plate 11, Figure 1

Angopora manitobensis Stearn, 1956, Geol. Survey Canada, Mem. 281, p.

67, plate 4, figures 4, 5, 8; plate 5, figure 5.

Diagnosis.--Corallum shape variable from hemispherical to irregularly tabular; small subpolygonal corallites with slightly rounded and crenulate walls, and rounded corners; corallite orientation varying from radiating to parallel; mural pores only in corallite corners, none observed in walls, oval outline where tabulae widely spaced, circular where closely spaced; walls crenulate in corallite corners, greatest amplitude and minimum length where tabulae closely spaced; septal development variable from absent to malellar, mostly highly developed in regions of close tabulae, extending up to 0.4 times the corallite radius into the lumen; tabulae complete, normal to corallite axis, predominantly plane with rare, slightly crenulate, tabular margins; tabulae zoned into closely and widely spaced forms.

Description of material.--Three hypotype corallum fragments show a variation in corallum shape from hemispherical to irregularly tabular. In the first (UND Cat. No. 13751), corallites radiate outward from the center of colony origin whereas in the latter (UND Cat. No. 13753) they are both subparallel to each other and radiating. Position of orientation in the latter type appear to have been controlled by either influxes of sediment killing off portions of the colony, or irregularity of the sediment surface. Corallites within the three hypotypes range in diameter from 1.0 to 1.95 mm with the range for each having approximately the same maximum and minimum values (Appendix B,

Table 26). Mean diameters for the three hypotypes range from 1.28 to 1.36 mm. Corallites are subpolygonal in outline with slightly curved corallite walls between corallite corners. Corners are angular and rounded. Slight transverse crenulation is superimposed on the curved corallite wall where septal structures are developed. Mural pores occur only in corallite corners. Pore profile varies from circular in regions where tabulae are closely spaced to oval in regions of widely spaced tabulae. Pore spacing is also dependent on tabular spacing, with one transverse row of pores usually occurring within each intertabular space.

Wall crenulation is present only in the immediate region of the mural pores. Crenulation length generally corresponds to pore spacing and pores most commonly occur within each consecutive concave flexure. However, only one hypotype (UND Cat. No. 13753) shows that mean crenulation length is approximately twice the pore spacing mean. The other two hypotypes did not have crenulation sufficiently exposed (Appendix B, Table 26). Amplitude shows a mean maximum of 0.16 times the mean corallite diameter. Crenulate walls commonly show the development of a poral process. Crenulation and poral processes are usually developed only in regions where tabulae are closely spaced.

Septal development ranges from a minimum of none where tabulae are widely spaced, through longitudinal rows of separate spines to longitudinal continuous septal lamellae where tabulae are closely spaced. None of the spines or lamellae merge peripherally with adjacent septal structures. These are mounted on the crests of the transverse crenulate wall flexures. Both the transverse crenulations and septa are maximized where tabulae are closely spaced. Mean maximum

septal extension varies from 0.18 (UND Cat. No. 13752) to about 0.4 (UND Cat. No. 13761) times the mean corallite radius (Appendix B, Table 26). Tabulae are all complete and normal to the corallite axes. Most are planar with no marginal deflection but one hypotype (UND Cat. No. 13751) has a very slight development of marginal crenulation. Other coralla exhibit some slight crenulation in isolated portions of corallites. Zonation of tabulae occurs in the hypotypes but is variable in terms of mean spacing values for closely and widely zoned tabulae between coralla (Appendix B, Table 26).

Types.--Hypotypes, UND Cat. Nos. 13751-13753.

Occurrence. -- The hypotypes came from a quarry exposure of the Stonewall Formation, directly south of Manitoba Highway 67, on the eastern side of Stonewall, Manitoba. Stearn (1956) noted that species is restricted to the Stonewall Formation but is widespread in Manitoba.

Discussion.--The three hypotypes have mean corallite diameters less than that expressed by Stearn (1956) for <u>Angopora manitobensis</u> (Appendix B, Table 26). Transverse wall crenulation was not noted in Stearn's original description but does occur in the studied hypotypes. Mural pore outline, pore spacing, longitudinal wall crenulation length and amplitude, and septal development are all variable, with a relationship to tabular spacing. Corallum regions with widely spaced tabulae are characterized by (1) oval pores with the long axis paralleling the corallite axis, (2) one or two transverse pore rows per intercorallite space, (3) increased crenulation length resulting from increased pore spacing, (4) decreased crenulation amplitude, and (5) ^{septa} absent or represented by spines.

Conversely, closely spaced tabulae result in (1) circular pores, (2) close longitudinal pore spacing, (3) decreased crenulation length, (4) increased crenulation amplitude, and (5) closely spaced septal spines or lamellar septa formed by merging of spines within a longitudinal row. These responses indicate that closely spaced tabulae reflect relatively slow rates of upward growth. Studied hypotypes of <u>Paleofavosites</u> and the holotype of <u>Angopora wyomingensis</u> n. sp. from the Hunt Mountain beds of northern Wyoming also show a relationship between wall thickness and tabular spacing. No such relationship was noted in the three hypotypes of <u>A. wyomingensis</u> since poor preservation did not permit retention of the original structure and wall thickness was distorted by dolomitization.

The hypotypes give the impression that they may be a small diameter corallite version of a form similar to <u>Paleofavosites</u> <u>prolificus</u> (Billings). Like that species it has most if not all pores occurring in the corallite corners, longitudinally crenulate corallite walls, poral processes, and plane, complete tabulae transverse to corallite axes. The prime difference between <u>P</u>. <u>prolificus</u> and the hypotypes of <u>A</u>. <u>manitobensis</u> are the presence of longitudinal septal lamellae and spines with extensions ranging up to 0.4 times the mean corallite radius and the near lack of marginal tabular crenulation in the hypotypes.

These hypotypes are very similar to Stearn's (1956) description of <u>Angopora manitobensis</u> and appear to be small corallite versions of the species in which contrasts in tabular spacing are due to growth. Hence they are assigned to <u>A. manitobensis</u> Stearn although they show a corallum form other than the hemispherical type described

in the holotype and paratypes (Stearn, 1956, p. 67), and corallite diameters less than those of the primary types.

Angopora wyomingensis n. sp.

Plate 11, Figures 2, 3, 6

Diagnosis.--Very small depressed hemispherical corallum with very small, subpolygonal corallites radiating from central portion of corallum, orientation varying from normal to 45 degrees to probable sediment surface; corallite walls moderately thick in relation to corallite diameter, thickest where tabulae closely spaced; mural pores only in corallite corners, walls crenulate in corallite corners; wall microstructures yarying from rugosan to fan-like, trabecular extensions of the axial plate; septa lamellar where tabulae most closely packed and absent where tabulae widely spaced, with spines as intermediate stages; twelve longitudinal rows of septal structures per corallite; tabulae complete and normal to corallite axis, with curvature varying from gently concave to convex, often pierced by or draped over septal spines; well defined zones of very closely and widely spaced tabulae.

Description of material.--The cerioid holotype corallum is very small and fragmental. Length is indeterminate. Width appears to be no more than 20 mm, and height is 9 mm. Corallites are very small and are approximately 1 mm mean diameter with a range of 0.7 to 1.2 mm. Corallites are subpolygonal with straight to gently curved walls, and angular to rounded corallite corners. Mural pores have a 0.13 mm mean diameter, are restricted to the corners, and have a mean longitudinal spacing of 0.32 mm (Appendix B, Table 27). Corallite walls near the mural pores are crenulate with a mean maximum crenulation amplitude of about 0.1 times the mean corallite diameter and a mean length of about 0.6 mm. The wall varies from thick in corallite regions where tabulae are closely spaced, to thin where they are widely spaced (Figure 31). Septal structures vary from continuous septal lamellae formed by the longitudinally merged septal spines, to separate spines. Maximum longitudinal packing of spines occurs in corallite regions where tabulae are most closely spaced. Twelve rows of spines and septa per corallite have a mean maximum axial extension of about 0.7 times the corallite radius whereas extension of the spines varies from 0.4 to about 1.0 times the mean corallite radius. Septal structures in the regions of widely spaced tabulae are separate, widely spaced spines with approximately the same length as septa in the regions of closely spaced tabulae.

Sclerenchymal fibers in the corallite wall are inclined upward and away from a uniformly thin axial plate in regions of widely spaced tabulae. In regions of closely spaced tabulae, the layered aspect of the wall deteriorates to such an extent that the fibrous sclerenchyme appears to be displaced longitudinally and laterally by fibrous, fanlike, trabecular extensions of the axial plate.

Tabulae are predominantly complete and normal to the corallite axes. Those in regions of well developed septal spines are frequently pierced by or draped over the spinose projections. Tabulae are segregated into well defined zones of closely spaced tabulae with a range of 0.08 to 0.26 mm and a mean of 0.15 mm. Widely spaced tabulae vary from 0.25 to 1.0 mm with a mean of 0.45 mm. Tabulae in the former zone vary in curvature from concave, through plane, to gently convex, whereas those in the latter are plane or concave.

Type.--Holotype, UND Cat. No. 13754.

Occurrence. -- The very small holotype fragment came from the uppermost shale bed of the Hunt Mountain beds in the upper portion of the Bighorn Formation (Appendix A, locality A549), western side of the Bighorn Range.

Discussion. -- The holotype resembles a very small corallite version of <u>Paleofavosites</u> with very long septal spines. Two generic assignments were considered. One, <u>Angopora</u> Jones, resembles <u>Favosites</u> in having discontinuous lamellar septa which break up into spines (Jones, 1936, p. 18). The other possibility, assignment to <u>Paleofavosites</u>, rests on the presence of corner mounted mural pores and a rugosan wall. The species is placed in <u>Angopora</u> because of the presence of apparent laterally discontinuous septal lamellae in regions of closely packed tabulae. Recent generic descriptions of <u>Paleofavosites</u> based on internal morphological features (Hill, 1959; Flower, 1961), indicate that septa, when present, are discrete spines. Teichert (1937) and Stearn (1956) both described <u>Paleofavosites</u> poulseni, the closest comparable species in that genus to Angopora, as having septa present as separate spines.

The presence of a three-layered, rugosan-type corallite wall in the holotype resolves Flower's (1961, p. 71) uncertainty on the character of wall and septal microstructures in <u>Angopora</u>. Stearn's (1956) description stated that the holotype and paratypes of <u>A</u>. <u>manitobensis</u> are dolomitized and no microstructural data was available. Nor does Jones (1936) mention wall structure. The rugosan type wall would divorce <u>Angopora</u> from a <u>Saffordophyllum</u> lineage mentioned by Flower (1961, p. 73) in which only a two-layered <u>Lichenaria</u>-

type wall with an axial plane occurs, instead of a structurally distinct axial plate. Therefore, the <u>Angopora</u> lineage, exemplified by the wall microstructure of <u>A</u>. <u>wyomingensis</u>, n. sp. appears to be most closely related to <u>Paleofavosites</u>. In the holotype the occurrence of lamellar septal structures occurs in corallum regions of closely spaced tabulae possibly reflecting regions where minimum rates of upward growth may have occurred. In these regions, lamellar septa may have resulted from the close longitudinal packing of septal spines. Emplacement of each spine in a row directly over the previous spine produced a septal lamella.

Wall structures in the holotype are similar to those in <u>Favosites manitobensis</u> n. sp. (Figure 33) in which the axial plate layer has expanded laterally to displace the fibrous scherenchymal layer within portions of the corallite wall. As is also observed in sections of <u>F. manitobensis</u> under crossed nicols, rotation of the longitudinal wall section of the holotype of <u>Angopora wyomingensis</u> n. sp. shows no distinct break in rotary extinction patterns. A narrow fan of extinction, reflecting a trabeculate wall structure, can be traced from the position of the axial plate to the position of the former sclerenchymal layer. There is no clear-cut textural break between the axial plate and its expanded lateral replacement of the sclerenchyme. Wall portions not showing displacement of the sclerenchymal layer continue to exhibit a sharp boundary between that layer and the axial plate.

The same question is posed for the holotype of <u>A</u>. <u>wyomingensis</u> as is considered for <u>Favosites manitobensis</u>. Does the expanded, fanlike fibrous structure represent a true lateral expansion of axial

plate secretory centers to form trabecular bundles of fibers? The presence of a distinct textural boundary between the normal rugosan axial plate and sclerenchymal layers, and its lack within the trabeculate wall type with apparent crystallographic continuity across the wall edge indicates that it does. This holotype is one of two colonial corals studied which has a rugosan wall exhibiting those trabecular structures. The isolated occurrence of the trabecular walls in the holotype of <u>Angopora wyomingensis</u> n. sp. and in no other corals from the same stratigraphic level and locality imply that it either reflects a variable level of physiology causing the entire wall to be composed of a trabecular axial plate homologue or it may be a genetic character of this species.

This appears to be the lowest stratigraphic occurrence of the genus. Due to its stratigraphic restriction to a Gunn Member correlative, its separation from previously described North American examples of the genus, and its unique morphology, it is designated <u>Angopora</u> <u>wyomingensis</u> n. sp. It is similar to forms of <u>Angopora</u> found in the Gunton Member of the Stony Mountain Formation and the Stonewall Formation in southern Manitoba.

[?] Angopora sp.

Plate 11, Figures 4, 5

Description of material.--Hypotype coralla are preserved as two fragments no more than 3 cm in size. Corallum shape appears to be hemispherical or flattened hemispherical, with corallites in parallel and radiating orientation respectively, reflecting fragments representing the central and peripheral portions of coralla. Corallites are

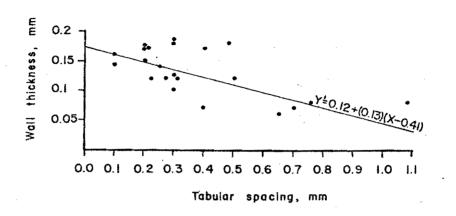


Fig. 31.--Scatter diagram and regression line for wall thickness plotted against tabular spacing for <u>Angopora wyomingensis</u> n. sp.

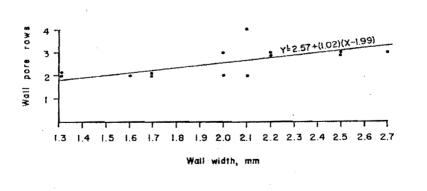


Fig. 32.--Scatter diagram and regression line for number of mural pore rows in the corallite walls plotted against wall width for Favosites manitobensis n. sp.

mature corallites observed ranges from 0.7 to about 1.8 mm. Mean corallite diameters for both hypotypes are approximately 1.2 and 1.3 mm. Mural pores are located in the corallite corners, but pore diameter and longitudinal spacing are indeterminable. Walls average approximately 0.1 mm in thickness and wall structure appears to be of the rugosan type with an apparently continuous, uniformly thin axial plate flanked by fibrous sclerenchyme. Septa in the fragmental hypotypes occur only as elongate septal spines, with estimated angles of spine inclination varying from 90 to 45 degrees to the corallite axis. Maximum septal length varies from 0.12 to 0.4 mm, mean septal extension into the lumen is approximately 0.4 times the mean corallite radius (Appendix Tabulae are complete, with orientation varying from B. Table 28). normal to oblique to the corallite axes. Total spacing of tabulae varies from 0.3 to 1.6 mm, with mean spacing values of about 0.37 and 0.9 nm for hypotypes UND Cat. Nos. 13755 and 13756, respectively (Appendix B, Table 28). Some tabulae are pierced by or are draped over long septal spines.

Types.--Hypotypes, UND Cat. Nos. 13755, 13756.

Occurrence.--One hypotype (UND Cat. No. 13755) was a float specimen from zero to 6.1 meters (0 to 20 ft) above the base of the Gunton Member (Appendix A, locality A557) near Stony Mountain, Manitoba. The other (UND Cat. No. 13756) came from zero to 6.1 meters (0 to 20 ft) below the top of the exposed section of that member at collecting locality A846 (Appendix A).

Discussion. -- Corallum fragment size and very poor preservation prevent confident assignment to <u>Angopora</u>. The hypotypes appear to correspond to types described by Stearn (1956) and assigned to the

genus <u>Angopora</u> Jones characterized by septal lamellae breaking up into septal spines within a cerioid corallum of a form representing <u>Paleo-favosites</u>. The hypotypes appear to have septa developed as spines. A comparison of these examples with <u>Angopora manitobensis</u> Stearn shows that the mean corallite diameters of the hypotypes from the Gunton Member are less than the mean given by Stearn (1956). All have pores in the corallite corners but none were observed in the walls of the Gunton hypotypes. Stearn made no mention of the occurrence of transversely crenulate corallite walls in the holotype and paratypes of <u>A</u>. <u>manitobensis</u> nor did his illustrations give any clear indication of their presence.

The Gunton hypotypes have septal spines and crenulate walls although no lamellar septa such as those in the holotype of <u>A</u>. wyomingensis n. sp., are present.

A progression of increasing corallite diameter within the genus is expressed, from the very small corallites of the holotype of <u>A</u>. <u>wyomingensis</u> n. sp. (d=0.97 mm), to those of the Gunton hypotypes (d=1.2 and 1.3 mm, respectively), to those stated by Stearn (1956; d=1.89 mm) for examples from the Stonewall Formation. All these examples have plane or curved, noncrenulate tabulae, long septa in spinose or lamellar form, and pores in the corallite corners. Thus an evolutionary trend within the genus is manifested mainly by the increase in diameter and the hypotypes in question seem to be midway through the progression of the trend.

Genus Favosites Lamarck, 1816

<u>Type species</u> (by subsequent designation, Milne-Edwards and Haime, 1850).--Favosites gothlandicus Lamarck, 1816, Hist. Nat. des Animaux sans Vertebres, II, p. 205.

Diagnosis.--Mural pores predominantly near middle of walls (Hill and Stumm, 1956, p. F461).

Discussion.--Generic assignment of the Gunn Member holotype of <u>F. manitobensis</u> n. sp. is predicated primarily on the abundance of mural pores in both the corallite corners and walls. The genus <u>Paleofavosites</u> by Twenhofel (1914, p. 24) was erected for tabulate corals assigned to <u>Favosites</u> which had pores at the corallite corners but none in the walls. Those with pores in the walls remained in the genus <u>Favosites</u>. This made no allowance for favositid corals with pores in both the corners and walls. Hill and Stumm (1956, p. F461) emended the diagnoses for both genera to ones which characterize <u>Paleofavosites</u> by predominance of mural pores at the corallite corners and <u>Favosites</u> by pores predominating in the corallite wall. Stearn (1956) followed suit by assigning species with more pores in the walls than in the corners to <u>Favosites</u> and those with more pores in the corners to Paleofayosites.

Favosites manitobensis n. sp.

Plate 11, Figures 7-9; Plate 12, Figures 1, 3, 5 <u>Diagnosis</u>.--Large hemispherical corallum with corallites radiating from center of corallum basal surface; moderately large, polygonal corallites approximately 2.8 mm mean diameter, attaining diameters of 3.8 mm; mural pores in corallite corners and walls, with 2

to 4 pore rows per wall; wall segments often slightly and transversely crenulate, with axial plate commonly expanded into fan-like trabecular structures; walls thin with variable number of septal ridges formed by wall crenulations, commonly capped with spines; tabulae all complete, normal to corallite axis, and crenulate with curvature varying from slightly concave, through plane, to slightly convex; tabular spacing zonation poorly defined.

Description of material .-- The original cerioid corallum of which the holotype is a fragment, was large, estimated to be approximately 28 cm in diameter, with a height of more than 7 cm. The original shape was hemispherical, with a nearly planar basal surface. Corallites radiate laterally and upwardly from the colony point of origin. Corallites are moderately large, ranging in diameter from 1.8 to 3.8 mm with an approximate mean diameter of 2.8 mm. Tn transverse section, they are polygonal in cross section with transversely crenulate walls and angular or rounded corners. Wall portions are not crenulate along corallite corners. Circular mural pores are located in both the corallite corners and walls. Those in the corners average 0.15 mm in diameter, and have a mean longitudinal spacing of about 0.6 mm (Appendix B, Table 29). Pores in the walls have a mean diameter of 0.16 mm and occur in two to four longitudinal rows per corallite wall (Figure 32). The number of rows apparently are controlled by width of the corallite wall. Pore arrangements within the wall rows are biserial or in transverse rows in walls with two rows. Walls with three or four rows have all pores arranged in transverse rows. Corallites on the basal surface of the corallum, close to the point of origin have

no pores on the basal corners and walls. Corallite walls are commonly transversely crenulate, with crenulation varying from absent to slight. This reflects development of a longitudinal wall ridge with a row of spines along the convex portions. Nine to 20 ridges per corallite are present with the highest counts occurring in the largest corallites. Walls vary from 0.16 to 0.3 mm in thickness, but, thickness does not appear to be related to tabular spacing. An axial plate is sporadically developed, varying from a continuous, uniform structure of 0.02 mm minimum thickness to an expanded, finely fibrous trabecula which occupies the entire thickness of the wall. The former developmental stage is flanked by fibrous sclerenchymal layers in the typical rugosan-type wall with the sclerenchymal fibers oriented normal to the axial plate when seen in transverse section, and inclined upward and away from the plate in longitudinal section. The trabeculate stage occurs where the axial plate is expanded into a longitudinal series of fan-shaped fiber sets originating from the position of the axial plate. These fan-shaped sets commonly completely displace the sclerenchymal layers of the rugosan-type wall (Figure 33). Tabulae are all complete and normal to the corallite axis. Most are plane or very slightly concave or convex. All appear to be crenulate at their periphery and are grouped into poorly defined zones of closely and widely spaced types which parallel the corallum growth surface.

Type.--Holotype, UND Cat. No. 13757.

記録のようの意思

Occurrence. -- The holotype is from the contact of the Gunn and Penitentiary Members of the Stony Mountain Formation near Stony Mountain, Manitoba (Appendix A, locality A841).

Discussion. --Mural pores in the wall seem to be twice to four times as abundant as at the corallite corners. <u>Paleofavosites</u> <u>okulitchi</u> has corallites of comparable diameter but lacks the transversely crenulate corallite walls. <u>P. okulitchi</u> has no more than two rows of pores in the walls. The form with which <u>F. manitobensis</u> might be most readily confused is <u>P. okulitchi</u> from which <u>F. manitobensis</u> differs by having the wall pores predominating, transversely crenulate walls with trabeculae, and crenulate tabulae.

The number of pore rows per wall appears to have been controlled by the width of the wall (Figure 32): more pore rows are present in the wide walls than in narrow ones. Spacing values between pore rows averages approximately 0.77 (Appendix B, Table 29). Within the holotype, increasing corallite size led to an increasing number of pore rows, reflecting a greater capacity for interpolypid communication at the calicinal level than <u>P. okulitchi</u> with the same size corallites. The colony's physiological processes required that a mural pore be formed to provide interpolyp communication at intervals around the perimeter of the corallite wall regardless of polyp and corallite diameter. This indicates increasing intercalcinal communication reflecting a higher metabolic rate or stage of evolution.

The trabeculate character of the axial plate or its homologue is a phenomenon not previously recorded in the favositid corals or in any Ordovician corals, other than <u>F. manitobensis</u> n. sp., and <u>Angopora wyomingensis</u> n. sp., both with a modified rugosan-type wall. Little, if any, differentiation can be made under crossed nicols between the thin axial plate and its trabeculate counterpart. Rotation of the longitudinal thin section under crossed nicols shows

simultaneous rotary extinction of the thin axial plate along the corallite wall, through approximately 50 degrees of stage rotation. This indicates that the axial plate is well preserved and is composed of calcite fibers with their c-axes oriented parallel or subparallel to the longitudinal wall direction (Figure 33). The apparent widening of the axial plate into a fan-like trabeculate structure which occupies the entire wall section shows these fibers tradiating out into these structures. Transverse sections of the axial plate under crossed nicols show no extinction as the slide is turned, indicating that the fiber c-axes are oriented in the axis direction of each fiber. This fanlike structure may be due to wall construction by secretory sites normally responsible for axial plate construction.

The axial plate between the fibrous sclerenchymal layers also exhibits the character of rotary extinction indicating the presence of fibrous material. Tracing of the axial plate upward to where it flares out to form the trabeculate structure shows very little contrast between the central portion of the wall and the flanking portions. The faint contrast appears to be due more to the divergence of uniformly textured fibers than to contrasting fiber size.

The presence of original or replicated skeletal material appears to be consistent with the textural similarity within the trabecular structures. This indicates uniform crystal size and suggests that the fine, radiating fibers and the fibrous axial plate were secreted by the same or very similar depositional site(s), replacing those sites of sclerenchymal deposition flanking the site of axial plate construction. If this is the mechanism that functioned, no explanation accounts

for its substitution for the more common rugosan wall. This trabeculate wall structure does not typify those Ordovician or later compound corallite walls. Swann's (1947) study of Devonian favositid wall structures revealed a rugosan type of wall. This showed that the trabeculate wall structure either did not survive until Devonian time or that it may be an aberrant form reflective of a pathological condition, an environmental factor, or a short-lived genetic trait confined to <u>Angopora</u> wyomingensis n. sp., and this species.

This species is to be a rare occurrence of a favositid with most of the pores in the walls, and represents the first report of Favosites in Ordovician strata in southern Manitoba. Nelson (1963, p. 54) described <u>F. wilsonae</u> from the Caution Creek Formation of the Hudson Bay region. He concluded that <u>F. wilsonae</u> is closely related to <u>F. forbesi</u> Milne-Edwards and Haime which occurs in latest Ordovician strata on Anticosti Island. The three species of <u>Favosites</u> represent the only occurrences of the genus in Ordovician rocks in North America. <u>Favosites manitobensis</u> has larger corallites and more mural pore rows in the walls than does <u>F. wilsonae</u> and Nelson (1963) did not discuss the character of the wall structure so the trabeculate walls may not be present.

Bassler's (1950), Baille's (1952), and Stearn's (1956) faunal lists of the Stony Mountain Formation and overlying Ordovician strata did not contain any <u>Favosites</u>. As a result, <u>F. manitobensis</u> appears to be a very uncommon or short-lived representative of the genus since all <u>Favosites</u> in the Silurian Interlake Group have no pores located in the corallite corners (Stearn, 1956).



Fig. 33.--Portion of corallite wall of <u>Favosites manitobensis</u> n. sp. Part of wall removed to show interior adjacent to axial plate. Fibrous sclerenchyme shown by dense stippling; spines by lined, patterned stippling. Axial plate and trabeculae shown by light, patterned stippling. Crenulation and wall thickness exaggerated, approx. X40.

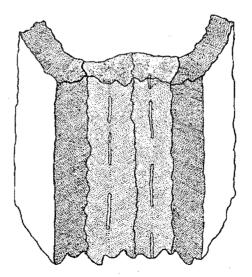


Fig. 34.--Portion of lateral and common walls of <u>Catenipora</u> robusta. Fiber orientation shown by patterned stippling. Discontinuous axial rods at trabecular centers shown by clear areas. Corallites in <u>C. rubra</u> similar but lack axial rods, approx. X100.

Family HALYSITIDAE

Genus Catenipora Lamarck, 1816

Type species (by subsequent designation of Lang, Smith, and Thomas, 1940, p. 33).--Catenipora escharoides Lamarck, 1816, Hist. Nat. des Animaux sans Vertebres, II, p. 207.

Diagnosis.--Halysitids with no microcorallites between corallites.

<u>Discussion</u>.--Three species <u>Catenipora rubra</u> Sinclair and Bolton, <u>C. robusta</u> (Wilson) and <u>Catenipora</u> sp. were encountered in the study. The most consistent characters which serve to distinguish between <u>C. rubra</u> and <u>C. robusta</u> in the field are the size and shape of the individual corallites. Those of <u>C. rubra</u> are usually subrectangular in transverse outline whereas those of <u>C. robusta</u> are smaller and suboval in transverse section. The common wall between adjacent corallites in <u>C. rubra</u> is proportionately longer than in <u>C. robusta</u>.

Balken in the southern Manitoba hypotypes of <u>Catenipora</u> appear as two or three subpolygonal bodies comprising the common wall. These balken appear to be closely packed monacanthine trabeculae with faint sutural surfaces between adjacent ones, and between them and the lateral corallite wall. These trabecular common walls are similar in structure to the walls of Trabeculites and Nyctopora.

Catenipora robusta (Wilson), 1926

Plate 12, Figures 2, 4, 6; Plate 13, Figures 1, 7 <u>Halysites catenularia</u> var. <u>gracilis</u> (Hall), Lambe, 1899, Geol. Survey Canada, Cont. Canadian Paleontology, p. 69-70, p. 74 (no. 4, Nelson River locality) pl. 3, figs. 5?, 5b.

Halysites robustus Wilson, 1926, Wilson, Geol. Survey Canada, Bull. 44, Geol. Ser. 46, p. 14, pl. 1, figs. 8-10.

Halysites gracilis (Hall), Troedsson, 1929, Medd. om Gronland, v. 72, p. 131-132, pl. 40, figs. 2, 3a, 3b.

Catenipora robustus (Wilson), Buehler, 1955, Peabody Mus. Nat. Hist., Yale Univ. p. 58.

Catenipora robusta (Wilson), Nelson, 1963, Geol. Soc. America, Mem. 90, p. 56, pl. 14, figs. 3-5.

<u>Diagnosis</u>.--Commonly large, hemispherical coralla, upper corallum surface convex with external growth increments on holotheca paralleling corallum growth surface; corallite ranks uniserial, with lacunae ranging in shape from elongate through trapezoidal to subcircular; small, thin walled corallites with lumen outline varying from subquadrate to suboval; tabulae complete, planar or convex, oriented normal to corallites axes, evenly spaced, no zonation.

Description of material. --- Two hypotype coralla (UND Cat. Nos. 13761, 13762) are shaped like a broad inverted cone with a convex growth surface. Other hypotypes (UND Cat. Nos. 13758-13760) are fragments of larger coralla. The corallites are arranged in uniserial ranks. Each corallite is connected to adjacent ones on its lateral margins through two prismatic trabecular rods that are closely attached to the lateral corallite walls at the constriction of the corallite rank. Well-preserved common corallite walls resemble and are probably homologous to trabecular baculae similar to those in the walls of <u>Trabeculites</u> Flower. Common walls between the corallites have longitudinal, central, axial rods or plates oriented normal to the rank, with upwardly directed, oblique fibers radiating outward from them (Figure 34).

At the boundary between the two trabeculae which form the common corallite wall, and the lateral corallite wall, there is a change in fiber orientation. Fibers within the trabecular common wall radiate outward from the center. By contrast, the interior portion of the lateral wall (Figure 34) contains fibers which are deflected around the common wall trabecula but are normal to the interior surface of the wall in the central portion of the corallite. Lateral corallite walls viewed in longitudinal section show one predominant mode of fiber orientation (Figure 35), fibers inclined upward toward the corallite center. This portion of the corallite walls shows a distinct, outwardly directed, banding of light and dark wall portions showing up best in thick sec-In transverse section (Figure 35) this banding is shown as well tions. defined wall portions with varying fiber orientation, the outermost, darkest band occurring in the position of where the holotheca would be located. No holotheca is apparent in all but one of the southern Manitoba and Wyoming hypotypes. Epizoic organisms attached to the corallum exterior show no underlying layer which would tend to be preserved. The hypotype from the Dog Head Member (UND Cat.No. 13761) however, has a thin translucent and finely corrugated outer wall layer representing a holotheca.

The layered aspect of the lateral wall appears to be produced by a variation in wall fiber texture. Coarse fibers in the peripheral portions of the wall show up as dark zones which are upwardly inclined toward the wall periphery. The inner part of the wall appears to be

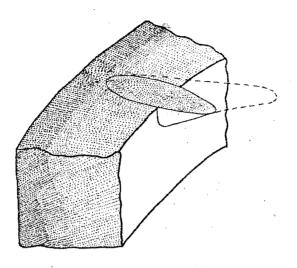


Fig. 35.--Portion of lateral wall typical of <u>Catenipora</u> robusta and <u>C. rubra</u>. Growth increments shown by heavy stippling. Inner portion of wall and septal spine shown by light stippling. Dashed line indicates spine outline, approx. X150.

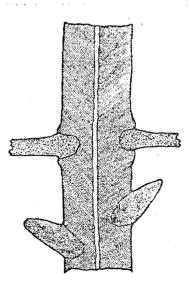


Fig. 36.--Portion of trabecula in common wall of <u>Catenipora</u> <u>robusta</u>. Longitudinal section plane parallel to plane of cateniform rank. <u>C</u>. rubra does not have axial rod (clear region), approx. X80. made of fibers with a finer texture than in the outer part. Fibers in both portions of the wall are in the same orientation. It is not known whether two separate sets of fibers are present or if fibers are continuous from the outer to the inner wall surfaces. Longitudinal sections (Figure 36) of well preserved portions of the common wall show upwardly divergent skeletal fibers abutting along the central axial rods or plates of the trabeculae. Within each trabecula, tabulae are inserted in recesses, delineating secretory differences between longitudinal and transverse skeletal elements.

Corallites are small. The outer surface of the lateral wall is convex at the corallite center and concave in the constricted region between adjacent ones. External corallite width is approximately 0.7 times the mean corallite length and, mean width at the point of constriction is about 0.75 times the mean maximum corallite width (Appendix B, Table 30). Corallite lumen outline varies from subquadrangular, with sharp corners at the intersections of the common intercorallite wall with each of the two lateral walls, to suboval, where the area of maximum curvature occurs centrally along the edge of the common corallite wall with the lumen. Mean lumen width varies from 0.55 to 0.67 times the mean lumen length for four hypotypes (Appendix B, Table 30). Up to 12, possibly 15 septal spine rows per corallite are present with one to six transverse rows of spines between adjacent tabulae. Longitudinal septal spacing within an intertabular space is about 0.18 mm. The number of transverse rows per intertabular space is controlled by the height of the space. Septa are inclined upward or are horizontal, and are represented by

sharp septal spines or blunt bosses within the same corallum. Peripheral ends of septa are emplaced within the inner wall layer (peripheral stereozone of Hamada, 1959, p. 281), not extending outward into what Hamada termed the "midwall," and outer wall. Mean extension of septa into the lumen is approximately 0.17 times the lumen width. Fibers within well preserved septal spines diverge axially and peripherally from the spine axis (Figure 35).

Septa also occur on the common wall, and appear to have the same fiber orientation as the septal spines in the lateral wall.

Tabulae are all complete, normal to the corallite axes, and slightly convex or planar, with mean longitudinal spacing of 0.75 and about 0.9 mm for two hypotypes (Appendix B, Table 30). Peripheral margins of the tabular plates terminate within the lateral and common corallite walls (Figure 36) and no merging of structures occurs. A sharp delineation between the fibrous wall and clear, non-fibrous tabulae is formed by the variation in texture between microstructures of the two types of skeletal elements.

Types.--Hypotypes, UND Cat. Nos. 13758-13762.

Occurrence.--One hypotype assignable to <u>Catenipora robusta</u> (Wilson) is from the Dog Head Member where it (UND Cat. No. 13761) was collected as a float specimen from 0.1 to 6.1 meters (0.3 to 20 ft) above the base of the unit on the northern end of Hecla Island, Manitoba, locality A907 (Appendix A). Three hypotypes (UND Cat. Nos. 13758-13760) came from quarry exposures of the Selkirk Member from localities A884 and A897 near Garson, Manitoba. One hypotype (UND Cat. No. 13762) was collected by John J. Delimata, a graduate student

at the Geology Department, University of North Dakota. The locality and exact stratigraphic level are not known, but it is known to have been collected from the lower massive portion of the Bighorn Dolomite in the Bighorn Range, northern Wyoming.

The holotype and other examples were recorded by Wilson (1926, p. 14) from the Beaverfoot Formation, from the Stanford Range, British Columbia. Lambe (1899, p. 74) reported examples attributable to the species in Ordovician strata in the Nelson River region, northern Manitoba. Troedsson (1929, p. 132) reported examples from the Cape Calhoun Formation in northern Greenland. Nelson (1963, p. 54) collected hypotypes from Member number 2 of the Portage Chute Formation on the Nelson, Churchill, and South Knife Rivers, northern Hudson Bay lowlands, northern Manitoba.

<u>Discussion</u>.--Hypotypes of <u>Catenipora robusta</u> (Wilson) from the Selkirk Member lack a holothecal layer of the type described by Flower (1961, p. 49) as a thin, dark band on types of <u>C</u>. workmanae Flower from the Montoya Group. Flower (1961, p. 49) observed epizooic forms attached to <u>C</u>. workmanae, under which the holotheca appeared to be dark and faintly granular. The lack of a holotheca suggests that the layer preserved on <u>C</u>. workmanae was not preserved in most of the southern Manitoba hypotypes.

A hypotype from the Dog Head Member (UND Cat. No. 13761) has an exceptionally well preserved holotheca (Pl. 13, Fig. 1) showing growth increments as minute corrugations at the base of the inclined sclerenchymal fibers. The holotheca is translucent and nonfibrous since the entire layer goes into extinction at the same angle of stage rotation under crossed nicols.

10% 07 Flower (1961, p. 49) concluded that the differences in wall structures between <u>C. workmanae</u> Flower and those in <u>C. rubra</u> Sinclair and Bolton described by Hamada (1959) could not be interpreted as the alteration of an original skeletal microstructure common to both species. If Flower's conclusion is correct, then wall microstructure is a character useful in diagnosis of species of <u>Catenipora</u>. An approach consistent with Flower's use of wall microstructure would be to use this to differentiate genera and subgenera or species within the family Halysitidae.

Comparison of Catenipora workmanae Flower (Flower, 1961, p. 48-50, plates 5-7; plate 8, figures 1-8; plate 13, figures 9-21) with C. robusta (Wilson) reveals differing wall microarchitecture. C. workmanae possesses a two layered lateral corallite wall with a dark, thin band, and an inner, homogenous, fibrous wall layer (Flower, 1961, p. 48). Flower's plate figures (1961, plate 5, figures 4, 7; plate 6, figures 2, 4-8; plate 7, figures 1-7; plate 8, figures 1-3; plate 9, figures 21, 22; plate 10; plate 12, figure 12) all illustrate a thick, essentially uniform, lateral corallite wall with long axes of fibers oriented normal to the corallite lumen. The hypotypes of C. robusta (Figure 35) show the tendency for the lateral walls to be differentiated into light interior and dark exterior layers similar to those described by Hamada (1959, p. 281, figure 7) in <u>C. rubra</u>. Hamada (1959, p. 281) differentiated the corallite wall of C. rubra into an external epitheca (holotheca of Flower, 1961, p. 49), a middle wall, and an inner stereozone within which the bases of the septal spines are embedded.

Transverse sections of C. robusta from southern Manitoba show what appears to be a two- or three-layered wall, the number of layers depending on where the wall is observed. The outer layer is dark, composed of calcite fibers oriented normal to the outer wall surface and is continuous around the corallite rank exteriors. The outermost layer of the C. robusta hypotypes appears to be composed of fibers that are coarse and apparently variable in length depending on the level of the transverse section. Longitudinal sections and schematic figures of C. robusta (Figure 35) show why two or three wall layers are observed. Axially sloping zones of dark and light wall layers occur with the dark zones peripheral to the light ones. The coarse, peripherally sloping fibers are apparently succeeded at their axial ends by fibers, similarly oriented, and characteristic of the inner stereozone of Hamada (1959). The peripheral inclination of the dark zone indicates that the coarse fibers of outer wall layer were secreted as progressively shorter forms as corallite growth continued. At the same time as the width of the outer layer was diminishing, that of the inner stereozone increased with the fibers characteristic of that zone being secreted as progressively longer forms. As upward growth of the corallites continued the cycle was reinitiated by the secretion of long outer and short stereozone fibers, forming the base of a wide, upwardly narrowing outer layer.

Microscopic examination in transmitted and polarized light, and under crossed nicols does not indicate whether or not the outer and stereozone lateral wall fibers are a series of continuous fibers

of two thicknesses or are separate from each other. This may be partially resolved by a sketch of very faint lineations observed within one corallite of <u>C</u>. robusta from southern Manitoba. Excellent preservation of the lateral and common corallite wall shows faint hints of the stereozone fibers nearest to the common intercorallite wall being deflected toward the corallite lumen. This deflection appears to cause a change in fiber direction between those in the outer layer and those in the stereozone (Figure 34), suggesting that two sets of fibers may be in the lateral wall.

Septa within the inner stereozone of hypotypes from southern Manitoba are embedded in and are apparently structurally separate from the stereozone layer. Hamada (1959, plate 12, figure 3) illustrated septal spines of <u>C</u>. <u>rubra</u> embedded in the stereozone layer where he showed <u>Catenipora rubra</u> differing from <u>C</u>. <u>robusta</u> by having bases of the spines being broad instead of peripherally tapering as in <u>C</u>. <u>robusta</u>. However specimens of <u>C</u>. <u>rubra</u> studied have tapering septal spines virtually identical in shape and relation with the stereozone as those of <u>C</u>. <u>robusta</u>.

The common wall between adjacent corallites is structurally separate from those lateral walls. Those in the southern Manitoba hypotypes of <u>C</u>. <u>robusta</u> are fibrous like the lateral corallite wall but the presence of a central axis or series of axes within a wall results in fibers radiating outward and inclining upward from the axis (Figures 34, 36). In microstructural pattern, the common wall is constructed of monacanthine trabecular wall elements like those occurring in walls of the cerioid tabulate genus Trabeculites.

These common wall trabeculae have been referred to by Hamada (1959) and Flower (1961) and others as balken. Their nature has been a topic of discussion in the past. Buehler (1955) was of the opinion that balken were results of recrystallization whereas Hamada and Flower were certain that they were organic in origin. Flower's excellent illustrations (1961, plate 6, figures 4, 7, 8; plate 7, figures 1, 2) show that what he terms "balken" to be the common wall trabeculae which Hamada (1959, p. 282) described as "a pair of dark coloured rods," but Flower made no comment on the structure of these elements.

Structural separation between the lateral and common walls is often indicated by extensive recrystallization of the common wall whereas the immediately adjacent lateral wall still shows its fibrous structure. In such a case, the suture between the two wall sets apparently served as a barrier to alteration.

One hypotype (UND Cat. No. 13761) from the Dog Head Member has exceptionally well-preserved wall microstructures and holotheca. Transverse sections show the presence of two or three dark spots in the intercorallite walls which represent trabecular axes.

Catenipora rubra Sinclair and Bolton, 1956

Plate 13, Figures 8-10

Halysites catenularia var gracilis (Hall), Lambe, 1899 [partim], Geol.

Survey Canada, Contrib. Canadian Palaeontology, v. 4, p. 1,

p. 69, 70, p. 74 (no. 3(?) Jack Head Island locality), pl. 3, figs. 5(?), 5a, 5b(?) non figs. 6, 7.

Halysites gracilis (Hall), Hussey, 1928, Contrib. Mus. Palaeontology, Univ. Michigan, v. 3, no. 3, p. 71, pl. 1, fig. 4; Teichert,

1937, Rept. Fifth Thule Exped., 1921-1924, v. 1, no. 5, p. 55, pl. 7, figs. 3(?), 6; Leith, 1944 [partim], Jour. Paleontology, v. 18, no. 3, p. 269, pl. 43, figs. 1, 5, 6, non figs. 2, 3, 4; Shimer and Shrock, 1944, Index Fossils of North America, p. 113, pl. 41, figs. 1(?), 2, 3(?).

[?]<u>Halysites gracilis</u> var. <u>borealis</u> Wilson, 1931, Trans. Roy. Soc. Canada, v. 25, sec. 4, p. 296, pl. 3, fig. 5.

Halysites cf. H. gracilis (Hall), Roy, 1941, Field Mus. Nat. Hist., Geol. Mem., v. 2, p. 79-80, figs. 40a, 40b.

Catenipora gracilis (Hall), Buehler, 1955, Peabody Mus. Nat. Hist.,

Yale Univ. Bull. 8, p. 36-38, 60(?), pl. 4, fig. 7, pl. 5, fig. 1. Catenipora rubra Sinclair [nomen nudum] 1955, Trans. Roy. Soc. Canada,

3rd ser., v. 49, sec. 4, p. 99, pl. 1, figs. 2, 6, 7, 11.

Catenipora rubra Sinclair and Bolton, 1956, Jour. Paleontology, p. 203;

Nelson, 1963, Geol. Soc. America, Mem. 90, p. 55, pl. 14, figs.

1, 2.

<u>Diagnosis</u>.--Very large tabular corallum with large cateniform corallites varying in transverse outline from quadrangularsubquadrangular to suboval, predominantly subquadrangular; moderately thick lateral corallite walls of two and three layers of fiber sizes, with septa embedded in inner stereozone; tabulae all complete, normal and oblique to corallite axes, convex, planar, and slightly concave; curvature, no zonation of tabular spacing.

Description of material. --- The very large, fragmental hypotypes are characterized by cateniform ranks of uniserial corallites arranged in such a way as to result in rank lengths up to 78 mm (Appendix B, Table 31) and lacunae which are often elongate. Circular or subcircular lacunae are rare. Intermediate lacunar shapes vary from elongate polygonal to oval. Rank exteriors have transverse growth increments, paralleling the corallum growth surface and continuous along the exterior. Corallites in one hypotype (UND Cat. No. 13763) are larger than those of <u>Catenipora robusta</u> (Wilson), averaging about 2.7 mm long and 2 mm wide. Transverse outlines of corallite lumina are essentially subquadrangular, with angular intersections between the lateral and common corallite walls, lending a subrectangular character to each corallite.

Corallites in that hypotype are relatively thick walled, with walls averaging approximately 0.3 mm in thickness, approximately 0.2 times the mean lumen width. The lateral corallite wall appears to be two layered, with an outer layer and an inner stereozone. Both are fibrous, with fibers upwardly inclined toward the corallite axis (Figure 34). The outer layer contains short, inclined fibers which seem to be coarser than those in the inner stereozone. These seemingly coarse fibers are arranged in zones which retreat toward the wall exterior when traced upward in the corallite. Those fully retreated toward the exterior are succeeded at their inner portions of the lateral wall by the outer layer in a fully advanced state (Figure 35).

In transverse section, the zonation of the retreated and advanced portions of the outer layer produce a triply zoned wall when the section cuts both a retreated and advanced zone of the outer layer and the inner stereozone.

The trabecular, common wall lies between each pair of adjacent corallite lumina. It is fibrous and consists of two monacanthine trabeculae with fibrous septal spines embedded in each trabecula.

Figure 36 shows chevron-like fiber orientation within longitudinal sections, inclined toward the axis of each trabecula. Transverse sections of the common wall show three intertrabecular sutures, subparallel to the direction of the corallite rank, and coincident with the boundaries the trabeculae and the adjacent lateral wall (Figure 34).

A maximum of twelve large septal spines per corallite occurs in the hypotypes. Short spines, embedded within the inner stereozone of the lateral wall, or projecting slightly from that layer are often interspersed between longer septal spines. Maximum length of the longest septal spines in one hypotype (UND Cat. No. 13763) average 0.27 mm and are 0.18 times the average lumen width. Septal microstructure is fibrous with fibers diverging peripherally from the spine center (Figure 35). All are embedded within the inner stereozone or common wall trabeculae, and are structurally distinct from those structures. Spines within intertabular spaces of this hypotype average 0.22 mm between adjacent ones. They are arranged in longitudinal and transverse rows, with an average of 2.5 transverse rows per intertabular space (Appendix B, Table 31).

All tabulae are complete, with a mean spacing in this hypotype of 0.9 mm. Orientations of tabulae are normal and inclined to the corallite axes. Curvature of these varies from very slightly concave, through planar, to convex. No zonation of tabulae is present and spacing in that hypotype is relatively constant.

Types.--Hypotypes, UND Cat. Nos. 13763, 13764.

Occurrence. -- Catenipora rubra is widespread in Ordovician rocks in southern and Arctic Canada, and Baffin Island. Lambe (1899, p. 74) noted its presence on Jack Head Island in Lake Winnipeg. Hussey (1928,

p. 71) described and illustrated it (U. of Mich. No. 10208) of <u>Halysites gracilis</u> (Hall) from Putnam Highland, on Baffin Island. Roy (1941, p. 80) listed an example on Sillman's Fossil Mount in the Frobisher Bay region of Baffin Island. Leith (1944, p. 268) described it from the Selkirk Member at Garson, Manitoba. Nelson (1963, p. 55) found it (GSC Nos. 10896, 10897) the Member No. 2 of the Portage Chute Formation and in the Chasm Creek Formation along the Nelson River in the Hudson Bay lowlands, northern Manitoba.

The hypotypes studied (UND Cat. Nos. 13763, 13764) came from the same exposures as cited by Leith (1944; Appendix A, locality A530).

<u>Discussion</u>. --<u>Catenipora</u> rubra Sinclair and Bolton from southern Manitoba differs from <u>Catenipora</u> robusta (Wilson) of the same region in several ways:

- Coralla of <u>C</u>. <u>rubra</u> are much larger than those of <u>C</u>. <u>robusta</u>. Those in the former have diameters up to 558 by 369 mm (Leith, 1944, p. 268) whereas those of the latter are a maximum of 170 mm in width by 90 mm in height.
- Corallite rank lengths of <u>C</u>. rubra range from 3 to 78 mm whereas those of <u>C</u>. robusta range from 3 to 27 mm. Lacunae of <u>C</u>. rubra are generally longer and wider than those of <u>C</u>. robusta.
- 3. Corallites of <u>C</u>. <u>rubra</u> have a greater mean length (about 2.7 mm) and width (about 2.0 mm) than those of <u>C</u>. <u>robusta</u> whose mean lengths and widths are about 2.2 mm and 1.6 mm respectively.

- 4. Lumen outlines of <u>C</u>. <u>rubra</u> are predominantly subquadrangular whereas those of <u>C</u>. <u>robusta</u> are predominantly suboval. Lumen mean length and width of <u>C</u>. <u>rubra</u> are approximately 2.35 and 1.5 mm respectively whereas those of <u>C</u>. <u>robusta</u> are approximately 1.9 and 1 mm respectively.
- Septa in corallites of <u>C</u>. rubra are longer (mean length
 0.27 mm) than those of <u>C</u>. robusta (0.19 mm).
- 6. The trabecular common wall length measured parallel to the corallite rank plane results in mean values of 0.4 mm for C. rubra and 0.2 mm to 0.24 mm for <u>C. robusta</u>.
- Trabeculae in the common wall of <u>C</u>. <u>robusta</u> appear to have an axial rod or plate at their center. Trabeculae of C. rubra have none.

Although prime differentiations between the two species are based on corallum dimensions, corallite size and shape, length of septa and dimensions of intercorallite walls, both species share similar lateral wall structure, septal spine spacing, and numbers of longitudinal spine rows per corallite.

Corallites of <u>Catenipora rubra</u> from southern Manitoba consistently show the common wall bordering on the lateral corallite walls by two suture planes, and split into two component parts by a central suture between the two trabeculae. All sutures are subparallel to the direction of the cateniform rank. These fractures appear to be in the same general position as the dark lines between balken in the species <u>Catenipora workmanae Flower</u>. Plate figures (Flower, 1961, plate 5, figures 4, 7; plate 6, figures 4, 6, 7, 8) or transverse sections of <u>C. workmanae</u> show three dark lines, subparallel to the rank direction; the same number and direction of the fractures noted in the hypotypes of Catenipora rubra.

Longitudinal sections through the trabecular common walls of both <u>C. rubra</u> and <u>C. robusta</u> show similarity between the two species in the chevron-like aspect of fiber orientation in the trabeculae. Both species are characterized by fibers inclined upward and outward from the trabecular center.

Physiological differences between the two species could account for the differing trabecular common walls in the two species. These differing physiological processes could have been genetically controlled, resulting in differing systematic positions for the two species. Use of the Flower Model for inferred relationships between Ordovician tabulate corals serves to illustrate probable differing systematic positions within the genus Catenipora.

- An axial plane or line defined only by changes in fiber direction within common wall trabeculae of <u>C</u>. <u>rubra</u>, not structurally or texturally distinct from the remainder of the trabeculae implies a more primitive evolutionary position than Catenipora robusta.
- 2. On the other hand, a structurally distinct axial rod or plane within common wall trabeculae of <u>C</u>. <u>robusta</u> indicates that the species may be more evolutionarily advanced than Catenipora rubra.

Flower's (1961) plate figures of <u>Catenipora workmanae</u> show common wall structures similar to those of <u>C</u>. <u>rubra</u>. Application of the

Model to <u>C</u>. workmanae implies that it is in the same general phylogenetic position as <u>C</u>. rubra, both species being closely related to each other and more primitive than <u>C</u>. robusta. <u>C</u>. robusta may be considered to be an advanced species by virtue of the nature of the axial structures within the trabeculae.

Catenipora sp.

Plate 13, Figure 2

Description.--Two dolomitized and poorly preserved corallum fragments (UND Cat. No. 13572, 13573) contain cateniform corallites in which the width, as measured from center-to-center of common walls, varies from 1.6 to 2.5 mm. Mean center-to-center widths are 2.26 and 1.97 mm (UND Cat. Nos. 13572, 13573). Poorly preserved septal spines occur at the axial margins of broad longitudinal septal ridges. Tabulae are complete. Most are normal to the corallite axis and planar with slightly crenulate margins. Poorly defined zones of closely and widely spaced tabulae are continuous at distinct levels across adjacent corallites (Appendix B, Table 32).

Types.--Hypotypes, UND Cat. Nos. 13572, 13573.

<u>Occurrence</u>.--One corallum fragment (UND Cat. No. 13572) occurred as float whereas the second fragment (UND Cat. No. 13573) was collected from within a stratigraphic interval of 1.3 to 2.2 meters (4.2 to to 7.2 ft) below the top of the exposure at the type section of the Fort Garry Member of the Red River Formation (Appendix B, locality A850).

Discussion. -- Poor preservation of the fragmental coralla restrict identification of these specimens to the generic level. No structures that would give information on wall thickness, microstructure, corallum

and corallite dimensions, or septal counts were preserved. Biometric data are insufficient for assignment of the fragments to a species of Catenipora.

Order RUGOSA Superfamily ZAPHRENTICAE Family STREPTELASMATIDAE Subfamily STREPTELASMATINAE Genus Streptelasma Hall, 1847

<u>Type species</u> (by original designation).--<u>Streptelasma corni-</u> <u>culum Hall, 1847, pt. 6, Palaeontology of New York, v. 1, p. 69, pl.</u> 25, figs. la-d.

Diagnosis.--Solitary; septa long; axial lobes few, forming a loose, narrow axial structure (Hill, 1956, p. F268).

Remarks.--Thin sections of species of <u>Streptelasma</u> observed in this study show a septal microstructure whose nature becomes most apparent under crossed nicols microscopy. Transverse thin sections of all these species show that the septa are composed of chevronlike sets of skeletal fibers diverging from the central plane of the septum. Only one transverse section close to the calyx of the holotype of <u>Streptelasma sheridanensis</u> n. sp., shows any discernible tendency for an aggregation or grouping of septal fibers. A very faint grouping of structures at the central plane of the septa can be seen in longitudinal sections.

Crossed nicol microscopy of these longitudinal sections reveals that the grouped structures in the central septal planes are short, "primitive," monacanthine, trabeculae wherein the

constituent fibers are observed to have an angle of fiber divergence of zero to 30 degrees. These "primitive" trabeculae are so termed because of their very short axial continuity. A schematic drawing of a calicinal portion of the corallum wall and septa of Streptelasma kelpinae n. sp., cut by a longitudinal section (Figure 39a) best illustrates The trabeculae are oriented with their long axes nearly normal this. to the corallum axis. Use of Wang's (1950, text-figure 76) angle of inclination applied to these trabeculae yields an angle ranging between 75 and 90 degrees. The striking feature of these trabeculae is their axial shortness. Most have lengths of no more than 3 or 4 times their length. The sutures (Wang, 1950, text-figure 76) between closely apressed, short trabeculae show their outlines. Each short trabeculae consists of a single bundle of fibers, termed a "fascicle" by Wang (1950, p. 185). The "primitive" nature of these trabeculae is manifested by their lack of longitudinal continuity and the lack of lateral separation between them (Figure 39a).

The lack of longitudinal persistence of the trabeculae indicates that the center or area of calcification of that structure at the apex of the invagination of the basal plate lasted only a short time during the life of the polyp before it was apparently replaced by another center adjacent to it which constructed the next axial trabecula. Longitudinally continuous septal trabeculae in descendant rugose genera such as <u>Bighornia</u> can frequently be traced from the corallum wall inward to, or nearly to, the corallum axis.

Longitudinal sections of <u>Streptelasma</u> poulseni and S. <u>sheridan</u>-<u>ensis</u> n. sp., which cut through the stereozone between the peripheral

ends of adjacent septa show steeply inclined dark lines. These lines, when viewed in transverse section, appear as U-shaped figures which represent lamellar layers of wall tissue (Wang, 1950, p. 190), probably deposited as areally continuous sheets between septa. The sutures at the center of the U-shaped figure and between the septa and the stereozone represent the borderlines between types and sets of calcification centers on the polyp basal disc.

Wang (1950, p. 191) stated that the lamellar skeletal tissue reflects the primitive function of the soft parts below the level of the polyp invagination where septal construction occurs. The difference between the fibrous septal and lamellar wall construction may be due to the segregation of secretory functions on the basal disc.

The evolutionary position of the species studied of <u>Strepte-lasma</u> is reflected in the degree of development of septal trabeculae. <u>Streptelasma poulseni</u> is the most "primitive" of the three identifiable species. Its septa are essentially nontrabeculate and it is in a fauna in the Selkirk Member which is ancestral to the faunas containing the other two species <u>S. kelpinae</u> n. sp. and <u>S. sheridanensis</u> n. sp.; both of which are trabeculate.

Streptelasma poulseni Cox, 1937

Plate 13, Figures 3-6; Plate 14, Figures 1, 2, 5, 7 <u>Streptelasma rusticum</u> (Billings), Troedsson, 1929, Meddeleser om Gronland, v. 72, p. 107, pl. 24, figs. 3, 5, 9(?); Bassler, 1950, Geol. Soc. America, Mem. 44, p. 22.

Streptelama poulseni Cox, 1937, Geol. Magazine, v. 74, no. 1, p. 9, pl. 2, figs. 8a-c, 9a-b; Bassler, 1950, Geol. Soc. America, Mem. 44, p. 23, 24.

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[?]Streptelasma cf. latusculum Okulitch, Brindle, 1960, Saskatchewan

Dept. Min. Resources, Rpt. 52, p. 12, 13, table 1, pl. 1, fig. 5.

<u>Species diagnosis</u>.--Streptelasmas of usually moderate size, though sometimes fairly large, curved, trochoid. Septa only moderately dilated; minor septa short and project very little from the stereozone, which is narrow. Axially complex simple, formed by the amalgamation of the ends of few septa. Tabulae relatively remote and only very gently inclined (Cox, 1937, p. 9).

Description of material.--Three poorly preserved coralla, designated hypotypes UND Cat. Nos. 13608-13610, are assignable to <u>Strepte-</u><u>lasma poulseni</u>. All are trochoid, with corallum angles of nearly 60 degrees within 2 mm of the apex. Between 2 to 13 mm from the apex the angle approaches 45 degrees. At distances greater than 13 mm the corallum angle decreases to about 20 degrees. Hypotype UND Cat. No. 13609 shows that the transverse dimension (parallel to the cardinal-counter plane) is slightly greater than the corallum height measured along the plane of the alar septa. This is evident in the 5 mm closest to the apex and is manifested by a slight development of angulation along the trace of the cardinal septum (Figure 37). At distances greater than 5 mm from the apex the transverse corallum profile becomes circular. The three hypotype coralla are all curved. The cardinal side is convex and the counter side is straight (Hypotype UND Cat. No. 13608) or concave (UND Cat. No. 13610).

All three hypotype coralla are poorly preserved and abraded. Partially preserved surfaces show little development of septal furrows or fine transverse striations. Only relatively coarse, transverse annulations occur. These are spaced approximately 12 mm apart on the exterior of hypotype UND Cat. No. 13608. Corallum length varies from a minimum of 25 mm for UND Cat. No. 13610 to a maximum of 36 mm for UND Cat. No. 13609.

The calices of all three hypotypes are deep in relation to corallum length, from a minimum of 0.33 times the length for UND Cat. No. 13608 to a maximum of 0.46 for UND Cat. No. 13609. Well preserved calices are characterized by a broad U-shaped longitudinal profile, with steep, sides and a concave central area. The columella does not form a calicinal axial projection.

Up to 37 major septa occur in a hypotype, UND Cat. No. 13609. The rate of septal insertion as a function of distance from the apex is at a maximum for the 5 mm closest to the apex, where the rate is one septum per millimeter of length. At distances greater than 5 mm, the rate decreases to approximately 5 septa per 4 mm length. The major septa 13 mm from the apex of hypotype UND Cat. No. 13609 are slightly thicker at their axial ends than at their peripheral ends. No pronounced axial lobation occurs however.

The minor septa are short and are inserted in hypotype UND Cat. No. 13609 at a distance of 4 mm above the apex. They are equal in number to the major septa and remain short, barely extending through the peripheral stereoplasm deposits between the peripheral ends of adjacent major septa.

Septal microstructure appears to be virtually nontrabeculate. One longitudinally sectioned hypotype (UND Cat. No. 13608) has the central planes of several major septa cut obliquely by the plane of the section. Rotation of the section under crossed nicols in the

areas of these cut septal planes produces parallel extinction. Very little rotary extinction was observed. This implies that the component fibers of the septal planes are arranged in parallel fashion, and that trabeculae are essentially absent. Transverse sections of one hypotype (UND Cat. No. 13609) show very faint rotary extinction of septal fibers under crossed nicols, indicating that the component fibers are arranged in chevron-fashion with the chevron apices directed toward the peripheral ends of the septa. Recrystallization has occurred in its septa so that fiber orientation cannot be seen without crossed nicols.

A columellar structure, similar to that in <u>Grewingkia</u>, is well developed 10 mm above the apex in this hypotype. The columella is composed of the vermiform axial ends of some of the major septa extending toward the axis. The remaining major septa are grouped together in pinnate fashion. These septa are also arranged in an axial vortex around the columella. Columellar width, as a function of corallum width varies from 0.2 to 0.27 times the corallum width for hypotype UND Cat. No. 13609.

Cardinal and alar fossulae are poorly developed and are commonly difficult to distinguish from the remaining interseptal spaces.

The peripheral stereozone consists of coarse lamellae arranged in U-shaped fashion with the U opening toward the corallum axis. Each U, as viewed in transverse section, is restricted to the region between adjacent major and minor septa. The central portion of each U is bisected by a zig-zag suture plane, oriented parallel to the plane of the septa. Therefore the coarse, curved lamellae within the U abut each other at the sutural plane and terminate against the lateral

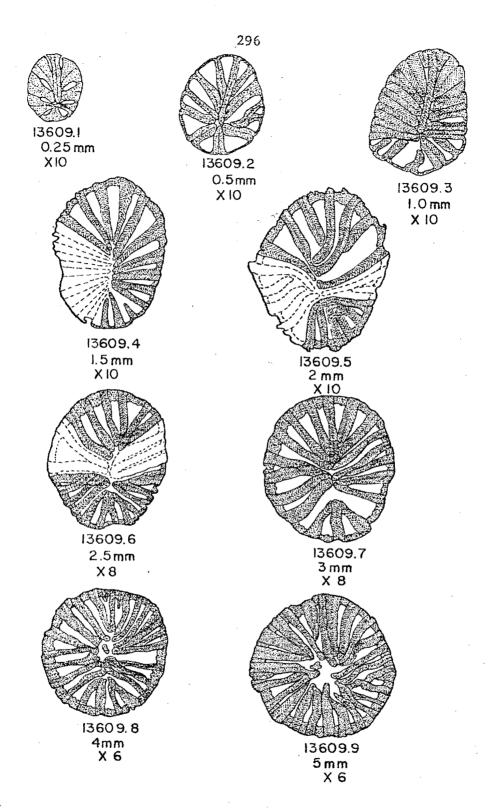


Fig. 37.--Serial peel tracings of apical 5 mm of hypotype (UND Cat. No. 13609) of <u>Streptelasma poulseni</u>. Patterned stippling shows septal microstructure. Distances from apex and scale given for each peel. Cardinal septum at twelve o'clock position.

surfaces of the septa. Stereozone thickness, 13 mm from the apex, is 1.3 to 1.8 mm and averages 1.48 mm, 0.22 times the mean corallum radius at that position.

Tabulae of one hypotype (UND Cat. No. 13608) are normal to the corallum axis. Those in the region of the columella are plane, with the columellar portions of the major septa on the distal surface of each tabula. Tabular portions peripheral to the columella are gently inclined toward the corallum periphery. These are convex and frequently incomplete. Spacing along the axis, based on 11 counts, was 0.6 to 1.90 mm.

Types.--Hypotypes UND Cat. Nos. 13608-13610.

Occurrence. -- Streptelasma poulseni Cox occurs in Ordovician strata in the following regions.

Arctic:

The Cape Calhoun Formation at the type locality, Washington Land, northwestern Greeland (Troedsson, 1929), Holotype, M.M.K. No. 182, float specimen from drift in Inugsuligarsuk, Cockburn Land (Teichert, 1937).

Southern Manitoba:

At quarries in the Selkirk Member of the Red River Formation near Garson, Manitoba (Appendix A, locality A884).

<u>Discussion</u>.--Cox (1937, p. 9) recognized that examples of <u>Streptelasma</u> assigned to <u>S</u>. <u>rusticum</u> (Billings) by Troedsson (1929, p. 107) actually represented a species separate from <u>S</u>. <u>rusticum</u>. <u>Streptelasma</u> <u>rusticum</u> is characterized by a wide axial structure composed of the vermiform axial ends of strongly dilated major septa that are superimposed on the distal surfaces of the tabulae in the axial region.

Cox recognized that coralla of <u>Streptelasma</u> from Ordovician strata of the Arctic region are characterized by axial structures simpler than that of <u>S</u>. <u>rusticum</u>. These are also recognized as distinct by thinner, moderately dilated major septa; and shorter minor septa, almost entirely restricted to the peripheral stereozone, and a narrower stereozone than those of <u>S</u>. <u>rusticum</u>. <u>Streptelasma poul-</u> <u>seni</u> appears to be ancestral to <u>S</u>. <u>rusticum</u>, which is usually considered to be Richmondian in age (Ulrich, 1895, p. 93; Cox, 1937, p. 12) and is widely distributed in North America. <u>Streptelasma</u> <u>poulseni</u>, <u>S</u>. <u>rusticum</u> of Duncan, 1956, plate 21, figures 1a, b (caption) is, as Duncan (1956) stated, closely related to <u>Grewingkia</u> <u>robusta</u>, and it may have given rise to <u>S</u>. <u>rusticum</u> by increased complexity of the axial structure, increased dilation of the major septa, increased length of the minor septa, and increased thickness of the peripheral stereozone.

<u>Streptelasma poulseni</u>, or a form ancestral to it, may have given rise to <u>G</u>. robusta by an increase in corallum size and septal number, shortening of the major septa, an increase in complexity of the axial structure, and the development of corallum angulation in the region of the cardinal septum. <u>S</u>. poulseni, however, as typified by hypotypes UND Cat. Nos. 13609, 13610, does show slight angulation in this region. Figure 37, sections 13609.2-13609.7 show increased width in the cardinal-counter septal plane whereas sections 13609.8 and 13609.9 show the circular transverse profile common to other species of Streptelasma.

<u>S. poulseni</u>, a Red River species, lacks observable septal trabeculae whereas the later species, <u>S. kelpinii</u> from the Stony Mountain, has discernible (though poorly defined) trabecular structures. This may illustrate the increasing development of septal trabeculae in the genus with time.

Streptelasma kelpinae n. sp.

Plate 15, Figures 4-12

- Streptelasma rusticum (Billings), Whiteaves, 1895, Geol. Survey Canada, Palaeozoic Fossils, v. 3, pt. 3, p. 113; Baille, 1952, Manitoba Dept. Mines and Mineral Resources, Pub. 51-6, p. 32; Proctor, 1957, M. Sc. Thesis, U. Manitoba, p. 15.
- Streptelasma latusculum Okulitch, 1943, Trans. Roy. Soc. Canada, v. 37, sec. 4, p. 61, 62; Bassler, 1950, Geol. Soc. America, Mem. 90, p. 22.
- Streptelasma aff. S. latusculum Okulitch, Duncan, 1956, U. S. Geol. Survey Bull. 1021-F, p. 218, p. 21, figs. 1a, b; Duncan, 1957, Jour. Paleontology v. 31, no. 3, p. 613.
- Streptelasma cf. S. latusculum Okulitch, Ross, 1957, U. S. Geol. Survey Bull. 1021-M, p. 474, pl. 37, figs. 4, 8.

Species diagnosis.--Small, curved trochoid coralla with diameter of mature forms less than corallum length; corallum exterior nearly smooth or with transverse annuli; longitudinal furrows absent on wellpreserved corallum exteriors; calyx depth up to 0.45 times the corallum length, with V-shaped calyx with smaller U-shaped central pit; up to 39 dilated major septa often filling corallum interior, weakly trabeculate, nondenticulate on distal margins, commonly form counterclockwise axial vortex, with lobate ends of major septa abutting to form columella; tabulae rare, restricted to septal interspaces between peripheral stereozone and columella.

Description of material.--A holotype (UND Cat. No. 13699), 11 paratypes (UND Cat. No. 13615, 13617-13620, 13622-13624, 13697, 13698, 13700), and 69 catalogued specimens (UND Cat. No. 13696, 67 individuals; UND Cat. No. 13616, 2 individuals) are assigned to <u>Streptelasma</u> kelpinae.

All coralla are all small to medium length trochoid types with a circular, transverse profile. The cardinal side of all coralla is convex whereas the counter side is concave as in most coralla of the genus <u>Streptelasma</u>. The corallum exterior is nearly smooth in well preserved coralla. Only coarse growth annulations such as those on the exterior of hypotype UND Cat. No. 13697 modify a nearly featureless epithecal surface. No longitudinal septal furrows occur on well-preserved surfaces.

The individuals from the Gunn Member include three paratypes (UND Cat. Nos. 13622-13624), 66 individuals (UND Cat. No. 13696) and one paratype from the Hunt Mountain beds (UND Cat. No. 13615) show that the rate of increase of corallum diameter, as measured between the traces of the cardinal and counter septa, decreases with increasing corallum length (Figure 38). The four paratypes closely merge with the point scatter represented by the 66 individuals (UND Cat. No. 13696). With increasing maturity and corallum length, the apical angle, which may be as high as 60 degrees very near the apex continually decreases with corallum maturity.

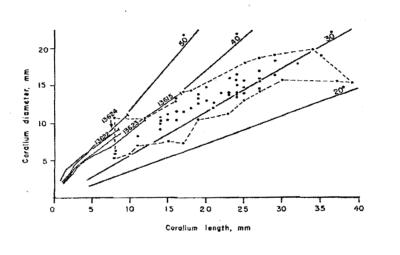


Fig. 38.--Line plots and scatter diagram of corallum diameter plotted against corallum length for <u>Streptelasma kelpinae</u> n. sp. (UND Cat. Nos. 13615, 13622-13624, 13696). Radiating lines represent corallum angles as a function of length. The calicinal rims are most commonly oriented normal to the corallum axis. Neanic individuals, however, commonly have inclined calicinal rims where the rim is inclined toward the counter side of the corallum. The longitudinal calyx profile of a mature paratype (UND Cat. No. 13697) and the holotype (UND Cat. No. 13699) is characterized by the peripheral portion occupying the peripheral half of the calyx radius, with a calicinal pit wall slope of 45 degrees to the corallum axis. At the axial border of the sloping pit wall, halfway between the calicinal rim and center, the wall parallels the axis, deepening the calyx. The calyx floor is planar and normal to the axis, and occupying the axial half of the calyx with no columella projection protruding from the floor.

Calyx depth increases proportionately with increasing length up to a maximum of approximately 0.45 times the corallum length at 23 mm from the apex. Coralla longer than 23 mm are characterized by calyx depths not exceeding 11 mm, and the proportional depths decrease with increasing corallum length.

A maximum of 39 major septa occur. With a maximum rate of insertion of approximately 6 septa per millimeter within 2.5 mm of the apex for six paratypes (UND Cat. Nos. 13615, 13619, 13620, 13622-13624). From 2.5 to 7 mm from the apex, the five types show a decreased rate of 2 septa per millimeter. From the 7 to 20 mm distance it further decreases to a rate of one per millimeter. At greater than 20 mm from the apex, the rate falls to zero, due to the increased prominence of the minor septa. These were inserted at distances from 5 to 7 mm above the apex.

Within the corallum interior the major septa are dilated and often completely fill it in the neanic portions. The ephebic portions, however, usually contain major septa dilated to a lesser degree in the tabularium, but they are axially expanded in lobate fashion where they form a columella. Major septa close to the calyx are usually dilated only at their peripheral margins and completely or nearly fill the corallum interiors, and no peripheral stereozone is present.

The corallum wall consists of a septotheca formed by the laterally abutting peripheral ends of the septa. Therefore, a peripheral stereozone of fibrous stereoplasm occurs only in regions where the peripheral ends of adjacent septa are not in contact with each other. Minor septa are usually buried within the stereozone with only their axial ends protruding from it.

A prominent cardinal fossula commonly forms the only unoccupied space in the corallum interior unless interseptal spaces are present. The columella is composed of the merged, lobate axial ends of the major septa which, when viewed from the calyx, form an axial vortex composed of a counter-clockwise twisting of the axial portions of the septa as typified by paratype UND Cat. No. 13620 (Plate 15, Figure 7).

Septal microstructure is faintly trabeculate. A longitudinal section of one paratype (UND Cat. No. 13617) cutting the plane of one septum, when viewed under crossed nicols shows diffuse, rectangular areas within which fan-like extinction patterns are produced by rotation of the microscope stage (Figure 39a). Each extinction pattern delineates the extent of a trabecula in the sectional septal plane. Transverse sections show a chevron-shaped fiber pattern with the

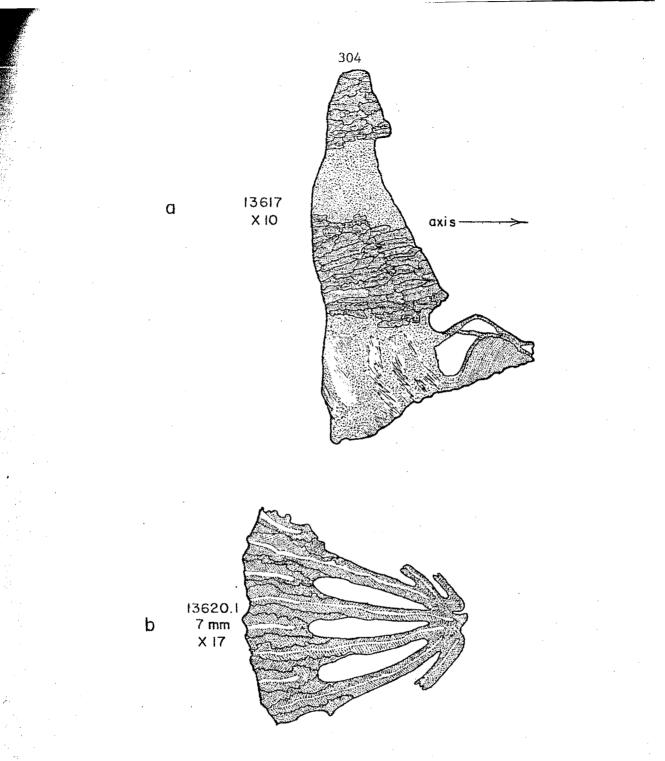


Fig. 39.--Paratypes of <u>Streptelasma kelpinae</u> n. sp. (a) Calicinal rim of (UND Cat. No. 13617). Longitudinal section cuts trabecular portion of minor septum (at top), and major septum (midway down section), approx. X10.

(b) Portion of (UND Cat. No. 13620). Transverse section. Patterned stippling shows septal microstructure, approx. X17.

chevron apices directed peripherally (Figure 39b). No well-defined layering of the septal transverse sections can be observed other than a translucent area at the central plane of each septum, probably the axial region of the longitudinally stacked, axially oriented trabeculae. The trabecular structures are less well-defined than those observed in <u>Bighornia</u>, <u>Dieracorallium</u>, and <u>Lobocorallium</u> indicating that this poor definition may be reflective of the taxonomic position of <u>Streptelasma</u> in relation to the other genera.

Tabulae are rare in the sectioned paratypes, having been observed in only one (UND Cat. No. 13617). In this, the tabulae consist only of inclined, convex tabellar plates restricted to the interseptal region between the axial margin of the peripheral stereozone and the periphery of the columella. Spacing varies between 0.45 and 0.9 mm in four counts.

<u>Types and catalogued specimens</u>.--Holotype, UND Cat. No. 13699; paratypes, UND Cat. Nos. 13615, 13617-13620, 13622-13624, 13697, 13698, 13700; catalogued specimens, UND Cat. Nos. 13616 (2 specimens), 13696 (69 specimens).

Occurrence.--Streptelasma kelpinae is very common in the exposures of the Gunn Member and in the lower 2.7 meters (9 ft) of the Penitentiary Member of the Stony Mountain Formation. It also has been collected from the Hunt Mountain and Rock Creek beds in the upper portion of the Bighorn Formation. It occurs in the following localities:

> Zero to 3.4 meters (0 to 11 ft) below the top of the Gunn Member of the Stony Mountain Formation in a quarry near Stony Mountain, Manitoba (Appendix A, locality A584). Zero to 2.7 meters (0 to 9 ft) above the base of the Penitentiary Member of the Stony Mountain Formation at the same locality as above.

The Rock Creek beds in the upper portion of the Bighorn Formation on the South Fork of Rock Creek, Johnson County, northern Wyoming, on the eastern flank of the Bighorn Mountains (Ross, 1957, p. 456).

The Hunt Mountain beds in the upper part of the Bighorn Formation in Shell Creek Canyon, 4 miles east of Shell, Bighorn County, Wyoming (Appendix A, locality A531). Four-tenths of a foot and 5.2 feet below the top of the Hunt Mountain beds east of the summit of Hunt Mountain, Sheridan County, Wyoming (Appendix A, localities A549, A539).

<u>Discussion</u>.--<u>Streptelasma kelpinae</u> is named for Miss Shelly Kelpin, assiduous collector and daughter of the superintendent of the Municipality of Winnipeg Aggregate Plant near Stony Mountain, Manitoba. The species is constructed for individuals of <u>Streptelasma</u> often previously assigned to <u>Streptelasma</u> aff. <u>latusculum</u> by Duncan (1956) and Ross (1957) and assigned to <u>Streptelasma latusculum</u> by Okulitch (1943). Twenhofel (1928, p. 112) described S. latusculum as follows:

The corallum of this species is almost smooth; rugose annulations are present in a few examples; and in unworn specimens small annulae to the number of 3 or 4 to a mm. band the shell. Septal ridges are present on a few species. The height and the diameter are nearly equal, with the diameter generally greater. The calyx has steep sides, the depth varies with age, but is generally from two-fifths to three-fifths the height of the corallum, proportionately greater in young specimens, and in individuals about 10 mm. long the calyx extends to the apex. The septa are in two sets; the smaller are very inconspicuous and in some sets are merely rows of tubercles, the larger decrease in length to the edge of the calyx and bear distinct denticulations on their edges. These extend over the sides of the septa and outwards to the walls of the corallum as small keels about 1/2 mm. apart. At their union with the wall the septa are somewhat thickened. The longer septa are 28 in number where the diameter is 13 mm., 23 where 8 mm. At the centre they twist together, uniting by twos and threes before so doing.

Bassler (1915, p. 1202) and Twenhofel (1928, p. 112) mentioned that Billings' (1865) original and subsequent descriptions of <u>S</u>. <u>latusculum</u> was based on material from Silurian strata of the Gun River and Jupiter Formations on Anticosti Island, Quebec.

S. latusculum, as described by Twenhofel (1928), is characterized by corallum diameters equal to or greater than height, a steepsided calyx with depths 2/5 to 3/5 of the corallum length, tuberculate minor septa and denticulate major septa. S. kelpinae, on the other hand, differs markedly from the above characters. Corallum diameters of S. kelpinae do not exceed, and are always less than corallum lengths in specimens exceeding 10 mm length (Figure 38). The longitudinal calyx profile of S. kelpinae differs from that of S. latusculum in that the former species has a U-shaped central area leading distally into a V-shaped portion whose distal portion terminates at the calyx rim. The resulting profile appears as a small U with a larger V sitting atop it: No mention of such a profile is made by Twenhofel (1928) for <u>S</u>. latusculum. Lambe however, (1901, plate 6, figure 9), illustrated Billing's (1865) holotype which showed a calyx profile not unlike that of S. kelpinae.

The presence of septal denticulation is the most important diagnostic feature in distinguishing between the two species. Lambe's (1901) illustration, mentioned above, showed discernible septal denticulation on the cardinal (?) side of the corallum, and Twenhofel (1928, p. 112) mentioned the presence of septal denticulation on individuals of <u>S. latusculum</u>. The individuals representing <u>S. kelpinae</u> are not denticulate on their distal margins. This may reflect the differing development of septal trabeculae in the two species. The denticulate,

Silurian <u>S. latusculum</u> reflects a greater degree of trabeculate development than the nondenticulate septal margins typical of <u>S. kelpinae</u> whose trabeculae are poorly differentiated. This differing development may reflect differing evolutionary and chronological positions.

The closely apressed, poorly defined trabeculae are not longitudinally continuous (with respect to the trabecular axis), but appear to be very short, terminating within the central portion of the septum (Figure 39a). Immediately abutting the terminated end of a given trabecula, another trabecula continues toward the corallum axis. Thus it appears that <u>S</u>. <u>kelpinae</u> represents a very primitive form of trabecular development; axial trabecular continuity has not been established and appreciable differentiation between laterally adjacent trabeculae has not occurred. This lack of lateral differentiation explains the lack of denticulate septal margins and constitutes one of the primary reasons for separating <u>S</u>. kelpinae from the denticulate <u>S</u>. <u>latusculum</u>.

Streptelasma sheridanensis n. sp.

Plate 14, Figures 3, 4, 6, 8; Plate 15, Figures 1-3 [?]Streptelasma rusticum (Billings), Bassler, 1950, Geol. Soc. America,

Mem. 44, p. 20.

<u>Species diagnosis</u>.--Medium sized (55 mm long, straight, trochoid corallum with slight flattening paralleling cardinal-counter plane; calyx shallow, inclined to axis with slight columellar boss, with 54 dilated major septa conspicuously twisted to form axial vortex; minor septa buried within thin peripheral stereozone; columella composed of vermiform and adjacent or abutted axial ends of twisted major septa; tabulae steeply inclined near corallum periphery, incomplete, convex.

Description of material. -- One, poorly preserved, corallum (holotype, UND Cat. No. 13634), 55 mm long, is a straight trochoid type slightly flattened parallel to the cardinal-counter plane (Plate 14, Figures 3, 4). Little remains of the corallum wall (Figure 40). Only a portion of the wall remains in the alar-counter region near the calyx. Due to the loss of most of the wall, the remaining corallum exterior consists of the peripheral margins of the septa. A preserved portion of the exterior exhibits no septal furrows or no transverse annulations.

Corallum width is greater than height throughout the length of the entire corallum. The corallum angle is at a maximum (75 degrees) within 2 mm of the corallum apex. From 2 to 10 mm from the apex, the angle decreases to approximately 60 degrees, and beyond 10 mm the angle decreases to approximately 30 degrees.

The calyx is inclined at an angle of approximately 45 degrees to the corallum axis; the calyx may have been shallow with a columellar boss projecting from the calyx floor.

Fifty-four major septa occur at the calyx. The maximum rate of septal insertion occurs in the apical 3 mm of the corallum, approximately 6 septa per millimeter. Three to 10 mm from the apex the rate decreases to approximately 2.5 per millimeter. More than 10 mm from the apex, the rate decreases to approximately one septum per 2.5 mm (0.4 septa/millimeter). Abrasion prevents determination of the region of insertion of the minor septa. They are first observed in a transverse section 25 mm from the apex. Here, they are short and completely immersed in the peripheral stereozone. All major septa exhibit pronounced counter-clockwise twisting (Figure 40). This twisting was

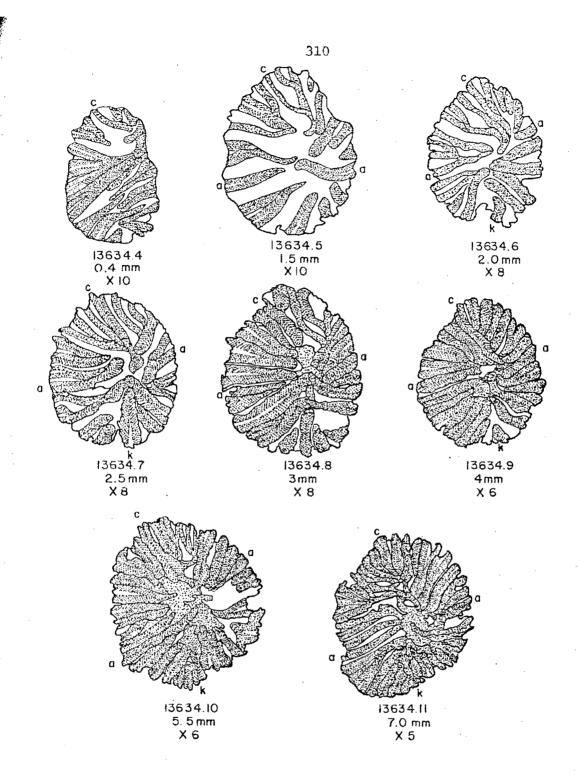


Fig. 40.--Serial peel tracings of holotype of <u>Streptelasma</u> <u>sheridanensis</u> n. sp. (UND Cat. No. 13634). Patterned stippling shows microstructure; c, cardinal septum; a, alar septum; k, counter septum. Distance from apex and scale given for each peel. initiated during the earliest stages of development and is discernible within 1 mm of the apex.

Septal microstructure 10 mm from the apex consists of prominent fibers in chevron-fashion with the apices of the chevrons directed toward the corallum periphery. At distances of 25 mm from the apex (Plate 14, Figure 8) peripheral portions of septa exhibit zig-zag sutural patterns between the central plane and flanking sclerenchymal layers. The sutures appear to represent textural boundaries apparently separating fine central fibers from coarser fibers of the sclerenchymal layers. Septa viewed in longitudinal sections show central planes composed of poorly defined bundles of subparallel fibers arranged in poorly defined, chevron patterns discernible only under crossed nicols. These bundles appear to be "primitive" septal trabeculae whose lateral fibers are continuous with those of the flanking sclerenchymal layers. End-on views of septa cut by planes of longitudinal sections show no discernible boundaries between trabecular and sclerenchymal regions.

Major septa are so dilated that they are in lateral contact with each other or are within close proximity.

The columella exhibits two basic modes of construction (Figure 40). Within 2.5 to 4 mm from the apex, it consists of the merged axial ends of major septa arranged in an axial vortex--twisted about the corallum axis. Greater than 4 mm, the columellar structure still exhibits the vortex-like twisting at its periphery, but its central portion consists of irregular, vermiform ends of major septa that extend from bundles of two to six septa merged at their axial ends.

Columellar width, a function of corallum width, remains relatively constant, about 0.35 times the corallum width.

The peripheral stereozone is thin, and consists of thin lamellae arranged in U-fashion with the U opening toward the corallum axis. Lamellae at the lateral margins of the stereozone abut fibers of the septal sclerenchyme at a zig-zag sutural surface. Minor septa are completely embedded within the stereozone.

Tabulae are incomplete and convex. Near the corallum periphery they are steeply inclined, approximately 45 degrees to the corallum axis. Tabular spacing, measured close to the axis and based on three available counts, is 0.66 to 1.4 mm with a mean of 0.93 mm.

Type.--Holotype, UND Cat. No. 13634.

Occurrence.--Collected from 0.1 meter (0.4 ft) below the top of the Hunt Mountain beds near the top of the Bighorn Formation, near the summit of Hunt Mountain, western side of the Bighorn Mountains, Sheridan County, Wyoming (Appendix A, locality A549).

Discussion.--Although the exterior surfaces and calicinal portions of the single holotype corallum are poorly preserved, the straight, trochoid corallum with the slightly flattened transverse profile, the shallow, inclined calyx, the pronounced twisting of the major septa, and the <u>Grewingkia</u>-like columella, are sufficiently unique to designate a new species, even though ordinarily one corallum would be insufficient to warrant construction of a new species. <u>Streptelasma sheridanensis</u> n. sp., is named for the northern Wyoming county where the holotype was collected.

<u>Streptelasma sheridanensis</u> n. sp. is closely related to <u>S</u>. <u>rusticum</u> (Billings) and <u>S</u>. <u>poulseni</u> Cox in that all three species share the same type of columella. Streptelasma sheridanensis differs

from the other two species in having (1) a straight corallum whereas coralla of the other two are curved, and (2) markedly twisted major septa whereas those of the other species are either straight or slightly twisted.

It may be a descendant of <u>S</u>. <u>poulseni</u> from the Red River Formation since both occurred in the Ordovician equatorial faunal realm at differing times. The descent of <u>S</u>. <u>sheridanensis</u> from <u>S</u>. <u>poulseni</u> would involve the straightening of the corallum, compression of the corallum along the cardinal-counter plane, inclination of the polyp basal disc to the corallum axis, and the twisting of the polyp mesentaries--resulting in the production of the twisted septa.

The inclination of the calyx may have been an attempt to enable the polyp to orient itself obliquely to the sediment surface. Since only an alar portion of the calicinal rim is preserved, the complete original character of the calyx is indeterminate and the possibility that the inclination of the calyx may in part be due to lack of preservation or deformation cannot be ignored. The probability that the calyx was originally inclined is indicated by the inclined calicinal floor wherein the distal margins of the septa and columella are inclined.

The conspicuous twisting of the major septa may have been the result of an increase of the length of the mesentaries within the polyp. The twisting resulted in greater septal lengths than would have been possible if they were arranged in simple radiating fashion. This may reflect an increase in absorptive area within the polyp gastrovascular cavity without an increase in the number of septa or increase in body column diameter.

Streptelasma sp.

Plate 16, Figures 1, 2

Description of material .-- The single specimen (UND Cat. No. 13702) is a small, straight, trochoid corallum 20 mm long and 16 mm wide at the distal ends of the traces of the cardinal and counter The calyx is deep, approximately one-half the corallum length, septa. and is floored by the distal margins of major septa extending nearly to the corallum axis. The angle near the apex between the cardinal and counter sides of the corallum is approximately 45 degrees in the apical 8 mm of the corallum, and approximately 25 degrees from this position to the calicinal rim. The corallum width is observable in its entirety in most transverse peels (Figure 41) at distances greater than 1 mm from the apex. The complete corallum height was usually unobservable due to obliteration of portions of the corallum. In these instances, height is taken as two times the distance from the corallum margin to the axis at an alar septum.

Width over height (w/h) varies from 0.85 to 1.15, resulting in a generally circular, transverse profile. The profile varies from a w/h value of 1.1 at the most proximal transverse section (05 mm from the apex where only the cardinal, the first cardinal laterals, the alar, and counter septa are present) to a circular profile at 7.5 mm from the apex with subsequent insertion of major septa (Figure 41).

Up to 30 major septa occur at a transverse plane 9 mm from the apex. Many of these extend to nearly the corallum axis and merge at their axial ends; other major septa are free at their axial ends. The cardinal septum is consistently the longest of any major septa.

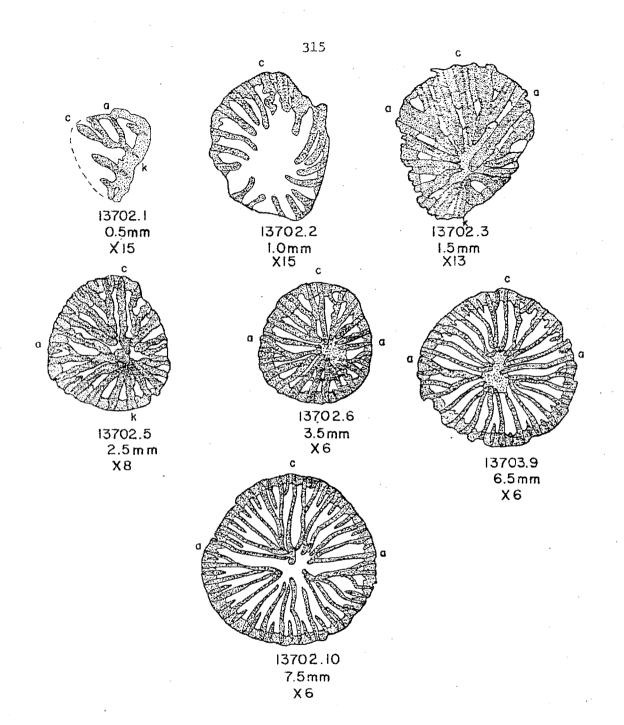


Fig. 41.--Serial peel tracings of <u>Streptelasma</u> sp. Patterned Stippling shows microstructure; c, cardinal septum; a, alar septum; k, counter septum. Distance from apex and scale given for each peel.

Major septa merged at the axis or extending close to it are frequently dilated within 5 mm of the apex whereas those more distant from the apex are thin, tending to taper toward the axis. Cardinal and alar fossulae become increasingly well-developed with increasing distance from the apex.

Minor septa equal in number to the major septa at any given levels are inserted 2.5 mm from the apex. They break through the marginal stereozone at about 2.8 mm and maintain a constant proportion of septal length to corallum radius through the remainder of the corallum. Adapically from their point of appearance, the minor septa are almost completely embedded within the stereoplasm and can only be discerned by variations in crystal structure between the stereoplasm and septa.

The corallite wall is first discernible 1 mm above the apex. Formation of a marginal stereozone occurs at approximately 1.5 mm and causes a marked thickening of the total wall-marginarium complex at that level. Distally from that level, the relative thickness of the complex gradually decreases with increasing distance from the apex.

Tabulae are domed distally and are restricted to levels between 3.5 to 6.5 mm from the apex.

<u>Type and occurrence</u>.--A single hypotype (UND Cat. No. 13702) was collected as float from a slumped, 6.1 meter (20 ft) exposure of the basal portion of the Dog Head Member of the Red River Formation, along the western shore of Lake Winnipeg near West Doghead Point, Manitoba, collecting locality A902 (Appendix A).

Discussion. -- That the hypotype belongs to the genus <u>Strepte-</u> <u>lasma</u> is indicated by the presence of dilated major septa merging at or near the corallum axis, the prominent cardinal and alar fossulae, and the deep calyx. Only very near the region of the calyx do the septa appear to be thin mostly with free axial ends. Within the calyx only the protosepta extend to the axis. These, plus the prominent fossulae, give a pronounced tetrameral appearance to the corallum.

These specimen may be a representative of the small solitary coralla mentioned by Whiteaves (1896, 1897), Dowling (1900), and Lambe (1901) from the Dog Head Member of the Red River Formation along the western shore of Lake Winnipeg and attributed by them as being small individuals of <u>Grewingkia robusta</u>. Study of this specimen (UND Cat. No. 13702) by serial transverse peels indicate it is more representative of <u>Streptelasma</u>. This is the lowest occurrence of the genus in the Red River Formation. Baille (1952, p. 25) noted the occurrence of two forms of <u>Streptelasma</u> in the underlying Winnipeg Formation exposed along the shores of islands in the southern half of Lake Winnipeg. These were described by Macauley (1952) as <u>Streptelasma</u> <u>simplicitas and S. winnipegensis nomina nuda</u>.

Macauley's description and figures show that the coral described by him is not the same as the hypotype.

Genus Palaeophyllum Billings, 1858

Type species (by monotypy).--Palaeophyllum rugosum Billings, 1858, Geol. Survey Canada, Rept. Progress 1857, p. 168.

Diagnosis.---Colonial, with phaceloid, and cateniform, and cerioid corallites; phaceloid corallites circular or ovoid in transverse profile, cateniform corallites polygonal or subpolygonal; corallite wall in phaceloid forms with thin epitheca, modified in adjacent cateniform corallites to a central axial plate; sclerenchyme faintly trabecular; septa variable in number, major septa extending near to corallite axis, peripherally thin, thin at tips, sometimes joining irregularly in pairs, or anastamosing irregularly; minor septa short, variable in development, lacking in some species; tabulae arched, downturned in genotype at edges and centers; in other species strongly sinuate and arched, with or without central depression (quoted in part from Flower, 1961, p. 88).

Remarks.--The three species of <u>Palaeophyllum</u> encountered in this study have a tendency toward closer corallite proximity with time. <u>Palaeophyllum argus</u>, in the Selkirk Member of the Red River Formation, is characterized by a phaceloid corallum in which cylindrical, parallel corallites are separated from each other. <u>Palaeophyllum pasense</u> and <u>P. sinclairi</u>, both with cateniform habits, occur stratigraphically higher than <u>P. argus</u>, in the uppermost portions of the Bighorn Formation, and are younger than the phaceloid <u>P. argus</u>. This illustrates a trend within <u>Palaeophyllum</u> from phaceloid toward cateniform or cerioid with time. Flower (1961, p. 88) discussed possible relationships between <u>Palaeophyllum</u> and Ordovician cerioid Rugosa. He stated that <u>Palaeophyllum</u> is related to <u>Favistina</u> Flower a new name (=<u>Favistella</u>) and <u>Cyathophylloides</u>, but the exact relationship is not certain since Flower's (1961, p. 83) concept of

<u>Favistina</u> encompasses a geologic age range from early Mohawkian to the latest Ordovician. <u>Cyathophylloides</u>, according to Flower, occurs later in Ordovician time, ranges into the Silurian and may be similar to a cerioid form of <u>Palaeophyllum</u>, both in terms of similar morphology and coincidence of occurrence in time.

Palaeophyllum argus Sinclair, 1961

Diphyphyllum stokesi Whiteaves, 1897, Geol. Survey Canada, Palaeozoic Fossils, v. 3, pt. 3, p. 152-153, pl. 17, figs. 5, 5a (?), 5b (?).

Columnaria rugosa Lambe, 1901, Geol. Survey Canada, Contrib. Canadian Palaentology, v. 4, pt. 2, p. 101-102, <u>non</u> pl. 6, figs. 3, 3a, 3b.

Palaeophyllum argus Sinclair, 1961, Geol. Survey Canada, Bull. 80, Contrib. Canadian Palaeontology, pt. 2, p. 12-13, pl. 4, figs. 1-4; pl. 7, fig. 4.

Diagnosis.--Phaceloid corallum with cylindrical corallites from 5 to 8.3 mm diameter; corallite wall thickness in hypotype averaging 0.05 times mean corallite radius; twenty to 21 major septa per corallite with a mean axial extension in hypotype of 0.77 times the mean radius; all but cardinal septum merging at or near corallite axis; twenty to 21 minor septa per corallite, short, averaging 0.05 times the mean radius in hypotype; adjacent corallites interconnected by "spiniform" or cone-shaped lateral processes interconnecting parent and daughter corallites; tabulae probably complete (?), convex with downturned peripheral margins. Description.--The small fragment of the phaceolid hypotype (UND Cat. No. 13704) appears to be at or near the point of origin of the colony. Corallites are cylindrical, with mature forms ranging in diameter from 7.0 to 8.3 mm (Appendix B, Table 33). Immature forms arise as hook-shaped or spinose, lateral processes giving rise to new individuals through peripheral increase. Corallite walls are longitudinally furrowed; each furrow corresponds to the position of the base of a major or minor septum. No transverse growth annuli were observed due to poor preservation. Twenty major septa occur in each corallite, and the average axial extension of all observed forms is 0.77 times the mean corallite radius (Appendix B, Table 33).

Major forms are thickened on their peripheral margins where they merge with the peripheral stereozone of the corallite wall. Much of this thickening may be due to these flanking stereoplasm deposits. Within the corallite lumen, they become progressively thinner closer to the corallite axis. Axial margins of the major septa are merged in a pattern in which two adjacent septa merge to form a pair at or near the corallite axis. These, in turn, frequently merge with other pairs of merging septa, forming a bilaterally symmetrical pattern about the cardinal-counter plane. The cardinal septum remains unmerged, as it is within a cardinal fossula formed by flanking major septa.

Minor septa are very short, 20 to a corallite, and barely project axially from the peripheral stereozone of the corallite wall. Observed length averages 0.05 times the mean corallite radius. Tabular spacing is indeterminable but the general tabular shape appears to be that of a central platform with peripherally downturned margins.

Type.--Hypotype, UND Cat. No. 13704.

Occurrence. -- The holotype (GSC No. 6878) and the paratype (GSC No. 6877) came from exposures of the Selkirk Member of the Red River Formation at Lower Fort Garry, Manitoba. The hypotype was collected from a quarry exposure of the Selkirk near Garson, Manitoba (Appendix A, locality A884).

Discussion.--Only one small fragment of a basal portion of a corallum of <u>Palaeophyllum</u> was collected from the Selkirk Member in Southern Manitoba. The degree of fragility and the occurrence of a single specimen (UND Cat. No. 13704) prevented the sectioning of the fragment for thin section study. Comparison with the holotype and paratype of <u>Palaeophyllum argus</u> Sinclair (Sinclair, 1961; Appendix B, Table 33) shows the hypotype to be very similar to Sinclair's (1961) original description of the species. All are phaceloid; all have "spiniform" (Sinclair, 1961, p.12) processes interconnecting adjacent corallites. All have a similar number of major septa with a similar degree of axial extension.

Tabular data in the hypotype was not determined. Sinclair's (1961) description of <u>P</u>. argus notes that the tabulae in the holotype and paratype have concave tabulae with steeply rising peripheries. One of his plate figures (1961, plate 4, figure 2) may be upside down. The lowermost corallite, in the figure, contains two incomplete tabulae, which if viewed in Sinclair's original orientation, are attached to the <u>underside</u> of a complete tabula. Few upwardly concave incomplete forms have been observed. Incomplete tabulae result from the partial detachment of the polyp basal disc from an existing tabula,

elevation of that basal area and secretion of an upwardly convex, dissepiment-like tabula. Therefore its description should be emended to indicate that tabulae are convex with downard-sloping peripheral margins. This agrees with partial sections observed in corallites in the fragmental specimen.

Palaeophyllum pasense Stearn, 1956

Plate 16, Figures 4, 5

Palaeophyllum pasense Stearn, 1956, Geol. Survey Canada, Mem. 281, p.

89, pl. 16, fig. 7.

Diagnosis.--Small, cateniform-cerioid corallum with corallite arrangement similar to Manipora sp., -- arranged in uniserial, cateniform ranks, outlines moniliform and trapezoidal outlines; corallites in cerioid portions polygonal with curved wall on outer surface; corallite diameter 2.6 to 4.6 mm; thirteen to 17 major septa in each corallite, uniformly thin, amplexoid, straight, merging only on distal tabular surface at or very near corallite axis; mean major septal extension 0.6 times the mean corallite radius in hypotype; minor septa 13 to 17 per corallite, short hypotype with mean extension of 0.33 times mean major septal length and 0.2 times mean corallite radius; corallite wall commonly of three layers; epitheca (=axial plate), fibrous sclerenchyme, fibrous peripheral stereozone. Axial plate and epitheca of uniform thickness and continuous along wall; tabulae complete, normal to corallite axis, with broad, planar central platform, and downturned peripheral margins segregated into zones of closely and widely spaced forms.

Description of material .-- The hypotype corallum (UND Cat. No. 13705) is small and fragmental with a maximum estimated diameter of 14 cm and a height of 5 cm. Adult corallites are 2.6 to 4.6 mm in diameter with a mean of 3.44 mm. A single budded offset is 2.2 mm in diameter. Corallites are cerioid-cateniform, grouped in agglutinative patches interconnected by uniserial cateniform ranks. Corallites within the ranks are usually in complete lateral contact with the adjacent ones and the intercorallite wall is nearly straight in transverse Corallites in the ranks have outlines varying from monilisection. form to trapezoidal. Agglutinative patches contain cerioid corallites with polygonal or subpolygonal transverse outlines. Major and minor septa per corallite vary from 13 to 17 for each type, with a mean count of 15.5. Increasing corallite diameter is accompanied by more septa (Figure 42) up to 17. Major septal extension is 0.3 to 0.92 times the mean corallite radius with a mean of 0.6 times the radius. Long major septa merge only on the distal surface of the tabulae at or very near the axis. Septa are generally straight, uniformly thin, and exhibit well-developed amplexoid retreat above the tabular surface where septal contact occurs. Maximum retreat shows major septa with an extension of only 0.3 times the corallite radius.

Minor septa are short, 0.03 to 0.15 times the mean corallite radius with a mean extension of 0.2 times the radius and 0.33 times the mean extension of the major septa.

Two types of corallite walls are present. Cateniform portions of the corallum have an outside wall composed of an outer epitheca and an inner fibrous sclerenchyme whereas walls between adjacent corallite

pairs in cateniform and cerioid regions contain a central axial plate flanked on both sides by sclerenchyme. Addition of stereoplasm to the wall structure produced a three-component wall similar to that in Palaeophyllum sinclairi (Figure 43). Intercorallite walls contain well-defined, continuous axial plates of uniform thickness and outside walls have an epithecal layer continuous with the plate layer and of the same thickness (Appendix B, Table 34). Fiber orientation of the sclerenchymal layer averages 48 degrees whereas mean fiber orientation in the stereozone is 134 degrees.

All tabulae are complete and normal to the corallite axis. All are elevated above the line of intersection with the corallite wall. The elevated platform is planar, no central depression occurs, and mean platform width is 0.52 times the corallite diameter. Zones of closely and widely spaced tabulae yield mean spacing values 0.59 mm and 1.23 mm respectively (Appendix B, Table 34).

Type.--Hypotype, UND Cat. No. 13705.

Occurrence.--The holotype of <u>Palaeophyllum pasense</u> (GSC No. 10403) was collected from the Stonewall Formation in the vicinity of The Pas, Manitoba. The hypotype occurred 5.2 meters (17 ft) above the top of the Hunt Mountain beds in the upper portion of the Bighorn Formation east of Hunt Mountain, western flank of the Bighorn Mountains, Wyoming (Appendix A, locality A546).

<u>Discussion</u>.--Comparison of the hypotype with the holotype of \underline{P} . pasense (Appendix B, Table 29) shows the following similarities:

 Corallum growth habits in both are cateniform; adjacent corallites are in ranks and are in lateral contact with each other.

- 2. Corallite diameters are similar.
- 3. Septal counts are comparable.
- 4. Major septa in both are very close to or in contact at the corallite axis but no extensive merging occurs.
- 5. Amplexoid retreat may occur in the holotype's major septa as close examination of Stearn's (1961, pl. 16, fig. 7) illustration of the holotype shows septa truncated by tabulae. The hypotype exhibits amplexoid retreat.
- 6. Tabulae in both have downturned peripheral margins, forming a broad, flat tabular platform.

Comparison of growth habits of the hypotype of <u>P</u>. <u>pasense</u> with <u>P. sinclairi</u> n. sp., reveals a possible evolutionary advancement in polyp intercommunication. <u>P. pasense</u> from northern Wyoming has a fragmentary corallum with peripheral offsets at discrete levels within the corallum. Surficial exposure of the upper portion of the corallum intersects a budding level where bursts of offsets with maturation form agglutinative patches. These appear to form a higher series of cateniform ranks that will, in turn, give rise to another budding level and resultant cerioid corallites. Lacunae in this species are commonly open and irregular in outline. <u>Palaeophyllum sinclairi</u> n. sp., by contrast, exhibits a greater degree of regularity in rank continuity and lacuna formation.

Lacunae near the corallum center are frequently closed and ranks are well-defined, continuous entities radiating from the point of colony origin. The greater regularity of rank and lacunae in

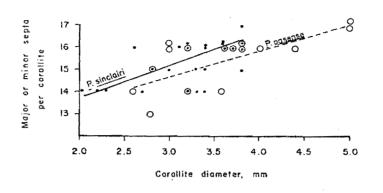


Fig. 42.--Scatter diagram and estimated lines for septal counts plotted against corallite diameter for <u>Palaeophyllum sinclairi</u> n. sp. (dots; UND Cat. No. 13706) and <u>P. pasense</u> (circles; UND Cat. No. 13705).

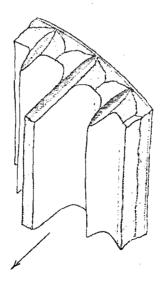


Fig. 43.--Portion of wall and septa of <u>Palaeophyllum sinclairi</u> n. sp. Fibrous septal structure shown by hachures. Patterned stippling shows wall fiber orientation. Clear area represents epitheca. Arrow toward corallite axis, approx. X50.

<u>p. sinclairi</u> n. sp., may be reflective of a greater degree of intercorallite communication and may illustrate an increment of evolutionary advancement away from <u>P. pasense</u>. This would signify a further step of the genus away from the phaceloid condition prevailing in older examples of the genus. Flower (1961, p. 40), in discussing growth habits of species of <u>Palaeophyllum</u> in the Second Value Member of the Montoya Group, noted the predominance of the phaceloid growth habit in these forms. Stearn's statement (1956, p. 90) that halysitoid (=cateniform) examples of the genus are generally restricted to the Richmondian stage when combined with Flower's discussion suggest that the phaceloid growth condition graded toward the cateniform habit with time.

Palaeophyllum sinclairí n. sp.

Plate 6, Figures 6-10

Diagnosis.--Small cateniform corallum, corallites commonly grouped in cerioid, agglutinative patches; corallites small; mean diameter approximately 3.5 mm in cateniform and cerioid corallum regions, with subrectangular or moniliform corallites in uniserial ranks, polygonal in agglutinative patches, circular when freestanding; thirteen to 17 major or minor septa per corallite, mean count 15; major septa commonly extending to corallite axis and fusing about septal plane of bilateral symmetry, predominantly uniformly thin from corallite wall to axial margin; amplexoid septal retreat rare or absent; minor septa short, embedded in sclerenchyme, mean total length 0.15 times the corallite radius, not intersecting elevated portions of tabulae; thick walls with well-defined, axial

plate; tabulae all complete, transverse to corallite axis, with rounded or planar, elevated central platform; spacing in poorly defined zones of crowded and less closely spaced tabulae.

Description of material. --- The holotype corallum (UND Cat. No. 13706) is small, 10 cm wide by 9 cm long with a height of 5 cm with an overall flattened hemispherical outline. Corallites radiate outward and upward from the point of origin of the colony. Cateniform portions of the corallum contain corallites arranged in uniserial ranks with no marked elongation parallel to rank direction. Merging of numbers of ranks produce agglutinative patches of cerioid corallites with an alternate biserial arrangement of corallites within them. Ranks in and near the central portion of the corallum often completely enclose lacunae that are oval or subcircular in transverse outline.

Corallites in cateniform ranks are subrectangular or moniliform in cross section whereas those in the cerioid regions are polygonal. Diameters of adult corallites in both cateniform and cerioid regions of the corallum range from 2.46 to 4.6 mm with a mean of approximately 3.6 mm. Budded corallites are approximately 2.2 mm in diameter. Mode of budding is extratentacular, with the offset arising from the parent corallite's periphery.

Fourteen to 17 major (an an equal number of minor) septa occur in each corallite with more in corallites of larger diameter (Figure 42). Major septa exhibit very little amplexoid retreat. Only 10 major septa in two corallites show retreat. The remainder of all observed major septa merge at or near the corallum axis. The pattern defined by merging is commonly bilaterally symmetrical. A central, cardinal-counter septal plane bisects the lumen, and the remaining

major septa tend to merge symmetrically on either side of the plane. All major septa are uniformly thin throughout their extent. Peripheral septal margins are embedded in stereoplasm that tends to remain structurally distinct from the septa. Wall thickening is due to the addition of wall stereoplasm on the flanks of the septa (Figure 43). Minor septa are short, with approximately half of their length buried in stereoplasm; the mean extension in this type of septa is 0.15 times the mean corallite radius. Observation of both major and minor types under transmitted and polarized light rarely shows a two-layered character, with septal fibers diverging outwardly and axially from a septal plane formed by the interior ends of the septal fiber sets (Figure 43).

Presence or lack of stereoplasm in both the outer corallite wall in cateniform ranks and the intercorallite wall between adjacent corallites results in varying types of wall structure. Walls without stereoplasm appear to be composed of two layers; an epitheca or axial plate and a flanking layer of fibrous sclerenchyme--the rugosan wall. This type is also present in such forms as <u>Paleofavosites</u> spp. and <u>Cyathophylloides hollandi</u> n. sp. Addition of stereoplasm to the corallite walls results in a third, structurally separate, fibrous layer, with fibers directed axially and downward into the corallite (Figure 43). Tabulae are complete and normal to the corallite axis. Tabulae are predominantly elevated above their level of attachment with the wall. A domed or planar platform above that level has a width nearly half the corallite diameter, with no axial sagging of the platform. Tabulae are closely spaced, from 0.16

to 1.1 mm, and are grouped into poorly defined zones of crowded and more widely spaced forms (Appendix B, Table 34).

Type.--Holotype, UND Cat. No. 13706.

Occurrence. -- The holotype was collected as float, 9.8 meters (32 ft) above the top of the Hunt Mountain beds in the upper portion of the Bighorn Formation, east of Hunt Mountain, Bighorn Mountains, Wyoming (Appendix B, locality A546).

Discussion .-- Species of Palaeophyllum with a cateniform growth habit are generally confined to the Richmondian stage (Stearn, 1956, p. 90), possibly indicating an evolutionary advancement over older species of Paleophyllum. These older forms are more commonly characterized by phaceloid growth in which cylindrical corallites separated from each other and frequently interconnected by tubules are oriented in subparallel fashion (Moore, Hill, and Wells, 1956, p. F248, F249). Transition with time to a cateniform (Moore, Hill, and Wells, 1956, p. F246) habit reflects increasing intercommunication between adjacent polyps, resulting in less amounts of skeletal material necessary to support a given number of polyps in closer proximity than in the phaceloid form. In the phaceloid coralla, communication between polyps was possible only if interconnecting tubules supported continuity of interpolyp coenosarc. Flower (1961) described and listed four species of Paleophyllum from the Montoya Group of New Mexico and west Texas. Of these four, only Palaeophyllum cateniforme Flower exhibits the cateniform growth habit. This occurs in the Second Value Formation, which contains a coral fauna notably similar to that of the Selkirk Member of the Red River Formation in southern Manitoba. Only Palaeophyllum argus is known from

the Selkirk Member. Therefore the cateniform habit of <u>P</u>. <u>cateniforme</u>, in a fauna correlative to that in the Selkirk, shows that <u>Palaeophyllum</u> in the Selkirk may not have had or needed the capability to form cateniform coralla. The ability for <u>Palaeophyllum</u> to form these coralla was established at the time that the fauna in the Selkirk and its correlative faunas were alive. This ability persisted up to the time that <u>P</u>. pasense and P. sinclairi n. sp., existed.

Comparison of these two species shows the following differences:

- <u>P. sinclairi</u> exhibits corallites in closer lateral contact and cerioid patches of corallites whereas Stearn's illustration of <u>P. pasense</u> (1956, plate 16, figure 7) shows corallites in less intimate contact. This may indicate that in the generic trend from phaceloid to cateniform, <u>P. sinclairi</u>, with its agglutinative patches and enclosed lacunae may be more advanced.
- Major septa of <u>P. pasense</u> are not fused at or near the corallite axis (Stearn, 1956, p. 89). <u>P. sinclairi</u> has the great majority of major septa fused in a bilaterally symmetrical pattern about a probable cardinal-counter plane.
- Tabulae of <u>P</u>. <u>pasense</u> are convex whereas those of <u>P</u>. <u>sinclairi</u> are strongly arched upward, commonly having a prominent axial platform or dome.

Only <u>P</u>. <u>pasense</u>, a closely related species, is closely comparable to <u>P</u>. <u>sinclairi</u>. These are the only cateniform species of <u>Palaeo-</u> <u>phyllum</u> found in the Bighorn Formation. <u>Palaeophyllum sinclairi</u> n. sp. is named for Dr. G. Winston Sinclair of the Geological Survey of Canada.

The walls of P. sinclairi contain two sets of fibers (Figure 43), forming chevron sets with their apices directed distally. Flower (1961, p. 88) mentioned the presence of a "fibrous lining with obscure radial units, obscurely trabecular." Fiber orientation in P. sinclairi is very faint (Plate 16, Figure 10). In other Tabulata and colonial Rugosa with the rugosan wall an axial plate or epitheca is flanked on one or both sides by fibrous sclerenchyme with fibers oriented upward and inward toward the corallite axis. In P. sinclairi the sclerenchymal layer is bounded laterally by the peripheral ends of the septa. Septal ends appear to merge or abut the epitheca or axial plate, isolating the sclerenchymal layer. Inward of the fibrous sclerenchyme, fibrous skeletal stereoplasm forms a third element in the corallite wall structure. Examination of the thickened corallite wall in longitudinal section revealed two sets of fiber orientation. Sclerenchyme has the orientation discussed above. The second, the stereozone, exhibits fibers oriented approximately 90 degrees away from those of the sclerenchyme (Plate 16, Figure 10). In longitudinal section, these are oriented upward and outward from the corallite axis (Figure 43). In transverse section, extremely faint longitudinal sutures are seen between each septum, defining a fiber set on each side of the suture. Fibers are directed away from the suture and appear to abut the flanks of the septa. The difference in fiber orientation between the sclerenchymal and stereoplasm layers indicates that the latter stereoplasm layers are formed by a process and basal plate location differing from that of the sclerenchymal layers formed-that stereoplasm is not simply a continuation of the sclerenchymal layer.

Flower (1961, p. 35) discussed the relation between septa and wall structures in <u>Palaeophyllum</u>, and noted an increase in specialization of septal fibers as species and septa grow larger. <u>P. sinclairi</u>, like <u>P. margaretae</u> Flower and <u>P. cateniforme</u> Flower, has septal fibers separate from the wall structure (Figure 43; Flower, 1961, figure 5c). However, <u>P. sinclairi</u> n. sp., does not show septal fibers aligned radially about the peripheral tip of axial planes within septa. This species seems to have the peripheral ends of the septa merging with the axial plate or its homologue, the epitheca. Thus the character of the peripheral ends of septa apparently varies within the genus.

Genus Grewingkia Dybowski, 1873

<u>Type species</u> (by subsequent designation, Sherzer, 1891, p. 284; not Wedekind, 1927, p. 18), <u>Clisiophyllum buceros</u> Eichwald, 1855, Leth. Rossica ou Paleont. de la Russie, v. 1, p. 108.

<u>Diagnosis</u>.--Solitary trochoid or ceratoid coralla with cardinalapical region commonly angulate, transverse outline varying from circular to subtrapezoidal; major and minor septa present; axial structure formed by vermiform axial ends of major septa and domed tabulae; planar portions of major septa restricted to regions peripheral to axial structure.

<u>Discussion</u>.--The species of <u>Grewingkia</u> encountered in the Selkirk Member of the Red River Formation exhibit forms gradational from <u>Grewingkia robusta</u> in which transverse profiles range from circular to subtrapezoidal or tear drop-shaped to <u>G</u>. <u>goniophylloides</u> in which the portion of the corallum exterior between the alar and cardinal septa is concave, reflecting two longitudinal, shallow furrows.

External corallum form, whether circular, subtrapezoidal, or slightly trilobate (as in <u>G</u>. <u>goniophylloides</u>) does not greatly affect the internal structures characteristic of <u>Grewingkia</u>. The prime differentiating character between <u>G</u>. <u>robusta</u> and <u>G</u>. <u>goniophylloides</u> in the Selkirk Member is the transverse outlines of the two species. Since the primary generic diagnostic features of the solitary Rugosa are based on internal morphological features, the prior assignment of <u>G</u>. <u>goniophylloides</u> to the genus <u>Lobocorallium</u> Nelson is not consistent with common practice. Nelson (1963, p. 34) remarked that the internal structures of <u>L</u>. <u>goniophylloides</u> appear very similar to those of <u>G</u>. robusta.

Grewingkia robusta (Whiteaves), 1896

[?]<u>Streptelasma corniculum</u>? Hall var., Whiteayes, 1881, Geol. Survey Canada, Rept. Progress 1879-1880, p. 57c.

<u>Streptelasma robustum</u> Whiteaves, 1896, Can. Record Science, v. 6, no.
7, p. 390; Whiteaves, 1897, Geol. Survey Canada, Palaeozoic
Fossils, v. 3, pt. 3, p. 153, pl. 18, figs. 1, la; Lambe,
1901, Geol. Survey Canada, Cont. Canadian Palaeontology, v.
4, pt. 2, p. 109, pl. 7, fig. 1; Troedsson, 1929, Medd. om
Gronland, v. 72, p. 108, pl. 24, figs. 1, 2, 4, 6-8, 9 (?);
Cox, 1937, Geol. Mag., v. 74, no. 1, p. 10, pl. 2, figs.
1-3; Baille, 1952, Manitoba Dept. Mines and Mineral
Resources, Pub. 51-6, p. 28.

<u>Streptelasma</u> cf. <u>robustum</u> Whiteaves, Wilson, 1931, Trans. Roy. Soc. Canada, 3rd ser., v. 25, sect. 4, p. 294.

Streptelasma ? arcticum Wilson 1931, Trans. Roy. Soc. Canada, 3rd ser., v. 25, sec. 4, p. 292, pl. 2, figs. 1-5.

Streptelasma arcticum Wilson, Cox, 1937, Geol. Mag., v. 74, no. 1, p.

10, pl. 1, figs. 6, 7, 8, 9.

- Streptelasma trilobatum Whiteaves ?, Baille, 1952, Manitoba Dept. Mines and Mineral Resources, Pub. 51-6, p. 28.
- <u>Streptelasma</u> spp. Miller, Youngquist and Collinson, 1954 [partim], Geol. Soc. America, Mem. 62, p. 10, pl. 7, figs. 1 (?), 2 (?), 3 (?), 4 (?); 5, 6; [non] 7, 8; 9 (?), 10 (?).
- <u>Streptelasma</u> aff. <u>S. foerstei</u> Troedsson, Duncan, 1956, Bull. U. S. Geol. Survey, 1021-F, pl. 22, figs. 4a, 4b.
- <u>Grewingkia robusta</u> (Whiteaves), Duncan, 1956, Bull. U. S. Geol. Survey, 1021-F, p. 226, pl. 21, figs. 4a, 4b; Nelson, 1963, Geol. Soc. America, Mem. 90, p. 33, pl. 8, figs. 1, a, b, 2, 3a-3f.
- [?]<u>Grewingkia</u> cf. <u>robusta</u> (Whiteaves), Brindle, 1960, Sask. Dept. Mineral Resources, Rept. 52, p. 12, pl. 1, figs. 1, 2.

Diagnosis.--Moderate to large, curved, trochoid to ceratoid corallum, usually with calicinal pit depth one-fifth to one-half the corallum length; most major septa withdrawn from axial region in mature coralla, with others forming an axial structure with width of 0.15 to 0.5 times the corallum diameter, with proportion of width occupied increasing with corallum maturity; angular projection along trace of cardinal septum an corallum exterior variable from absent to very prominent; resultant transverse profiles varying from circular to subtrapezoidal; cardinal septum in region of strongly developed cardinal angulation frequently shortened and emplaced in cardinal fossula. Description of material. -- The solitary hypotype coralla characteristic of the species (UND Cat. Nos. 13537, 13646, 13649-13650) vary in external form from trochoid in examples less than 35 mm in length to ceratoid for forms longer than that. All coralla are convex along the external trace of the cardinal septum and concave along the trace of the counter septum. Approximately one half to two-thirds of all observed coralla show development of external angulation of the cardinal surface of the corallum. This angulation produces coralla with transverse outlines varying from nearly circular to a subtrapezoidal to tear drop-shaped.

Angulate forms are wider than high, producing w/h values of more than 1 and show an increasing ratio as the corallum length increases. Angulation is most prominent in the apical and near apical portion of the coralla but it commonly carries into the distal portions of coralla that are more than 30 mm long.

Nonangulate coralla are commonly circular in outline or are higher than wide, yielding w/h values of 1 or less. The hypotypes studied show a maximum of 79 major septa and an equal number of minor types.

Septal insertion of both orders occurs at the cardinal and alar septa, forming distally diverging, longitudinal traces of their peripheral ends on the corallum exterior. Maximum rate of insertion for the hypotypes occurs between 0.5 and 4 mm above the apex. Minimum rates of insertion occur in the mature portions of the corallum at distances greater than 65 mm from the apex where lateral corallum growth of the corallum is at a minimum. Major septal length increases

as a function of the rate of increasing corallum diameter, but at a lesser rate (Figure 44a). This results in septa in mature portions of the coralla occupying proportionally less cross sectional area than in the immature growth stages, leaving a greater area at the axial region of mature coralla to be occupied by the axial structure than in less mature forms.

Minor septa do not occur in coralla or portions of coralla less than 10 mm distant from the apical end (Figure 44b). Extension of minor septa varies between 0.1 and 0.24 times the corallite radius. The minor septa are commonly completely embedded in the deposits of peripheral stereozone in corallum regions 10 to 15 mm above the apex. Distally from this, increasing septal extension and proportionately decreasing wall and stereozone thickness occur and the septa protrude through the stereozone.

Tabulae are axially domed axially, predominantly complete in the central portion of the corallum, and commonly incomplete in the regions between adjacent septa.

Major septa are withdrawn from the axial region of the corallum, resulting in an elevated calicinal floor formed by the distal surface of the uppermost tabula. Beginning at distances of 13 mm above the corallum apex, all hypotypes show that the exposed portion of the tabular surface increases in proportion to corallum width with increasing distance from the apex.

Axial structures are formed by a complex of merged axial ends of a minority of the major septa that form a vermiform, aulophylloid type of structure interconnecting adjacent levels of domed tabular structures. Strongly angulate examples frequently possess a strongly

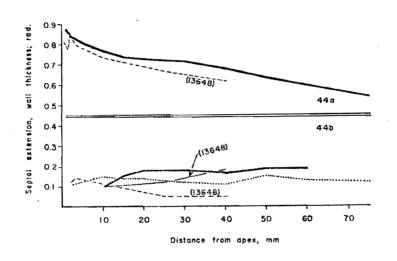


Fig. 44.--(a) Averaging curve (heavy solid line) for major septal extension for hypotypes of <u>Grewingkia robusta</u> and major septal extension (dashed line) for <u>G</u>. <u>goniophylloides</u> plotted against distance from apex.

(b) Averaging curves for minor septal extension (heavy solid line), wall-stereozone thickness (dotted line) for <u>G</u>. robusta; and minor septal extension (light solid line), wall-stereozone thickness (dashed line) for <u>G</u>. goniophylloides plotted against distance from apex. developed cardinal fossula in which the cardinal septum is commonly withdrawn from the axial structure. Coralla with little or no cardinal angulation usually have a cardinal septum as long as or longer than the remaining septa.

Types. -- Hypotypes, UND Cat. Nos. 13637-13646, 13649, 13650.

Occurrence. -- The species is widespread throughout Ordovician strata from the Canadian Arctic region, into southern Canada and the northern portion of the United States. Listed by region the species occur in the following areas:

Arctic:

Cape Calhoun, Greeland Cape Calhoun Formation (hypotypes, RMS Nos. 161(?), 179-181, 183, 185, 186) (Troedsson, 1929, p. 108): Snow Goose Bay, Lake Nettilling Baffin Island (hypotype, GSC No. 6499) (Wilson, 1931, p. 294), Akpatok Island, Ungava Bay, Northwest Territories, Canada (hypotypes, SMC Nos. A7865-A7868) (Cox, 1937, p. 11).

Hudson Bay Lowlands:

Member No. 1, Portage Chute Formation: North Knife River, Member No. 2, Portage Chute Formation: North Knife, South Knife, Nelson, and Churchill Rivers all near southwestern shore of Hudson Bay, northern Manitoba (hypotypes GSC Nos. 10358, 10807; plastotype GSC No. 10797) (Nelson, 1963, p. 33).

Southern Canada:

Jack Head Island, Snake Island, Deer Island, Little Black Island, Jack Head, Dog Head, Dancing Point Little Tamarack Island, and Selkirk Island, Lake Winnipeg Manitoba; junctions of the Little and Great Churchill Rivers (Whiteaves, 1897, p. 154, questionably referable to the species, hence only tentative assignment of above localities) Selkirk Member, Red River Formation; Lower Fort Garry, East Selkirk, Manitoba (hypotypes, GSC Nos. 6499, 6880a) (Cox, 1937), quarry exposures at and east of Garson, Manitoba (hypotypes, GSC No. 6880, SMC 7864, UND Cat. Nos. 13637-13646, 13649, 13650; Appendix A, localities A530, A884, A889, A892, A897), Yeoman beds, subsurface of southern Saskatchewan (Brindle, 1960).

Northern United States:

Bighorn Formation (lower massive portion?) Wyoming (Duncan, 1956); Red River Formation, subsurface of Dawson County, Montana (Ross, 1957).

<u>Discussion</u>.--A wide variety of sizes and corallum forms are characteristic of <u>G</u>. <u>robusta</u> with much of the variation of the two features due to the developmental stage at the time the coral died. Short, relatively young coralla are usually trochoid whereas older coralla tend to be longer and cylindrical or ceratoid. Both the angulate and nonangulate forms possess similar rates of lateral growth in relation to longitudinal growth.

Immature portions of coralla, 0 to 20 mm above the apex, show a great deal of variability of w/h values. Most angulate forms are wider than high (w/h>1) near the apical region with w/h ratios progressively decreasing away from the apex. At 20 mm from the apex, the angulate forms show an increase in w/h ratios, becoming wider with increasing maturity. A minority of the nonangulate forms also show w/h values greater than 1.0 at distances 0 to 20 mm from the apex. Increasing distance from the apical region and maturation shows a stabilization or decline in w/h ratios at or below 1--height exceeding width with increasing maturity.

Rates of insertion of major septa appears to be relatively constant for both angulate and nonangulate forms. Rates per unit distance above the apex yield the following for all hypotypes:

Distance Above Apex	Rate of Major Septal Insertion Per Unit Length
0.5-2.5 mm	16/mm
2.5-12 mm	1 to 1.7/mm
12-38 mm	0.3 to 1/mm
38-65 mm	0.1 to 0.42/mm
>65 mm	0

The proportional retreat of major septa from the corallum axial region show generally the same rate of withdrawal per unit length (Figure 44a).

Minor septa are inserted between 10 and 13 mm above the apex in the hypotypes southern Manitoba coralla (Figure 44b). Insertion of the minor forms occurs at an interval where major septa vary from 40 to 58 for the population studied. Minor forms increase in total length as a function of corallum radius, increasing age of the corals. Minor septal extension usually increases in relation to radius or remains constant. When compared to wall and stereozone thickness, minor septa are completely embedded in stereoplasm in their earliest stages. Minor septa protrude through the peripheral stereozone between 13 and 24 mm from the apex with septal extension and stereozone thickness values of 0.1 to 0.22 times the corallum radius. At greater distances from the apex, minor septa protrude for the remainder of the corallum.

Axial structures in <u>Grewingkia robusta</u> show a continuous increase of width proportional to corallum diameter and absolute width of the structure increases with polyp maturity and corallum length. Only two coralla (UND Cat. Nos. 13637, 13646) exhibit anomalous axial structures. This occurs in the first 12 mm above the apex where axial structures are wide with respect to corallum diameter, decreasing rapidly to above 12 mm where the proportional increase attains a nearly constant upward trend for the remainder of the life of the corals. Other hypotypes show increasing proportional axial structure widths in the coralla observed up to a point where, in mature adult coralla, the rate of axial structure width equals the rate of increase of the corallum diameter.

Evolutionary relationships.--Cardinal angulation in <u>G</u>. robusta varies from being completely absent to prominent. Hypotypes from the Selkirk Member show this and also show degrees of development between the extremes. The hypotypes characterized by very prominent angulation appear to have led to a form of <u>Grewingkia</u> characterized by this angulation and the development of a pair of shallow longitudinal furrows along the corallum exterior between the traces of the cardinal and alar septa. According to Nelson (1963, p. 35) these characters typify the species <u>G</u>. <u>goniophylloides</u> (Teichert). He describes the species, apparently a descendant of <u>G</u>. <u>robusta</u>, as

rather weakly trilobate and can attain maximum height of 130 mm. Poorly defined, shallow longitudinal furrow present along thecal wall of each cardinal quadrant. Cardinal lobe in most specimens disappear in ephebic stages and corallum has subquadrangular transverse outline.

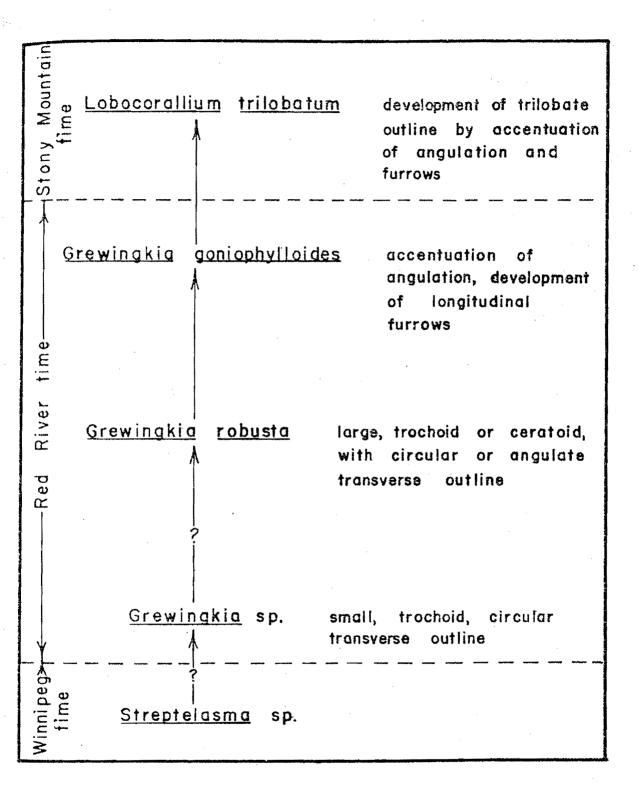


Fig. 45.--Suggested evolutionary relationships among <u>Streptelasma</u>, <u>Grewingkia</u>, and <u>Lobocorallium</u> (adapted in part from Nelson, 1963).

The existence of an angulate descendant of <u>G</u>. <u>robusta</u> and no nonangulate descendant of the species implies that the nonangulate representatives of the species were less well adapted than the angulate forms. The absence of nonangulate descendants of the species in faunas succeeding the Selkirk fauna indicates that the Selkirk fauna and its correlatives were where the survivability of the two forms was determined. Failure for the nonangulate forms to survive in succeeding faunas is further accentuated by the predominance of angulate and calceolid solitary corals such as <u>Lobocorallium</u>, <u>Dieracorallium</u>, and <u>Bighornia</u> in the succeeding faunas. Figure 45 illustrates the suggested evolutionary lineages for Grewingkia.

A hypotype of <u>G</u>. <u>robusta</u> Manitoba (UND Cat. No. 13641) illustrates the transition from this species to <u>G</u>. <u>goniophylloides</u>. The hypotype corallum is strongly angulate, nearly as much as the hypotypes of <u>G</u>. <u>goniophylloides</u> (UND Cat. Nos. 13647, 13648) but does not have the longitudinal furrow between the cardinal and alar septa. Only the presence of that feature distinguishes <u>G</u>. <u>goniophylloides</u> from its closely allied ancestor, <u>Grewingkia robusta</u>.

Grewingkia goniophylloides (Teichert), 1937

Plate 17, Figures 13, 14; Plate 18, Figures 1, 4 [?]Zaphrentis haysii Meek, 1865, American Jour. Sci. ser. 2, v. 40,

p. 32.

[?]<u>Streptelasma haysii</u> (Meek), Kirk, 1925, American Jour. Sci., ser. 5, v. 10, p. 445; Ladd, 1929, Iowa Geol. Survey, Annual Rept., v. 34, pt. 1, p. 396, pl. 4, figs. 1-5.

<u>Streptelasma foerstei</u> Troedsson, Cox, 1937, Geol. Mag., v. 74, no. 1, p. 6, pl. 1, figs. 10, 11a, 11b, 12, 13 (?), 14 (?), 15a, 15b, [non] fig. 16.

Streptelasma goniophylloides Teichert, 1937, Rept. Fifth Thule Exped.

1921-1924, v. l, no. 5, p. 49, pl. 3, figurs 5, 6 (?), 7-11. [?]Streptelasma sp. II, Roy, 1941, Geology Memoirs, Field Mus. Nat.

Hist., v. 2, p. 68, fig. 34d.

[?]Streptelasma sp. III, Roy, 1941, Geology Memoirs, Field Mus. Nat. Hist., v. 2, p. 68, figs. 34e, 34f.

- Streptelasma trilobatum Whiteaves, Baille, 1952, Manitoba Dept. Mines and Nat. Resources, Pub. 51-6, p. 28.
- [?]<u>Streptelasma</u> spp., Miller, Youngquist, and Collinson, Geol. Soc. America, Mem. 62, p. 10, pl. 7, figs. 7, 8.
- Streptelasma aff. S. goniophylloides Teichert, Duncan, 1956, U. S. Geol. Survey, Bull. 1021-F, pl. 22, figs. 3a, 3b.

Streptelasma aff. S. foerstei Troedsson, Duncan, 1956, U. S. Geol. Survey, Bull. 1021-F, pl. 22, figs. 4a, 4b.

[?]Streptelasma cf. goniophylloides Teichert, Brindle, 1960, Sas-

katchewan Dept. Min. Resources, Rept. 52, pl. 1, figs. 3, 4.

Lobocorallium haysi goniophylloides (Teichert), Nelson, 1963, Geol.

Soc. America, Mem. 90, p. 35, pl. 9, figs. 1a, 1b, 2a, 2b, 2c, 3a, 3b, 4.

<u>Diagnosis</u>.--Moderate size trochoid coralla with very pronounced cardinal angulation, faintly to strongly developed shallow, longitudinal furrows between traces of cardinal and alar septa; internal structures similar to <u>Grewingkia</u> robusta. Description of material.---Two hypotypes assigned to <u>Grewingkia</u> goniophylloides Teichert (UND Cat. Nos. 13647, 13648) are trochoid forms with very well developed cardinal angulation, especially pronounced in the apical one-third to one-half of the coralla. Each has one or two very faint longitudinal furrows located between the cardinal and alar septa. If one furrow is present, the opposite side is characterized by a planar region between the cardinal and alar septa. A slight of angulation developed at the alar and counter septa, plus the cardinal angulation, lends a slightly trapezoidal appearance to the transverse outline of coralla so equipped. The trapezohedron has angulation most prominent on the cardinal side and with less angulation on the counter and alar sides.

The two hypotypes show corallum width to be greater than height close to the apex (1 to 12 mm from apex). Distal to these regions, they exhibit a greater width increase per unit corallum length than for <u>G. robusta</u>. This is due to greater widths reflecting angulation present at the cardinal and counter regions of the perimeter of <u>G</u>. <u>goniophylloides</u>. Comparison of w/h ratios with the average of ratios for <u>G. robusta</u> show that <u>G. goniophylloides</u>, as represented by UND Cat. No. 13648 is consistently wider than high throughout its entire length. This is especially pronounced in the apical 18 mm of the corallum. Eighteen to 32 mm above the apex this specimen shows the width decreasing in relation to height, but above 32 mm corallum width rate increases markedly in relation to height throughout the remainder of the corallum.

The other hypotype (UND Cat. No. 13647) is characterized by the apical portion of the corallum being higher than wide (3 to 6 mm

above apex), but in the remaining distal portions of the corallum the width steadily increases in relation to height, reflecting cardinal angulation. Seventy-two major and an equal number of minor septa occur. Septal increase for both forms occurs at the cardinal and alar septa, and the direction of septal migration with continued longitudinal growth and septal increase is toward the counter side of the corallum.

Rates of septal increase closely parallel those of <u>G</u>. robusta up to approximately 21 mm from the apex. At greater distances, more septa have been inserted per unit corallum length than for <u>G</u>. robusta, reflecting a larger corallum perimeter in <u>G</u>. goniophylloides. Major septal extension relative to corallum radius closely parallels the average expressed for <u>G</u>. robusta whereas the rate of increase of septal length decreases relative to radius (Figure 44a). Minor septa are inserted at 10 to 12 mm above the apex and increase in relative length at a rate greater than that of the radius. Comparison with the averaging curve of <u>G</u>. robusta (Figure 44b) shows that the rate of increase for the hypotype of <u>G</u>. goniophylloides is greater than that of the <u>G</u>. robusta population.

Neither the major or minor forms are dilated with stereoplasm along their flanks. Both forms taper axially and are flanked at their peripheral ends by adjacent septa. Minor septa, 10 and 13 mm from the corallum apex, are immersed in peripheral stereoplasm (Figure 44b) but farther than 13 mm from the apex, they protrude through the stereozone. Stereoplasm deposits on the hypotype (UND Cat. No. 13648) are thinner than those shown by the averaging curve of <u>G. robusta</u>, indicating less stereozone or preburial abrasion of the theca.

Complete tabulae are domed axially and, with the vermiform axial ends of the major septa, form an aulophylloid axial structure. Relative width of the structure, compared to the average for <u>G</u>. <u>robusta</u>, shows a relative increase greater than that of G. robusta.

The cardinal septum is drastically shortened in mature portions of the corallum, forming a pronounced fossula containing the peripherally inclined portions of the tabulae.

Types.--Hypotypes, UND Cat. Nos. 13647, 13648.

<u>Occurrence</u>.--The species is widespread throughout the Arctic Islands, northern and southern Canada, and the northwestern United States where Ordovician strata contain macrofaunas similar to those of the Red River Formation.

Arctic:

Cape Frazier, West shore of Kennedy Channel, Ellesmere Island (Kirk, 1925, p. 445); Ordovician strata, Silliman's Fossil Mount, Frobisher Bay, southern Baffin Island (Miller, Youngquist, and Collinson, 1954); Cape Calhoun Formation, Cape Calhoun, northwestern Greeland (Cox, 1937).

Northern Canada:

Lowermost members, Surprise Creek Formation, Churchill and Nelson Rivers, west of southwestern portion of Hudson Bay, Hudson Bay Lowlands, northern Manitoba (Hypotypes, GSC Nos. 10793, 10795; plastotype, GSC No. 10794) (Nelson, 1963, p. 35).

Southern Canada:

Selkirk Member, Red River Formation (hypotypes UND Cat. Nos. 13647, 13648; southern Manitoba, Appendix A, localities A884, A893), Yeoman beds, subsurface southern Saskatchewan (Brindle,

Northern United States:

(?)Basal Bighorn Dolomite, Wyoming, Duncan, 1956). Midcontinent United States:

> (?)Upper portion of Elgin Member or possibly Clermont Member, Maquoketa Formation, Rodger's Creek exposure, Fort Atkinson, Iowa (Ladd, 1929, p. 397).

Small angulate coralla, possibly attributable to this species occurred 21.4 meters (70 ft) above the base of the lower portion of the Bighorn Formation, in Shell Creek Canyon, Bighorn Mountains, Wyoming (Appendix A, locality A532).

<u>Discussion</u>.--This species is similar to <u>G</u>. <u>robusta</u> (Whiteaves) in internal structure. Corallum width is slightly but consistently greater in the mature portions of the corallum than in <u>G</u>. <u>robusta</u>. All biometrics for <u>Grewingkia goniophylloides</u> are based on only two hypotypes. All biometrics for <u>G</u>. <u>goniophylloides</u> must be interpreted with the qualification that a wider range of biometrical features are highly likely.

Rates of major septal insertion, major and minor septal extension, wall and stereozone thickness, and axial structure relative width (Figure 44a, 44b) are all slightly different from the average for <u>G</u>. <u>robusta</u>. All are based on one hypotype and, when compared with individual variations for <u>G</u>. <u>robusta</u>, show less variation from the norm than do individuals of <u>G</u>. <u>robusta</u>. The two coralla assigned to <u>G</u>. <u>goniophylloides</u> are very close to the transition from <u>G</u>. <u>robusta</u> to that species. Only the presence of the longitudinal cardinal-alar furrow separates them from <u>G</u>. <u>robusta</u>. Even coralla with extreme development of cardinal angulation would be assigned in <u>G</u>. <u>robusta</u> if no furrow was present.

Nelson (1963, p. 34) stated that hypotypes of <u>Lobocorallium</u> <u>goniophylloides</u> have more closely spaced and strongly arched tabulae than <u>G. robusta</u>. However one hypotype (UND Cat. No. 13648) of <u>G</u>. <u>goniophylloides</u>, is close to the transition from <u>G. robusta</u>, has essentially the same internal structure as <u>G</u>. robusta.

Nelson's (1963) concept of <u>Lobocorallium goniophylloides</u> was based on a solitary coral with internal structures similar to <u>Grewingkia robusta</u> and an exterior surface with two broad longitudinal depressions between the alar and cardinal septa. The existence of a continuous gradation from <u>G. robusta</u> to forms corresponding to Nelson's <u>Lobocorallium goniophylloides</u> implies that the former species gave rise to a new genus with transitional forms in between the two, all within the same general time and space. The primary criterion used to distinguish <u>L. goniophylloides</u> from <u>G. robusta</u> is external shape-two longitudinal furrows--since internal structures of the two are similar.

Lobocorallium goniophylloides (Teichert) is placed in synonomy with <u>Grewingkia goniophylloides</u> because of similar internal structures showing that the polyp basal and secretory surfaces of both are similar in terms of basal plate invaginations, mesentary counts, and skeletal secretory centers. The prime differentiations between the two appears to have been a genetically controlled alteration of polyp shape due to variations in rates and direction of skeletal deposition, resulting in a corallum form with two longitudinal furrows. Such slight variations

do not warrant placement of the species in <u>Lobocorallium</u> if external shape is the prime diagnostic charater used to separate it from <u>Grewingkia</u>.

Evolutionary relationships. -- The hypotypes of <u>G</u>. goniophylloides resemble a specimen figured by Nelson (1963, plate 9, figures 3a, 3b; hypotype GSC No. 10795) in which transverse sections show a very slight pair of depressions between alar and cardinal septa. The hypotypes studied show transverse outlines most similar to that specimen and appear to represent a continuation of cardinal elongation and angulation began in <u>G</u>. robusta (Figure 45). Continued accentuation of longitudinal furrowing between the alar and cardinal septa; the resultant development of a trilobate outline and the resultant modifications to the interior structures produced a coral which corresponds to the diagnosis of <u>L</u>. trilobatum (Figure 45).

Grewingkia sp.

Plate 18, Figures 2, 3

Description of material.--A single straight, trochoid corallum (UND Cat. No. 13701) is 9 mm long and 9 mm wide along the traces of the cardinal and counter septa with a corallite angle of 45 degrees. Width along the cardinal-counter traces is 0.93 to 1.3 times the corallum height.

A portion of the preserved calicinal rim rises 1.3 mm above the distal margins of the major septa and the calicinal floor is slightly convex.

A maximum of 42 major septa occur at a distance of 10 mm above the apex. The length of major septa relative to the radius decreases

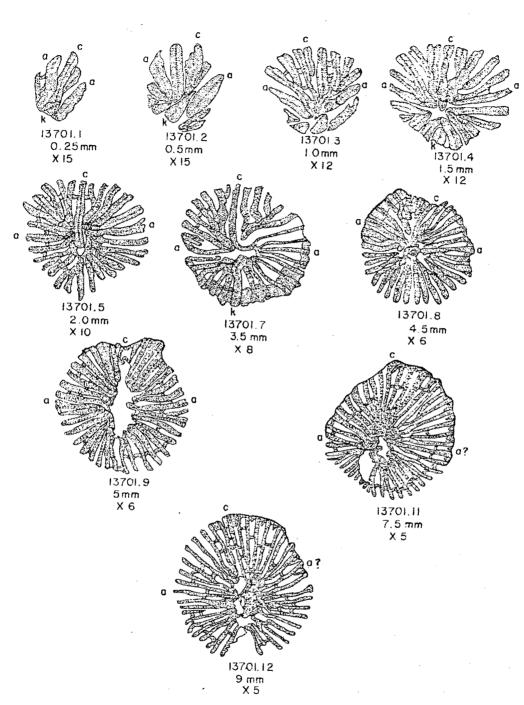


Fig. 46.--Serial peel tracings of <u>Grewingkia</u> sp. (UND Cat. No. 13701). Patterned stippling shows microstructure; c, cardinal septum; a, alar septum; k, counter septum. Distance from apex and scale given for each peel.

with increasing distance from the corallum apex and polyp maturation. The cardinal septum extends farther into the axial region of the corallum than do the other major septa, resulting in a relative length usually greater than the corallum radius. This results in a bilaterally symmetrical septal pattern with the remainder of the major septa extending close to the corallum axis, their slightly lobate axial ends remaining free or merged with adjacent septa (Figure 46). Minor septa are short and sparsely developed. Septa are not dilated and tend to be uniformly thick throughout their length (Figure 46).

Where preserved, corallum walls are thin, with no stereoplasm. Tabulae at the corallum center are complete, plane and normal to the corallum axis, whereas those at the periphery are predominantly convex, inclined toward the corallum periphery, and commonly incomplete. The resultant tabular composites are convex and have a surface deflection of 35 degrees from a plane normal to the axis. Tabular spacing varies from 0.6 to 1.3 mm with a mean of 0.78 mm 9 to 12 mm from the apex. An axial structure is formed by withdrawal of most septa from the corallum axis and by the twisted ends of the remaining septa emplaced on the distal surfaces of the tabulae. Axial structure width in relation to corallum diameter increases with distance from the apex, attaining a maximum of 0.4 times the diameter 9 mm above the apex.

Type.--Hypotype, UND Cat. No. 13701.

<u>Occurrence</u>. -- The single corallum (UND Cat. No. 13701) was collected as float from a slumped exposure of the Dog Head Member of the Red River Formation near West Dog Head Point on Lake Winnipeg (Appendix A, locality A902).

Discussion .-- Whiteaves (1897, p. 154) stated,

. . . a few comparatively small and very imperfect specimens which may be referrable to this species [<u>Grewingkia robusta</u>] were collected . . . at Dog Head, Dancing Point, Little Tamarack islands, and on the main shore opposite the north end of Selkirk Island and north of the Saskatchewan by D. B. Dowling in 1891.

Lambe (1901, p. 109) repeated Whiteaves' quotation but gave no description of the solitary corals he discussed to which the Dog Head corallum could be compared. The single coral collected may represent one of the corals referred to as <u>Grewingkia robusta</u> by the early workers (Whiteaves, 1897; Dowling, 1900; Lambe, 1901).

Assignment of the corallum to <u>Grewingkia</u> is predicated on the presence of an axial structure composed of the vermiform axial ends of a few of the major septa, slight lobation of the free axial ends of those not extending into the axial structure, and the merging of the axial ends of the remainder of the major septa with adjacent ones.

The corallum angle between the cardinal and counter sides is approximately 47 degrees for the hypotype coral whereas that for the hypotypes studied of <u>G. robusta</u> ranges from 80 degrees for the apical region to a minimum of 22 degrees. However, an estimated composite yields an angle of 55 degrees reflecting the greater rate of lateral increase in <u>G. robusta</u>.

The number of major septa versus distance from the apex does not reflect the greater rates of lateral increase in the <u>G</u>. <u>robusta</u> population where at a point 9 mm from the apex, the septal count of the hypotype coincides exactly with that of the average for G. robusta.

The comparative rates of septal retreat from the axial region are more rapid in the hypotype than in the <u>G</u>. robusta population.

Based on the hypotype of <u>Grewingkia</u> sp., growth rates may be less than that of the <u>G</u>. robusta population, but possible equal rates of longitudinal growth appear in this instance to have resulted in equal septal counts. Differing rates of septal retreat may be reflective of a proportionately wider axial structure in the individual example.

The Dog Head example probably represents a species separate from that of <u>G</u>. <u>robusta</u> based on (1) the predominance of small forms in the Dog Head Member as reported by earlier workers (Whiteaves, 1897; Lambe, 1901) and (2) varying rates of biometric changes compared to the <u>G</u>. <u>robusta</u> population. No large examples of that species have been previously reported from the member nor were any observed by the writer.

If the small Dog Head coralla do represent examples of the species <u>G</u>. robusta, then full maturity was not attained as occurred in the Selkirk Member. If this was true, then to maintain a viable widespread Dog Head population reproductive maturity must have occurred in relatively early developmental stages of the polyp. If the Dog Head specimen is an adult, then it may well represent a species separate from <u>G</u>. robusta. The occurrence of only small solitary coralla in the Dog Head Member may indicate this.

Macauley (1952) described two species he assigned to <u>Strepte-lasma</u> from the underlying Winnipeg Formation. No suitable illustrations of the corallum interiors were given so it is not possible to determine if both corals described by Macauley (1952) do indeed, belong to <u>Streptelasma</u>. Mention, by Macauley (p. 76) of major septa which are twisted to form a "pseudo-columella" in one of the forms

indicates that it belongs to <u>Grewingkia</u> and not <u>Streptelasma</u>. Only reexamination of Macauley's specimen will show if it is a Winnipeg Grewingkia.

<u>Evolution</u>.--If the hypotype of <u>Grewingkia</u> sp. (UND Cat. No. 13701) represents an adult and, if the single corallum is representative of the Dog Head Member population of <u>Grewingkia</u>, then an evolutionary trend toward forms of <u>Grewingkia</u> that occur in the Selkirk Member of the Red River Formation may be inferred (Figure 45):

- 1. A large, curved trochoid form (<u>G. robusta</u>) developed from earlier, small, straight, trochoid individuals.
- Cardinal angulation seen in some specimens of <u>G</u>. <u>robusta</u> developed from corals with a circular transverse outline.

Genus Lobocorallium Nelson, 1963

<u>Type species</u> (by original designation, Nelson, 1963, p. 34).--<u>Streptelasma</u> <u>rusticum</u> var. <u>trilobatum</u> Whiteaves, 1895, Geol. Survey Canada, Palaeozoic Fossils, v. 3, pt. 2, p. 113.

Emended generic diagnosis.--Curved solitary corals with markedly trilobate, transverse profile; strongly developed lobe crest at trace of cardinal septum on convex side of corallum, two less strongly developed lobe crests between alar septa and the counter septum; alar septal traces at bottoms of two, deep, longitudinal furrows on each side of the cardinal lobe; septa strongly dilated, cardinal lateral septa abutting cardinal septum; counter lateral septa commonly alar septa; cardinal fossula in mature portions of corallum; columella composed of anastamosing, vermiform axial ends of major septa; tabulae in columellar region planar and normal to corallum axis, proximally deflected in tabulatium periphery. <u>Remarks.</u>—The distinction between <u>Grewingkia</u> and <u>Lobocorallium</u> is made on the development of a lobate transverse profile and markedly dilated septa, commonly oriented in nonradiating fashion, in the <u>Lobocorallium</u> genus. These are reflective of a genetically controlled factor which determined the trilobate transverse shape of the polyp which in turn determined the trilobate profile of the corallum and the resulting arrangement of the septa in the interior of <u>L. trilobatum</u>. Assignment of <u>L. goniophylloides</u> Nelson <u>Grewingkia</u> leaves only one species, <u>L. trilobatum</u>, within the genus.

Lobocorallium trilobatum (Whiteaves), 1895

Plate 18, Figures 5-12

Streptelasma rusticum var. trilobatum Whiteaves, 1895, Geol. Survey

Canada, Palaeozoic Fossils, v. 3, pt. 2, p.113.

Streptelasma latusculum var. trilobatum Whiteaves, Lambe, 1901, Geol.

Survey Canada, Contributions Canadian Palaeontology, v. 4,

pt. 2, p. 115.

[?]Zaphrentis vaurealensis Twenhofel, 1928, Geol. Survey Canada, Mem.

154, p. 116, pl. 3, fig. 1.

- [?]<u>Streptelasma robustum</u> Whiteaves, Troedsson, 1929 [partim], Medd. om Gronland, v. 72, p. 108, pl. 25, fig. 2, non pl. 24, figs. 1, 2, 4, 6-8.
- [?]Streptelasma robustum var. amplum Troedsson, 1929, Medd. om Gronland, v. 72, p. 108, pl. 26, figs. 1, 2, 3 ?, 4a, 4b.

Streptelasma foerstei Troedsson, 1929, Medd. om Gronland, v. 72, p. 109, pl. 25, figs. 1, 3; pl. 26, fig. 5. [non]Streptelasma foerstei Troedsson, Cox, 1937, Geol. Magazine, v. 74, no. 1, p. 6, pl. 1, figs.10-11, 12, 13-16.

Streptelasma trilobatum Whiteaves, Cox, 1937, Geol. Magazine, v.74,

no. 1, p. 13, pl. 2, figs. 5a-c; Bassler, 1950, Geol. Soc.
America, Mem. 44, p. 20, 22, 23; Baille, 1952, Manitoba Dept.
Mines Nat. Resources, Pub. 51-6, p. 32; Duncan, 1956, U. S.
Geol. Survey Bull. 1021-F, p. 226, pl. 21, figs. 3a-b; Ross,
1957, U. S. Geol. Survey Bull. 1021-M, p. 456, 469, 474, pl.
37, figs. 1, 2; Nelson, 1959, Jour. Alberta Soc. Petroleum
Geologists, v. 7, no. 3, pl. 21, figs. 3a, b; Brindle, 1960,
Saskatchewan Dept. Min. Resources, Rept. 52, p. 17, table 1,
appendix, pl. 4, figs. 1, 2.

[?]Streptelasma sp. III Roy, 1941, Field Mus. Nat. Hist., Geology Mem., v. 2, p. 68, fig. 34f.

[non]Streptelasma trilobatum Whiteaves, Okulitch, 1943, Trans. Roy.

Soc. Canada, v. 37, sec. 4, pl. 1, figs. 13, 14.

Lobocorallium trilobatum var. major Nelson, 1963, Geol. Soc. America, Mem. 90, p. 35, pl. 5, fig. 1, pl. 8, fig. 4, pl. 10, figs. 1, 2a-h.

Diagnosis.--Large solitary corallum with strongly developed trilobate transverse profile; two deep, longitudinal furrows, floored by traces of alar septa; three lobes, one at cardinal region, two in counter-alar region; counter region commonly slightly convex in transverse profile; calyx deep in large coralla, with trilobate profile, steep sides; major septa in near-apical region dilated, filling corallum interior; minor septa and peripheral stereozone only where major septa not in lateral contact; columella commonly trilobate in large coralla, only where dilated septal portions withdrawn from axial region.

Description of material. -- Eleven of 14 complete and fragmental coralla are designated hypotypes (UND Cat. Nos. 13587-13589; 13597-13601, 13685, 13689). The range of corallum length for hypotypes from the Gunn Member of the Stony Mountain Formation is 23 mm (UND Cat. No. 13600) to 113 mm (UND Cat. No. 13686). One hypotype (UND Cat. No. 13687) collected from the upper part of the Bighorn Formation in the Hunt Mountain beds has a length at least of 21 mm whereas the longest hypotype (UND Cat. No. 13685) from the unit is in excess of 140 mm in length. All are trochoid or ceratoid types with a trilobate outline and with the trace of the cardinal septum on a cardinal lobe. The two other lobes trend longitudinally within each of the counter-alar quadrants. The alar septal traces are at the center of two well developed furrows separating the cardinal lobe from the two counteralar lobes. The trace of the counter septum occurs on the concave side of the corallum. The transverse profile of the counter region is often developed as a slight lobe separated from the two counteralar lobes by two very shallow longitudinal furrows, one on each side of the counter lobe. The corallum exteriors of hypotypes in excess of 30 mm length exhibit coarse annulate growth increments transverse to the corallum axis. These annuli are approximately 10 mm apart. Finer growth increments do not occur. Well preserved, epithecal surfaces do not exhibit septal furrows. One hypotype (UND Cat. No. 13587) possesses an corallum exterior free of all features other than the coarse annuli. The apical region of this hypotype and another (UND Cat. No. 13589) have a sharply pointed, trilobate apex

3.59

that appears to be similar to a mature corallum of <u>Dieracorallium</u> manitobense.

Calices on large, complete hypotypes (UND Cat. Nos. 13587, 13589, 13685) are deep, from 0.18 to 0.2 of the corallum length. The calicinal pit is floored by a broad, convex columella. The columellar width with respect to corallum height (measured between the counter lateral lobes) is 0.25 to 0.6 times the height.

Corallum height for the hypotypes from the Stony Mountain and Bighorn Formations increases uniformly as a function of increasing corallum length. At distances more than 90 mm from the apex however, the height per unit length decreases, possibly as a function of senescence. Corallum width between the traces of the cardinal and counter septa increases uniformly with increasing distance from the apex. No decrease in width occurs as there did with corallum height.

Corallum width/height plotted as a function of length yields a confusing picture when individual hypotypes are considered. The following UND Cat. Nos. 13588, 13589, 13600, 13601, 13685, are predominantly higher than wide throughout their length, whereas others (UND Cat. Nos. 13587, 13597, 13599, 13686) were wider than high.

The group studied of <u>L</u>. <u>trilobatum</u> is characterized by a steadily increasing width/height ratio as a function of increasing distance from the corallum apex.

The number of major septa increases as a function of corallum length up to a maximum of 140 mm from the apex in hypotype 13685. Serial peels of one hypotype No. (13599) and transverse sections of another (13597) show that dilated major septa almost completely fill the corallum interiors. Lateral attenuation of these septa occurs

in the calyx. Septal microstructure is of the trabeculate type. In transverse section (Plate 18, Figure 11) the septa consist of fibers radiating from a light, central portion. These fibers curve outward slightly and are arranged in V-shaped sets, the Vs opening toward the corallum axis. Longitudinal sections cutting through the plane of a septum (Plate 18, Figure 12) of one hypotype (13588) show the central portion of that septum to consist of rodlike trabeculae oriented with their axes normal to the corallum axis. The septa are thickened by fibrous sclerenchyme in which the fibers are arranged in the same orientation as those arising from the trabeculae.

Short, thin minor septa are observed only in the calicinal regions of two of the largest hypotypes (13685, 13686) where the major septa are attentuated. None of the transverse sections of other hypotypes (13597, 13598) shows any indication of minor septa. Minor septa occur only where major septa are not dilated to such a degree that they are in complete lateral contact.

No cardinal or alar fossulae occur in any transversely sectioned hypotypes (13597, 13598, 13599). In mature portions of these coralla the cardinal septum is commonly thinner than the adjacent major septa. The cardinal septum, at the apex of the cardinal lobe is flanked by septa in this lobe terminating with their axial ends touching the flanks of the cardinal septum. In one sectioned hypotype (Figure 47) serial peels taken from 0.25 to 3.25 mm from the apex show the cardinal septum to be the largest and thickest one at intervals closest to the apex (0.25-1.0 mm). Succeeding peels, however, show a gradual reduction of the length and thickness of that

septum as the corallum diameter increases and increasingly larger numbers of septa are contained.

Alar septa, on the other hand, are thick and prominent (Figure 47) with the axial ends of the counter lateral septa touching the counter side of the alar septa. The counter septum in the apical region of hypotype UND Cat. No. 13599 is shorter than any of the "mature" major septa. With increasing corallum maturity, however, the counter septum becomes as long as any of the adjacent septa (Figure 47).

A peripheral stereozone is developed only in regions where the major septa are not dilated so that they are in lateral contact. Tabulae, like minor septa and a peripheral sterezone, are developed only where major septa are either attenuated or withdrawn from the axial region.

The columella is developed in coralla sufficiently large to have major septa withdrawn from the axial region. Only four hypotypes studied exhibit septal retreat from the axial region. All these hypotypes are greater than 56 mm long. A rough trend occurs wherein the columellar width increases in proportion to corallum height as a function of increasing corallum length, with the width varying from 0.25 to 0.56 of the height.

The columella is constructed of anastamosing, attenuated axial ends of major septa similar to those in <u>Grewingkia</u>. Its transverse outline is trilobate, reflecting the trilobate, transverse profile of the corallum.

One hypotype (UND Cat. No. 13588) has tabulae near the calyx that are deflected at their margins, planar at their centers, and normal to the corallum axis. Spacing ranges from 1 to 2 mm (8 counts).

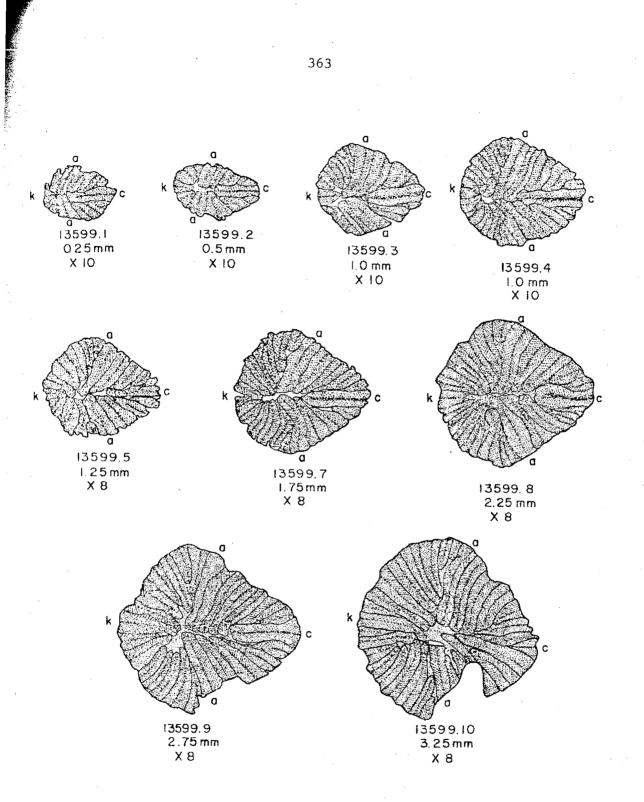


Fig. 47.--Serial peel tracings of <u>Lobocorallium trilobatum</u> (UND Cat. No. 13599). Patterned stippling shows microstructure. Corallum oriented in life position; a, alar septum; k, counter septum; c, cardinal septum. Distance from apex and scale given for each peel.

Types.--Hypotypes, UND Cat. Nos. 13587-13589, 13597-13601, 13685, 13687, 13688.

<u>Occurrence</u>.--Coralla assignable to <u>Lobocorallium trilobatum</u> (Whiteaves) and species definitely and questionably synonomous with the species are widespread throughout the central and northern portions of North America and the Arctic islands. Listed by region these occur in the following areas and rock-stratigraphic units.

Arctic Islands:

Cape Calhoun, southwestern corner, Washington Land, northwestern Greenland in the Cape Calhoun beds (Troedsson, 1929, p. 109); (?) Frobisher Bay, southern Baffin Island in Ordovician strata at Silliman's Fossil Mount (Roy, 1941, p. 69).

Eastern Canada:

(?) Vaureal River region, northern Anticosti Island in zone 5 of the Vaureal Formation (Twenhofel, 1928, p. 117).

Northern Canada:

Churchill River region, lowlands near southwestern shore of Hudson Bay, northern Manitoba; Hypotypes GSC No. 10796; Member No. 3, 10811 Member No. 1, Chasm Creek Formation (Nelson, 1963, p. 36).

Southern Canada:

Stony Mountain, Manitoba; Hypotypes UND Cat. Nos. 13587-13589, 13597-13600, 13686, 13687, zero to 4 meters (0 to 13 ft) below the top of the Gunn Member of the Stony Mountain Formation; zero to 1.8 meters (0 to 6 ft) above the base of the Penitentiary Member of the Stony Mountain Formation (Appendix A, localities A583-A585); Subsurface of southern Saskatchewan, in the Stoughton beds (Brindle, 1960, table 1). North-central United States:

South Fork of Rock Creek, eastern flank of Bighorn Range, Johnson County, Wyoming (Ross, 1957, p. 456); 1.6 km (1 mi) east of the summit of Hunt Mountain, on the western flank of the Bighorn Range, Sheridan County, Wyoming; Hypotype, UND Cat. No. 13687, 1.6 meters (5.2 ft) below the top of the Hunt Mountain beds, upper portion, Bighorn Formation (Appendix A, locality A539); Hypotype, UND Cat. No. 13685, 61 meters (20 ft) above the top of the Hunt Mountain beds (Appendix A, locality A547).

<u>Discussion</u>.--Small individuals of <u>Lobocorallium trilobatum</u> (Whiteaves) can be mistaken in the field for the small angulate coral <u>Dietacorallium manitobense</u>. The averaging curves for height, width, and width/height of the <u>D</u>. <u>manitobense</u>, when compared to those of <u>L</u>. <u>trilobatum</u> of the former species show the following contrasts. Corallum height per unit length of <u>D</u>. <u>manitobense</u> is less than that of <u>L</u>. <u>trilobatum</u>. Width/height values are slightly greater in <u>D</u>. <u>manitobense</u> than in <u>L</u>. <u>trilobatum</u>. <u>Lobocorallium trilobatum</u> is both wider and higher at specific distances from the apex than is the <u>D</u>. <u>manito-</u> <u>bense</u> population.

The largest contrast between the two species is in the rates of septal insertion per unit length. Comparison of Figures 47 and 48 show that <u>L</u>. trilobatum has a significantly greater number of septa at comparable distances from the apex than does D. manitobense.

The Stony Mountain hypotypes at hand correspond to Nelson's (1963, p. 36) statement that specimens from the unit are smaller than those in the group of <u>L</u>. <u>trilobatum</u> from the Ordovician strata in the

Hudson Bay region. Nelson (1963) stated, however, that the coralla from the Stony Mountain Formation lack an axial structure. The largest hypotypes (UND Cat. Nos. 13587,13686), however, show well developed columellae. Nelson (1963, p. 36) stated that a prominent cardinal fossula is characteristic of the mature hypotypes (GSC Nos. 10796, 10811) from the Hudson Bay region. None occurred in the sectioned hypotypes (UND Cat. Nos. 13597, 13598, 13599) from the Stony Mountain Formation.

None of the hypotypes of L. trilobatum from the Stony Mountain Formation attains the sizes (up to 230 mm length) cited by Nelson (1963). The largest Stony Mountain hypotypes attain lengths of up to 110 mm. Of the two hypotypes collected from within and above the Hunt Mountain beds in the upper part of the Bighorn Dolomite (UND Cat. Nos. 13687 and 13685) the first is small, 20 mm long and the latter is the largest hypotype at hand, in excess of 140 mm length. If these can be construed as being representative of the sizes attained by the species, then the <u>L. trilobatum</u> population in the argillaceous Hunt Mountain beds is characterized by very small coralla whereas the population in the overlying strata attained sizes nearly comparable to those cited by Nelson (1963, p. 36) for Ordovician strata in the Hudson Bay region.

Thus, it appears that the Hudson Bay region population lived under very favorable environmental conditions. Those in the strata overlying the Hunt Mountain beds apparently existed under environmental conditions nearly as favorable as those which prevailed in the Hudson Bay region during the Ordovician. The Stony Mountain population of <u>L. trilobatum</u> existed under conditions less favorable than those of the two previous populations, and the Hunt Mountain population appeared to exist under the least favorable conditions of all.

Lobocorallium trilobatum represents the terminal stage in an evolutionary lineage (Nelson, 1963, p. 34) beginning with <u>Grewingkia</u> sp. in the Dog Head Member of the Red River Formation (Figure 45). The lineage began with a small ceratoid <u>Grewingkia</u> sp. with a circular transverse outline and continued through a type of <u>G</u>. robusta characterized by a large, curved corallum with a distinct cardinal angulation. Development of two shallow, longitudinal furrows on each flank of the angulation produced <u>Grewingkia goniophylloides</u>. Deepening of the longitudinal furrows and accompanying modification of the <u>Grewingkia</u>-type corallum interior to one characteristic of Lobocorallium trilobatum indicated the terminal state of the evolutionary lineage.

Genus Dieracorallium Nelson, 1963

<u>Type species</u> (by original designation).--<u>Dieracorallium manito</u>bense Nelson, 1963, Geol. Soc. America, Mem. 90, p. 37.

Generic diagnosis.--Solitary corals in which the longitudinally convex side of the thecal wall is markedly angulated, the angulation corresponding to the outer extremity of the cardinal septum. The calyx is fairly deep.

Septa are numerous, simple, show excellent tetrameral symmetry and join at the center of the corallum without twisting. A welldefined cardinal fossula is present.

Tabulae are closely spaced and nearly flat or gently convex upward (Nelson, 1963, p. 37).

<u>Remarks</u>.--Species of the genus occur in the Selkirk Member of the Red River Formation, the Gunn Member of the Stony Mountain Formation of southern Manitoba, and the Hunt Mountain beds in the Bighorn Formation in northern Wyoming.

The Gunn and Hunt Mountain specimens are represented by <u>Diera</u>corallium manitobense Nelson that may be mistaken for immature specimens of <u>Lobocorallium trilobatum</u> since both exhibit a prominent cardinal angulation. Internal structures however, are not similar.

Dieracorallium manitobense Nelson, 1963

Plate 19, Figures 1-12

[?] Streptelasma angulatum (Billings), Lambe, 1901, Geol. Survey Canada,

Cont. Canadian Palaeontology, v. 4, pt. 2, p. 112; Twenhofel,

1924, Geol. Survey Canada, Mem. 154, p. 11.

[?]Streptelasma prolongatum Wilson, 1926, Geol. Survey Canada, Bull.

44, Geol. Ser. 46, p. 11, pl. 1, figs. 3, 4, 5, <u>Streptelasma trilobatum</u> Whiteaves, Okulitch, 1943, Trans. Roy. Soc.

Canada, v. 37, sec. 4, p. 61 (?) pl. 1, figs. 13, 14.

Dieracorallium manitobense Nelson, 1963, Geol. Soc. America, Mem. 90, p. 37, pl. 13, figs. 1,2a, b.

p, 57, p1, 15, 1260, 1,20, 5, 5

<u>Diagnosis</u>.--Small trochoid coralla up to 25 mm length with prominent cardinal angulation and epitheca marked by growth increments or featureless; calyx deep, up to one half the corallum length with prominent cardinal fossula; up to 46 trabeculate major septa abutting without merging, tetrameral symmetry; short minor septa.

Description of material.--A total of 95 coralla represent the species studied. Seventy-three were collected from the Gunn Member of the Stony Mountain Formation. Of these, 16 are designated as hypotypes (UND Cat. Nos. 13574-13580, 13590-13602, 13603). Twenty-two coralla were collected from the Hunt Mountain beds of the Bighorn Formation and five are designated at hypotypes (UND Cat. Nos. 13676-13680). All are characterized by being curved, trochoid types modified by a prominent cardinal angulation. The cardinal side of the curved corallum is strongly convex. The counter side is concave and the alar portions of the corallum are commonly angulate, lending a distinctly trilobate and triangulate, transverse outline to most of the specimens.

Specimens of <u>D</u>. <u>manitobense</u> from the Stony Mountain and Bighorn differ slightly. Specimens from the Hunt Mountain beds are generally less than 15 mm whereas those from the Gunn Member are up to 25 mm long. Specimens from the Bighorn population vary less in height and have greater height per unit of corallum length than the Gunn population. The Gunn population shows a wider range of variability of height than the Bighorn population but the average height per unit corallum length is generally less.

Corallum width between the cardinal and counter septa for the two populations shows similar variation. The Bighorn population is characterized by a lesser range of variation in width and a greater verage width per unit corallum length than the Gunn population. However, between 10 and 15 mm from the apex the averaging curve and range of widths for the Bighorn population converge toward those of the Gunn population.

The average w/h ratios for the Gunn population varies between width/height values of 1.04 and 1.14. Calyx depth with respect to corallum length is variable. Small coralla (less than 9 mm long) have calices ranging in depth that are from 0.15 to 0.23 times the corallum length. Coralla between 9 and 14 mm in length have depths that vary from 0.1 to 0.4 times the length with most ranging from 0.2 to 0.4. The longest coralla (more than 14 mm length) have shallow calices, with depths ranging from 0.2 to 0.3 times the length.

These are based upon the measurement of 7 hypotypes (UND Cat. Nos. 13603, 13575, 13577-13580, 13590) and 11 specimens (UND Cat. No. 13682). Calyx depth tends to increase with increasing corallum length for coralla up to 14 mm length. Beyond those lengths, the calices do not exceed a maximum of 5 mm depth.

Up to 46 major septa are present and are arranged in tetrameral symmetry. The prominent cardinal fossula and smallar alar fossulae demarcate portions of the transverse corallum profile (Figure 48).

Septa are dilated and commonly fill the corallum interior. Exceptions to this occur in the fossulae and close to the calyx where the septa are not as thick as those deeper in the corallum.

Minor septa, if present, are completely embedded within the septal stereoplasm or within the peripheral stereozone near the calyx. One hypotype (UND Cat. No. 13590) has 14 short minor septa and 27 major septa 7.5 mm from the apex.

Septal microstructure in transverse section (UND Cat. No. 13596) consists of chevron-shaped bundles of fibers radiating from the central plane of the septum. Longitudinal sections through the plane of a septum show each septum to be comprised of trabeculate rods. These rods are oriented axially and slightly proximally, at an angle of 80 degrees to the corallum axis.

Tabulae, observed in only one hypotype (UND Cat. No. 13594) are planar axis and normal to the axis. Peripheral regions of the tabulae are deflected proximally. Tabular spacing varies from 0.64 to 1.4 mm (5 counts).

<u>Types</u>.--Hypotypes UND Cat. Nos. 13574-13580, 13590-13596, 13602, 13603, 13676-13680; catalogued specimens UND Cat. Nos. 13681 (56 speci-

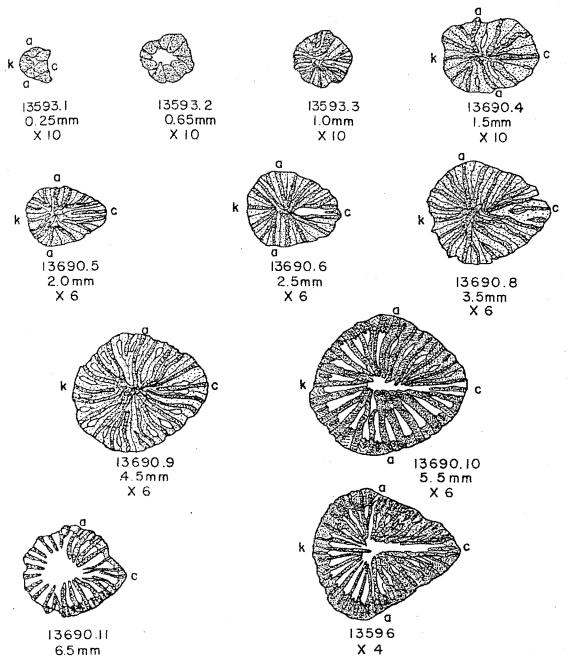


Fig. 48.--Serial peel tracings of <u>Dieracorallium manitobense</u> (UND Cat. Nos. 13590, 13593, 13596). Corallum oriented in life position. Patterned stippling shows microstructure; c, cardinal septum; a, alar septum; k, counter septum. Distance from apex and scale given for each peel.

X 4

Occurrence.--Nelson (1963, p. 38) collected the holotype and paratypes from the following rock units and localities in the lowlands near the southwestern shore of Hudson Bay.

Holotype GSC No. 10844; Member No. 1 of the Caution Creek Formation on

the Churchill River,

Paratypes GSC Nos. 10355, 10846; Member No. 1 of the Caution Creek Formation on the Churchill River,

Paratype GSC No. 10845; Member No. 1 of the Chasm Creek Formation at the Churchill River.

The hypotypes and specimens studied occurred in the stratigraphic units at the following localities:

Hypotypes UND Cat. Nos. 13574-13580, 13590-13596, 13602, 13603, 13676-

13680; Zero to 3.4 meters (0 to 11 ft) below the top, Gunn Member, Stony Mountain Formation at a quarry near Stony Mountain, Manitoba (Appendix A, locality A584).

Hypotypes UND Cat. Nos. 13676, 13677, 13679, 13680; specimen, UND Cat. No. 13682; Hunt Mountain beds, Shell Creek Canyon, Bighorn County, Wyoming (Appendix A, locality A531).

Hypotype UND Cat. No. 13678; specimen, UND Cat. No. 13683, 13684; 0.4 and 5.2 ft below the top of the Hunt Mountain beds, east of Hunt Mountain, Sheridan County, Wyoming (Appendix A, locality A539, A549).

<u>Discussion.--Dieracorallium manitobense</u> Nelson can be readily distinguished from coralla of similar size of <u>Bighornia patella</u> (Wilson). <u>Bighornia patella</u> is characterized by two subdued angulations along the traces of the alar septa that show a slight degree of lateral curvature when coralla are viewed from the apical end. <u>Dieracorallium</u> <u>manitobense</u>, on the other hand, is characterized by a single, prominent cardinal angulation which, when viewed from the apex, shows no lateral curvature. <u>D. manitobense</u> is distinguished from the <u>B. patella</u> by a prominent fossula in the plane of cardinal angulation. Transverse outlines of coralla of the species show a variation in shape from circular outline modified by cardinal angulation through a subtriangular to a strongly trilobate outline.

The Gunn population is characterized by values for width, and width/height a gap exists between 1.75 and 2.5 mm from the apex. This is due to two differing methods of measurement used. For measurements in the apical region (less than 1.75 mm) height and width was measured by the use of serial acetate peels of four of the hypotypes (UND Cat. Nos. 13590-13593). For measurements farther from the apical region (greater than 2.5 mm) a vernier caliper was used. This method of measurement is less accurate than the use of peels and the difference in resolution between the two is expressed as the previously mentioned gap.

Comparison of the number and length of the coralla in the Gunn Mountain and Hunt Mountain populations shows these differences: 1) more individuals (73) in the Gunn than in the Bighorn population (22); and 2) larger coralla (up to 25 mm length) in the Gunn population than in the Hunt Mountain (no more than 15 mm length). This indicates that the individuals in the Stony Mountain population may have existed under more favorable environmental conditions than did those representing the <u>D</u>. <u>manitobense</u> population in the Hunt Mountain beds. The two populations represent fossil assemblages however and may not necessarily reflect the <u>D</u>. <u>manitobense</u> communities extant during the Ordovician.

If the fossil populations do represent, at least in part, the living populations of <u>D</u>. <u>manitobense</u>, then it would appear likely that individuals in the Gunn population lived longer (or grew faster) and were more numerous than in the Bighorn population. The probability of longer life is reflected in the greater length of the attained by coralla in the Gunn population than in the Hunt Mountain population.

Wilson (1926) discovered small, prominently angulate, streptelasmoid corals in the Beaverfoot Formation of eastern British Columbia. Nelson (1963, p. 38) mentioned that these corals, assigned to <u>Strepte-lasma</u> prolongatum Wilson, are very similar to <u>D. manitobense</u> but that they are larger and less strongly angulated. Wilson (1926, p. 11) stated,

The strikingly elongated pseudofossula is the cause of a sharp angle upon the slightly curved side of the outer surface, the outline at the opposite end of the diameter [counter side of the corallum] being semi-circular.

Wilson (1926, p. 38), in discussing the characters of <u>S</u>. prolongatum, mentioned that the axial ends of the 35 to 55 major septa twist slightly at the axis. This twisting is not present in the figured holotype and paratype (Nelson, 1963, plate 13, figures 1, 2a, b) and hypotypes and specimens of <u>D</u>. <u>manitobense</u> from the Gunn Member and Hunt Mountain beds. Furthermore Wilson (1926, p. 12) said that the twisted ends of the septa cause a "cellulose" structure that forms a columella rising above the calyx floor.

Wilson (1926) cited corallum lengths of up to 40 mm, whereas Nelson (1963) had holotype and paratypes of <u>D. manitobense</u> that did not exceed 20 mm in length. Hypotypes cited in this study attain a maximum length of 25 mm.

It is possible that <u>S</u>. <u>prolongatum</u> represents a mature form of a species corresponding or similar to <u>D</u>. <u>manitobense</u>. The lengths cited by Wilson (1926) are all greater than those cited for any coralla of <u>D</u>. <u>manitobense</u>. If this possibility is true, then septal twisting and "cellulose" columella cited by Wilson (1926) would represent mature features not occurring in younger coralla of <u>D</u>. <u>manitobense</u> and <u>S</u>. <u>prolongatum</u> would definitely be a senior synonym. This could be verified by examination of serial sections of <u>S</u>. <u>prolongatum</u> to determine whether the neanic portions of the coralla correspond to those of <u>D</u>. <u>manitobense</u>.

However, three hypotypes of <u>D</u>. <u>manitobense</u> (UND Cat. Nos. 13578-13580) have corallum walls bent inward at the calicinal rims. These are presumed to be mature examples of the species since they are up to 20 mm in length. This axial deflection of the corallum wall at the calicinal rim represents a reduction in polyp diameter, probably reflecting senescense. This may represent the terminal developmental state of <u>D</u>. <u>manitobense</u>, and coralla of 20 to 25 nm lengths would be the maximum size, making <u>D</u>. <u>manitobense</u> a species separate from <u>Streptelasma prolongatum</u>. Therefore <u>S</u>. <u>prolongatum</u> Wilson is only questionably included in synonomy with D. manitobense.

Dieracorallium sp.

Plate 19, Figures 12-14

Description of material. -- One poorly preserved corallum (UND Cat. No. 13674) is the only representative available for study. It is small, 10.9 mm long by 8.5 mm high (along the trace of the alar septa) by 10.9 mm wide (along traces of cardinal and counter septa).

At least 0.5 mm of the apical region is missing. The corallum is essentially a modified trochoid form with an apical angle between the cardinal and counter septal traces of 66 degrees. The angle between the alar septal traces is 35 degrees. The angle between the cardinal and counter traces is less acute than the other angle, due to a pronounced angulation in the region of the cardinal septum. Only a shallow calyx, 2.0 mm in total depth and 0.18 times the total corallum length, is preserved. Twenty-seven major septa occur 5.75 mm from the corallum apex. All but the cardinal septum are dilated to such a degree that the corallum interior is completely filled save for a pronounced cardinal fossula. All generally merge or nearly merge at the axis without twisting (Figure 49).

Septal microstructure is generally indeterminable as viewed in serial peels but vague chevron-shaped patterns were discernible. Apices of the chevron-like fiber sets appear to have been directed both axially and peripherally. These, however, may not represent true fiber orientation. No minor septa or tabulae are present in the specimen at hand.

Type.--Hypotype, UND Cat. No. 13674.

Occurrence. -- The single specimen occurred in the Selkirk Member of the Red River Formation at a quarry near Garson, Manitoba (Appendix A, locality A530).

<u>Discussion</u>.--The single hypotype at hand is the only example of <u>Dieracorallium</u> reported from the Red River Formation. Due to extensive silicification of the wall region of the corallum and accompanying loss of a portion of the apical region, assignment to a species was not attempted. Generic assignment, however, is possible since diagnostic characters of the genus <u>Dieracorallium</u> are discernible. These are (1) pronounced angulation of the corallum in the cardinal region, (2)

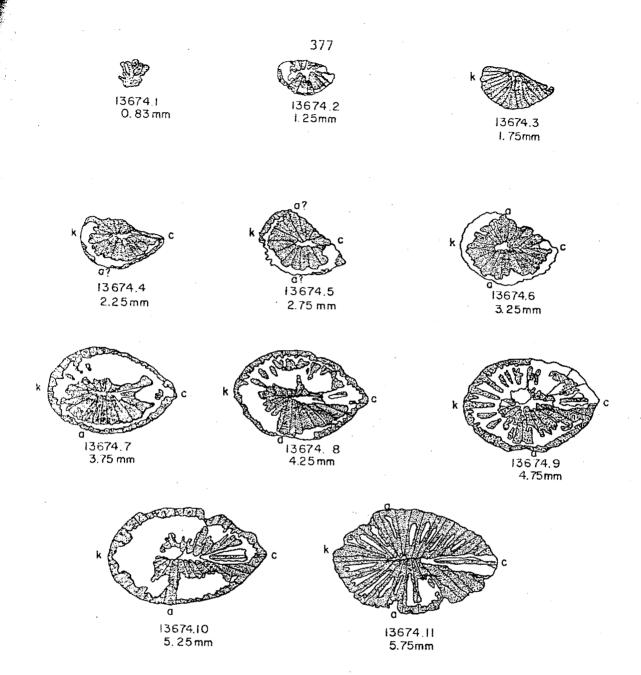


Fig. 49.--Serial peel tracings of <u>Dieracorallium</u> sp. (UND Cat. No. 13674). Corallum oriented in life position. Patterned stippling shows microstructure; c, cardinal septum; a, alar septum; k, counter septum. Distance from apex given for each peel, approx. X6.

filling of the corallum interior except for the prominent cardinal fossula by dilated cardinal lateral and counter lateral septa, and (3) septa meeting axially without twisting (Figure 49).

The corallum is small and possibly represents a relatively immature form. Nelson (1963, p. 37) stated that two diagnostic characters of <u>Dieracorallium</u> are a deep calyx and closely spaced, planar or slightly convex tabulae. Neither occur in the hypotype.

Genus Bighornia Duncan, 1957

<u>Type species</u> (by original designation).--<u>Bighornia parva</u> Duncan, 1957, Jour. Paleontology, v. 31, no. 3, p. 608.

<u>Diagnosis</u>.--Solitary corals with streptelasmid septal structure; counter side of corallum convex, always flattened in the apical region; angulation generally developed along traces of alar septa in neanic stages; epitheca marked by faint longitudinal ridges and grooves, fine transverse striae, and in some species, relatively weak rugae; conspicuously shortened cardinal septum in well-defined fossula on concave side of corallum; typically with a lathe-like terminally rounded columella formed primarily by thickened axial end of counter septum and arising from a Grewingkia-like axial structure (Duncan, 1957, p. 608).

Remarks.--Duncan (1957, p. 608) stated,

Septal microstructure in <u>Bighornia</u> is similar to that in other Ordovician streptelasmid corals (see Wang, 1950, p. 213, pl. 5, fig. 22, 23). The septa and columella are fibrous and not clearly trabeculate and the axial edges of the septa are finely denticulate.

The species <u>Bighornia cvancari</u>, n. sp., a flattened ceratoid species, contains a paratype (UND Cat. No. 13606) in which the septal microstructure shows a trabeculate character. This is shown by the expansion of the septal axial plate (Flower, 1961, p. 35) at irregular intervals along the length of the septa. This character appears to fit with Duncan's statement (1957, p. 608) that the distal edges of <u>Bighornia</u> septa are denticulate. This contrasts, however with her statement (1957, p. 608) that the septa of the genus are "not clearly trabeculate."

Hill (1956, p. F338) stated that <u>septal teeth</u> or <u>dentations</u> in Scleractinia are "... formed along the upper margin of the septum if the trabecular axes project beyond the connective tissue or if the trabeculae are too far apart for the intervening spaces to be filled. They reflect the underlying structure of the septum."

Kato (1963, p. 582) recognized two types of rugosan septa; (1) <u>fibro-normal</u> in which the component fibers are oriented normal to a median dark line (Flower's, 1961, p. 35, axial plate), and (2) <u>trabecular</u> in which divergent fibers make up a septum. Kato (1963, p. 582) stated, "... as a consequence of gently doming or folding of basal ectoderm, divergent fibers are formed to make up a septum. This doming also occurs in the direction of septal elongation so that the distal end of septum or basal ectoderm looks like a series of cone-like invaginations." Thus septal denticulation should be regarded as indicative of a trabecular aspect of septal microstructure in <u>Bighornia</u>.

In <u>Bighornia</u>, width is measured as the distance between the traces of the alar septa and height is the distance between the cardinal and counter septal traces.

Bighornia tyndallensis n. sp.

Plate 19, Figures 15, 18, 19

Diagnosis.--Small calceolid corallum with coarse transverse growth annulations; width greater than height; cardinal side of

corallum slightly concave in longitudinal profile, curved in transverse profile; counter side convex in longitudinal profile, subplanar in transverse profile, expanded laterally in direction of alar portions of corallum; maximum of 38 major septa and no discernible minor septa within 6 mm of the corallum apex; columella formed by massive structure in which axial ends of septa terminated; no tabulae.

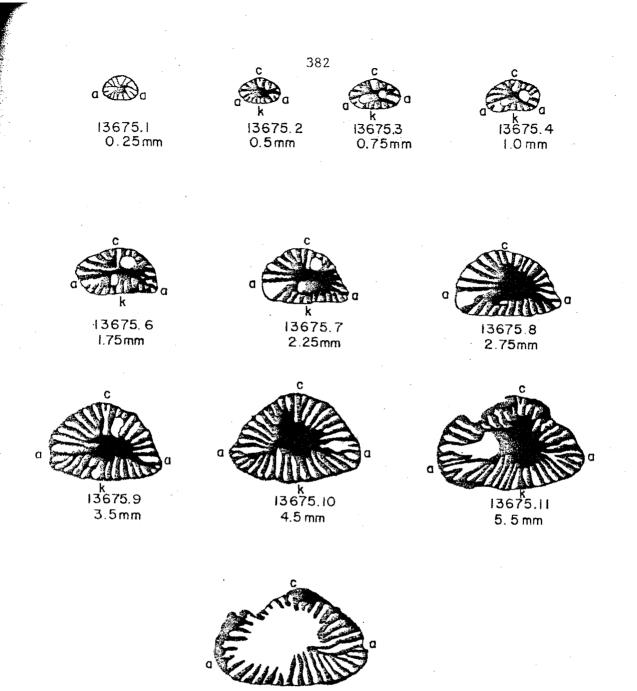
Description of material .-- One small holotype (UND Cat. No. 13675) corallum, 9.6 mm long, is 9.4 mm wide by 6.9 high as measured at the calyx. The very small corallum is similar in shape to immature coralla of Bighornia patella. It is calceolid with a transverse outline that is flattened on the counter side, rounded on the cardinal side, and gently flattened in the alar region. In longitudinal profile the counter side is gently convex and the cardinal side is slightly concave. Corallum angles near the calyx are 59 degrees between the traces of the cardinal and counter septa and 66 degrees between the traces of the alar septa. Rates of increase of corallum height and width tend to decrease at a distance of more than 6 mm from the corallum apex. Width is greater than height throughout the length of the corallum but is greatest between 0.5 and 2.25 mm from the apex, gradually becoming less in relation to height at distances greater than 2.25 mm from the apex. The corallum exterior has been abraded or weathered but transverse growth annulations are preserved. No corallite wall appears to have been preserved nor has the entire calyx been preserved. A maximum of 38 major septa occur 6 mm from the corallum apex. The maximum rate of septal insertion, 14 per millimeter of corallum length, occurs in the first millimeter from the The rate of insertion decreases with increasing distance apex.

from the apex, culminating in an insertion rate near the calyx of 1.2 septa per millimeter.

The major septa are dilated at their peripheral margins and taper slightly toward the axis. The region between the peripheral ends of adjacent septa are occupied by a thin peripheral stereozone. The position of the septa is typical of <u>Bighornia</u>. The cardinal septum is on the concave side of the corallum. The counter septum is on the convex side, and the alar septa are at the lateral corallum margins. Figure 50 shows that the division of the alar septa occurs toward the bottom of the transverse profile, on the counter side. This is well demonstrated in the peel sections 3.5, 4.5, 5.5, and 6 mm from the apex. No clearly defined minor septa occur.

The columella is a complex structure composed of what appear to be axial continuations of the septa (Figure 51). The center of the columella is composed of a central segment oriented parallel and leading into the cardinal and counter septa. The central plane of both of these septa can be traced into the central portion of the columella. The central portion is flanked on its alar sides by lateral portions of the columella into which the axial ends of most other septa are embedded. The microstructure of the columella, exclusive of the septa on its periphery, cannot be discerned in acetate peels. No preferred orientation of component fibers is seen in the columella because fibers may be oriented normal to the plane of the peel.

The septa contain a central planar structure from which fibers of the flanking sclerenchymal layers diverge axially in chevron-fashion from the central plane. The peripheral stereozone



13675.12 6.0 mm

Fig. 50.--Serial peel tracings of <u>Bighornia tyndallensis</u> n. sp. (UMD Cat. No. 13675). Corallum oriented in life position; c, cardinal septum; a, alar septum; k, counter septum. Distance from apex given for each peel, approx. X10.

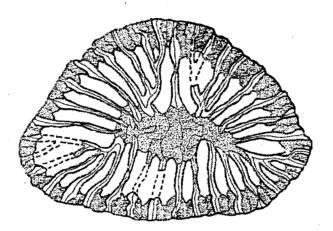


Fig. 51.--Serial peel 4.5 mm from apex of holotype <u>Bighornia</u> <u>tyndallensis</u> n. sp. Streptelasmoid columella shown by patternless stippling. Patterned stippling shows fiber orientation, approx. X10. shows a central, irregular, suture halfway between each acjacent septal pair. No tabulae are discernible in any of the peel sections.

Type.--Holotype, UND Cat. No. 13675.

Occurrence. -- The holotype was collected from the Selkirk Member of the Red River Formation a quarry near Garson, Manitoba (Appendix A, locality A530).

<u>Discussion</u>.--The single corallum available for study represents the only recorded occurrence of the genus <u>Bighornia</u> from the Red River Formation.

The corallum shape is similar to that of <u>Bighornia patella</u> in being a small calceolid or subcalceolid type and has the septal arrangement common to <u>Bighornia</u>.

The type of columella present in the holotype prevents assignment of the specimen to <u>Bighornia patella</u> (Wilson). The columella in <u>B</u>. <u>patella</u> is formed by an axial elongation and lateral swelling of the counter septum whereas that of <u>B</u>. <u>tyndallensis</u> is more reminiscent of the columella characteristic of <u>Streptelasma</u> in which the dilated axial ends of all major septa form the axial structure. The columella in <u>B</u>. <u>tyndallensis</u> can be traced to no one single septum (Figure 51), but certain component portions of that structure can be traced to certain groups of septa. The central portion can be traced to the cardinal and counter septum where the central septal plane continues from the counter septum. The lateral portions flanking the central one cannot however, be traced to any single septum. These connect to axial ends of all the remaining septa.

The columella is reminiscent of a streptelasmoid-like affinity more than it is of "typical" <u>Bighornia</u> in which the counter septum is the major structural element. However, the location of the septa and the corallum shape are characteristic of <u>Bighornia</u>. Hence a new species, <u>Bighornia tyndallensis</u> named for a small village in the region of Garson, Manitoba, is established to include coralla of <u>Bighornia</u> with the streptelasmoid type of columella.

This species may indicate a relationship between <u>Bighornia</u> to the <u>Streptelasma</u> since it contains a columella which the counter septum is not typically that of <u>Bighornia</u>. Figure 52 illustrates the inferred relationship of <u>B. tyndallensis</u> with <u>Streptelasma</u> and later species of <u>Bighornia</u>, in which it may be an early example of the genus shortly after having arisen from a streptelasmoid ancestor.

Bighornia cvancari n. sp.

Plate 19, Figures 16, 17, 20, 21; Plate 20, Figures 1, 2, 6, 10 <u>Diagnosis</u>.--Small, ceratoid coralla, strongly compressed along cardinal and counter septal traces; wider than high, width to height ratio decreasing away from apical region; calyx shallow, nearly planar with distal margin of corallum exterior, inclined at 45 degrees to corallum axis; maximum of 37 major septa, no minor septa; major septa dilated, filling nearly all of the corallum interior; alar fossulae very small or absent; cardinal fossula formed by peripheral retreat of cardinal septum; no tabulae.

Description of material. -- Thirteen solitary coralla, one holotype (UND Cat. No. 13581), eleven paratypes (UND Cat. Nos. 13582, 13583, 13606-13608, 13666-13671) and two fragmental speciments were collected

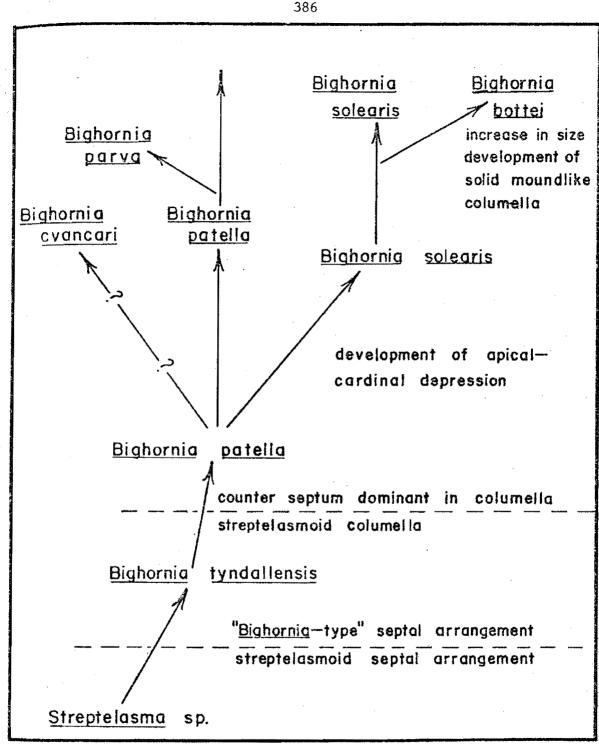


Fig. 52.--Suggested evolutionary relationships between Streptelasma and Eighornia (partially adapted from Nelson, 1963, p. 41).

from the Gunn Member of the Stony Mountain Formation. These range in type and length from a flattened calceolid paratype 6 mm long (UND Cat. No. 13666) to the ceratoid holotype that is 25 mm long and compressed in the cardinal and counter regions.

All coralla show cardinal-counter compression and all have their shallow calices inclined at approximately 45 degrees to the corallum axis. Most have prominent lophophyllidiid columella formed by a dilated counter septum projecting from the calyx floor.

As corals of this species mature (corallum regions more than 12 mm from apex), the rate of corallum height increase per unit length decreases.

The width/height ratio representative of the species shows that height (Figure 53) never equals width at any point along the length of the corallum. Relative width is greatest near the apical region of the coralla and decreases steadily with increasing distance from the apex.

Epithecal surfaces are not present in any of the coralla. No transverse growth increments or septal grooves are preserved.

Thirty-seven major septa occur in one paratype and no minor septa are present in any of the coralla. Major septa are thickened by septal stereoplasm to such a degree that adjacent septa are usually in complete lateral contact with each other throughout their length. The axial plate in each septum appears to be laterally expanded into a series of trabeculate structures (Figure 54) in which the central layer of the septum occupies much of the septal width, the only interseptal spaces present are small alar fossulae, the axial ends of septa in the apical region of some coralla (UND Cat. Nos. 13606, 13607), and a cardinal fossula. Septa in the calyx of the holotype show the

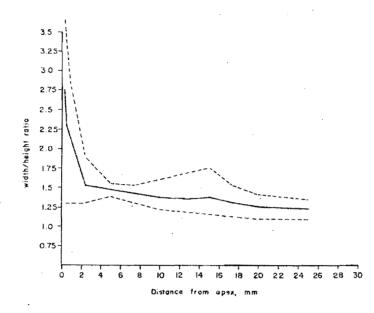


Fig. 53.--Corallum width/height plotted against distance from apex for population of <u>Bighornia cvancari</u> n. sp. Dashed lines show limits of variability; averaging curve shown by solid line, n=9.

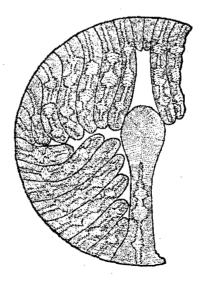


Fig. 54.--Schematic, partial transverse section of <u>Bighornia</u> <u>cvancari</u> n. sp., (UND Cat. No. 13606). Trabeculae in concentric arrangement. Cardinal fossula at top. Fiber orientation shown by patterned stippling, approx. X12.

columella arising from a vermiform septal pattern similar to that of <u>Grewingkia</u>. No tabulae are present because the dilated septa almost completely occupy the corallum interior.

<u>Types</u>.--Holotype UND Cat. No. 13581; Paratypes UND Cat. Nos. 13582, 13583, 13606-13608, 13666-13671.

Occurrence.--All coralla were collected from 0 to 4 meters (0 to 13 ft) below the top of the Gunn Member of the Stony Mountain Formation at a quarry near Stony Mountain, Manitoba (Appendix A, locality A584).

<u>Discussion</u>.--<u>Bighornia cvancari</u> n. sp., is named in honor of Dr. Alan M. Cvancara, Professor of Geology at the University of North Dakota. The species should read <u>B. cvancarai</u> throughout.

This species differs most markedly from others in the genus <u>Bighornia</u> by its compressed ceratoid shape, its prominently inclined, shallow calyx, and the absence of minor septa. Neanic stages of development are characterized by a modified flabellate shape with a shallow calyx inclined at approximately 30 degrees to the corallum axis (paratypes UND Cat. Nos. 13666-13668). However, as the individual coral matured, the margins of the corallum in the alar changed from sharply divergent to nearly parallel in the ephebic stage. This reflects a decreasing rate of width increase with respect to longitudinal growth as the coral matured.

As discussed in the section on the genus <u>Bighornia</u>, the septa of a paratype of the species (UND Cat. No. 13606) have trabeculate microstructures. The holotype and paratypes of <u>B. cvancari</u> do not have the finely denticulate septal margins that Duncan (1957, p. 608) mentioned as being characteristic of the genus. This is due to preburial abrasion of the coralla.

Hill (1956) implied and Kato (1963, p. 582) stated that denticulate septal margins are reflective of a trabeculate type of microstructure. Figure 54 is a representation of a transverse section of a paratype (UND Cat. No. 13606) 12 mm from the corallum apex and it shows the lateral expansions of the septal central plate occurring in concentric patterns. These expansions are most common in and are best displayed in mature regions of the paratype. The fibers in the axial and central portions of the septa are oriented in chevronshaped patterns in both the central and sclerenchymal layers (Figure 54). Fibers in the extreme peripheral portion of the septa parallel the corallum periphery.

Kato (1963) made an extensive study of rugosan microstructure and stated that all Ordovician solitary corals have trabeculate septa of a type he termed (1963, p. 588) "ini-trabecular," in which trabeculae are arranged uniserially along the septal plane. For transverse sections of septa showing chevron-like fiber orientation he gave this explanation (1963, p. 603): "As the result of oblique cutting trabeculae fibres are seen to be arranged divergently from the median part of a septum. Dark spots representing the centre of calcification of trabeculae may be present." A longitudinal thin section (Plate 19, Figure 21) of a paratype (UND Cat. No. 13608) shows faint dark lines in the plane of the septa that are inclined upward toward the corallum axis and appear to be in the same position and general orientation as that shown by Kato (1963, text-figure 7-0) for a species of Streptelasma.

The trabeculae in the septa of the paratype of <u>Bighornia cvan-</u> <u>cari</u> are more highly developed than in septa of other species studied of <u>Bighornia</u>, or in <u>Streptelasma</u> and <u>Grewingkia</u>. The trabecular prominence in <u>B</u>. <u>cvancari</u> may be due to a fiber textural variation in which lateral expansions of the central septal layer (Figure 54) contain finer fibers than those in the lateral portions of the septa.

Flower (1961), in his study of Ordovician colonial tabulate and rugose corals, did not mention the occurrence of trabeculae in septal structures of the colonial Rugosa. Rather, most of the septal types (Flower, 1961, figure 5) were (a) little more than extensions of the fibrous sclerenchymal layer of the wall, (b) fibers were oriented normal to the septal axial plane in two sclerenchymal layers which abut, and (c) septal structure was not an integral part of wall but a separate element with its axial plate detached from the wall.

Based on the study material at hand, the trabeculate type of septal microstructure represented by <u>Bighornia cvancari</u> is a characteristic of North American solitary rugosans living during Stony Mountain time and later. This provides a transition from apparently nontrabeculate or primitively trabeculate Rugosa of pre-Stony Mountain time to the well developed trabeculate structures of the Silurian Rugosa which exhibit acanthine and rhabdacanthine trabeculae arranged in both uni-trabecular and multi-trabecular patterns (Kato, 1963, p. 609).

Bighornia patella (Wilson), 1926

Plate 20, Figures 3-5, 7-9, 11-13; Plate 21, Figure 2 Streptelasma patellum Wilson, 1926, Geol. Survey Canada, Bull. 44,

Geol. Ser. 46, p. 13, pl. 2, fig. 1.

[?]<u>Streptelasma</u> aff. <u>breve</u> Winchell and Schuchert, Troedsson, 1929, Medd. om Gronland, v. 72, p. 109, pl. 26, 6a-d, 7a-c.

[?]<u>Holophragma scheii</u> Cox, 1937, Geol. Mag., v. 74, no. 1, p. 15, pl. 2, figs. 14-16.

- Holophragma anticonvexa Okulitch, 1943, Trans. Roy. Soc. Canada, v. 37, sec. 4, p. 68, pl. 1, figs. 11, 12.
- "<u>Holophragma</u>" sp. Duncan, 1956, U. S. Geol. Survey, Bull. 1021-F, p. 226, pl. 22, figs. 1a-c; Ross, 1956, U. S. Geol. Survey, Bull. 1021-F, p. 474, pl. 37, figs. 3, 5-7.
- Bighornia parva Duncan, 1957 [partim], Jour. Paleontology, v. 31, no. 3, p. 611, pl. 70, figs. 5-7, [non] figs. 1-4, 8-13, figs. 14-18.
 Bighornia patella (Wilson), Nelson, 1959, Journ. Alberta, Soc. Petroleum

Geologists, v. 7, no. 3, pl. 4, figs. 1a-d; Nelson, 1963, Geol. Soc. America, Mem. 90, p. 40, pl. 11, figs. 1a-c, 2, 3a-d.

Diagnosis.--Small to moderate, subcalceolid, trochoid and ceratoid coralla with flattening in counter near the apex, flattening decreasing progressively from apex; up to 34 mm long; longest forms with oval or subcircular transverse outline; calicinal rim oblique or normal to corallum axis; up to 42 strongly dilated major septa; minor septa weakly developed, completely covered by major septal sclerenchyme. Septal interiors completely occupied by dilated major septa; small cardinal fossula near apex in mature coralla; no tabulae.

Description of material. -- Two hundred and thirty-eight (238) coralla assignable to <u>Bighornia patella</u> (Wilson) are at hand, and occurred in the top 3.4 meters (11 ft) of the Gunn Member of the Stony Mountain Formation. Of these, 12 are designated as hypotypes (UND Cat. Nos. 13584-13586, 13625-13633) and the remaining 214 coralla are catalogued specimens (UND Cat. No. 13692).

The species in Gunn Member contains coralla attaining lengths of 34 mm. All coralla are characterized by a sub-calceolid-trochoid or subcalceolid-ceratoid corallum shape in which a prominent flattening occurs in the counter region near the apex. The counter side of all coralla is convex in longitudinal profile, the cardinal side is slightly concave or straight, and the traces of the alar septa on the coralla exteriors represent lines of maximum corallum width.

Transverse outlines of coralla at hand vary with the distance from the respective corallum apex. Those nearest the apex are distinctly D-shaped or subtriangulate whereas those farther from the apex are oval or subcircular.

Well preserved exteriors of representative specimens (UND Cat. No. 13692) and a hypotype (UND Cat. No. 13685) exhibit fine, transverse, growth increments spaced longitudinally from 0.5 to 1 mm apart. Septal furrows are prominent only on coralla that have undergone some surficial abrasion.

Corallum height for 99 coralla (UND Cat. No. 13692) of <u>Big</u>hornia patella expressed as an average for the Gunn Member population increases at a relatively uniform rate away from the corallum apex, tending to be about halfway between the lower and upper limits of height variation from the population. At distances of greater than 20 mm from the apex, however, the averaging curve tends to approach the lower limit of height variation. This is due, in part, to a decreasing number of coralla having lengths greater than 20 mm and dependence of the averaging curve on a smaller sample number.

Overall average rate of height increase for the entire population is a 1 mm increase in height for each 2 mm from the apex.

Using the same 99 catalogued specimens mentioned above, width derived for these coralla shows that the greatest rate of lateral expansion occurs in the 7.5 mm closest to the apex--1 mm lateral expansion per 1 mm of length. Above 7.5 mm from the apex the rate decreases to 1 mm lateral expansion per 2 mm length up to 20 mm from the apex. Above 20 mm, the rate decreases still further, about 1 mm increase per 3 mm corallum length. This illustrates that the entire population is characterized by (1) rapid lateral corallum expansion during youth, and (2) decreasing, nearly static, expansion in the most mature coralla.

Average corallum width/height ratios for the population indicate that the species is characterized by corallum widths markedly greater than height at corallum portions within 7.5 mm of the apex (w/h=1.5-1.6). The decreasing rate of lateral increase, coupled with the uniform rate of height increase, results in the average and range of width/height values continually decreasing as a function of increasing distance from the apex (w/h=1.2 at 30 mm).

Orientation of the calicinal rim with respect to the corallum axis varies from oblique to normal within the population of <u>Bighornia</u> <u>patella</u> at hand. No distinct separation between coralla with oblique or normal calicinal rims can be made as there is a complete intergradation between extremes of these orientations.

The transverse calyx outline of coralla studied varies from subtriangulate to subcircular depending on the distance of the calyx from the apex. The peripheral portions of the major septa are at the

level of the calicinal rim, forming a narrow calicinal platform. This platform surrounds a U-shaped calicinal pit. The pit floor is formed by the distal margins of the axial portions of the septa and surrounds a prominent, bladelike columella formed by the counter septum.

The maximum rate of septal insertion (5 septa/mm length) occurs in the 6 mm nearest the apex. The rate of insertion tapers off above 6 mm from the apex and appears to be nearly static (1 septum/2 mm length) despite the occurrence of increasing corallum height and width as a function of increasing distance from the apex. This is partially accounted for by the insertion of minor septa as close as 5 mm to the apex in one hypotype (UND Cat. No. 13631). Therefore, the break in slope in the rate of major septal insertion may be interpreted as the point where minor septa are inserted between major septa. Major septa are commonly dilated to such a degree that they completely or nearly fill the corallum interiors.

The only cavities within the corallum interior are formed by the cardinal fossula in regions near the calyx, small alar fossulae, and small interseptal spaces where the major septa taper toward the corallum axis. Other coralla have no internal cavities, the interior being entirely filled by dilated major septa.

Septal microstructure of <u>Bighornia patella</u> is strongly trabeculate. Monoacanthine trabeculae arise close to the corallum periphery at an orientation of approximately 45 degrees. The trabecular rods then turn in the peripheral portions of the septa and project toward the axis at an orientation normal to the axis (Plate 20, Figure 12).

Transverse sections cut the septal trabeculae which appear as broad dark lines at the center of each major septum. Each line

has a diffuse border where the trabecular fibers extend into the sclerenchymal layers flanking the lateral sides of each trabecula (Plate 20, Figure 13). The flanking sclerenchymal layers are translucent in transverse thin section and are composed of axial extensions of the lateral fibers of the trabeculae. Orientation of these fibers is normal or nearly normal to the septal plane.

The lophophyllidiid type columella consists of the axial lobe of the elongate counter septum in which the sclerenchymal layers are thickened by the axial extensions of the component fibers.

The minor septa are completely embedded in the septal sclerenchyme and never project into the lumen except within the calyx. No peripheral stereozone occurs. All the corallite wall inside the thin epitheca is composed of septal material in complete lateral contact at the corallum periphery.

Tabulae are completely absent in most longitudinally sectioned hypotypes.

Types and specimens.--Hypotypes, UND Cat. Nos. 13584-13586, 13611-13614, 13625-13633, 13693-13695; catalogued specimens, UND Cat. Nos. 13690 (14 coralla), 13691 (2 coralla), 13692 (214 coralla).

Occurrence. -- Bighornia patella (Wilson) and species possibly synonomous with it are widespread.

Arctic Region:

Strandpilaren, Norman Lockyer Island, Princess Marie Bay, Ellesmereland, in Ordovician strata (Cox, 1937, p. 16), Cape Calhoun, Washington land, northwestern Greeland in the Cape Calhoun beds (Troedsson, 1929, p. 109).

Hudson Bay Region (Nelson, 1963, p. 40):

Hypotype, GSC No. 10872, Member No. 1 of the Caution Creek Formation on the Churchill River,

Hypotypes, GSC Nos. 10873, 10874, Member No. 1 of the Chasm Creek Formation on the Churchill River.

Southern Manitoba:

Hypotypes, UND Cat. Nos. 13584-13586, 13625-13633; and 214 catalogued specimens, UND Cat. No. 13692; Zero to 3.4 meters (0 to 11 ft) below the top of the Gunn Member of the Stony Mountain Formation, near Stony Mountain, Manitoba (Appendix A, locality A584).

British Columbia:

Fifty feet (15.2 m) above the base of the exposed section of the Beaverfoot Formation at the head of Windermere Creek in the Stanford Range, southeastern British Columbia (Wilson, 1926, p. 13).

Northern Wyoming:

Specimen, USNM 124801 from the red shaly beds (Rock Creek beds; Macomber, 1970) in the uppermost part of the Bighorn Dolomite on the South Fork of Rock Creek, Johnson County, Wyoming (Ross, 1957, p. 456).

<u>Discussion</u>.--This writer agrees with Nelson's (1963, p. 40) opinion that <u>Bighornia patella</u> (Wilson), and <u>B. anticonvexa</u> (Okulitch), are conspecific. <u>B. parva</u> of Duncan appears to include at least one specimen assignable to <u>B. patella</u>. Duncan's species diagnosis for <u>B</u>. <u>parva</u> (Duncan, 1957, p. 611) falls well within the diagnosis given previously for <u>B. patella</u>. Both species <u>B. patella</u> and <u>B. parva</u> are small and subcalceolid, with a prominent columella with 36 to 46 major septa and weakly developed minor septa. <u>Bighornia parva</u>, however, appears to be more consistently triangulate in outline than <u>B. patella</u>.

The population of <u>B</u>. <u>patella</u> in the Gunn Member contains the largest individual (hypotype, UND Cat. No. 13586) assignable to the species. This hypotype attains a maximum length of 34 mm, which is much larger than the 24 mm recorded for the holotype (Nelson, 1963, p. 41) and is larger than the largest hypotype (GSC No. 10874) occurring in the Chasm Creek Formation in northern Manitoba.

The Gunn Member population of <u>B</u>. <u>patella</u> is very abundant in terms of number of individuals. Nelson (1963) made no statement as to the abundance of individuals of the species in the Hudson Bay region. If the Gunn Member fossil assemblage is in any way reflects the Ordovician biologic community that existed, then <u>B</u>. <u>patella</u> appears to have been one of the most well developed species in terms of abundance of individual corals.

Another species common in the Gunn Member, <u>Streptelasma kel-</u> <u>pinae</u> n. sp. is represented by individual corals attaining similar lengths and is also well represented by large numbers of individuals. Both species, <u>B. patella</u> and <u>S. kelpinae</u>, are the dominant coral taxa in the Gunn fossil assemblage and may represent dominant taxa within the biologic community. However, the occurrence of these species, in association with a bioclastic and argillaceous unit such as the Gunn Member makes post-mortem selective sorting and transport, and subsequent concentration of skeletal material a distinct possibility. It is more likely that both mechanisms affected the community.

Comparison of data for the hypotypes (GSC Nos. 10872-10874) of <u>B. patella</u> cited by Nelson (1963, p. 41) with the hypotypes and specimens from the Gunn Member population show that the hypotypes from the Hudson Bay region are very similar in terms of height, width and septal number to the Gunn Member population.

Bighornia parva Duncan, 1957

Plate 21, Figures 1, 3-7

Bighornia parva Duncan, 1957, [partim] Jour. Paleontology, v. 31, no. 3,

p. 611, p1. 70, figs. 1-4, [non] figs. 5-7, figs. 8-13 (?), figs. 14-18.

Diagnosis.--Small, trochoid to ceratoid, subcalceolid to triangular coralla, commonly with planar external regions between cardinal and alar septa; counter side flattened along entire length of corallum; transverse outline triangulate; columella prominent; 36 to 46 dilated major septa, filling corallum interior; small cardinal fossula opening into cardinal side of columella; minor septa poorly developed, confined to peripheral stereozone; tabulae incomplete, present (adapted from Duncan, 1957, p. 611).

Description of material.---Twenty three complete and fragmentary coralla are available for study. Seven of these are designated as hypotypes (UND Cat. Nos. 13611-13614, 13693-13695). All of the specimens are characterized by the corallum being flattened along its complete length on the counter side. Maximum corallum length is 26 mm (hypotype, UND Cat. No. 13695). The coralla are commonly characterized by two longitudinal, planar surfaces between the traces of the alar and cardinal septa. These surfaces, plus the counter flattening, result

in a distinctly triangular transverse outline. Like <u>Bighornia patella</u>, the longitudinal profile of the cardinal side of each corallum is slightly concave whereas that of the counter side is slightly convex. The alar extremities constitute the lines of maximum lateral extent of all coralla. None of the coralla have well preserved exteriors, but the partially preserved exterior of one hypotype (UND Cat. No. 13695) exhibits transverse growth annuli spaced from 0.5 to 1.5 mm from each other.

Comparison of the heights and width of one hypotype (UND Cat. No. 13611) with the Gunn Member population of <u>B</u>. <u>patella</u> reveals that (1) corallum height of the hypotype is closely comparable to that of the Gunn population of <u>B</u>. <u>patella</u>, (2) corallum width for the hypotype agrees with that of the Gunn Member population, and (3) width/ height ratios as a function of distance from the apex are less than those of the averaging curve for the population average of <u>B</u>. <u>patella</u>.

The calicinal rims of all ephebic coralla are normal to the corallum axis and the traces of the alar septa. Neanic individuals are characterized by calicinal rims oblique to the axis. Calices of ephebic individuals such as hypotype UND Cat. No. 13693 are bordered by a platform formed by the ends of the major septa. The calyx, like that in <u>B. patella</u> is U-shaped with steep walls and a calicinal floor formed by the axial ends of the septa.

Septal counts of one hypotype (38; UND Cat. No. 13611) when compared to the population of <u>B</u>. <u>patella</u> from the Gunn Member show that this specimen has a rate of septal insertion from 5 to 14 mm distant from the apex (1 septum/2 mm length) which is similar to to the rates for the population of <u>B</u>. <u>patella</u> at the same distances.

One hypotype (UND Cat. No. 13613) has 44 major septa but, since its transverse section was taken from a corallum from which the apical region was broken, the distance of the section from the apex is not known.

Transverse sections from two hypotypes (UND Cat. No. 13611, 13613) show that their septa are not as dilated as those in <u>B</u>. <u>patella</u>. The peripheral ends of the dilated major septa are either in full contact with each other or are interspersed with poorly developed minor septa. In both instances a thick peripheral septotheca is covered only by a thin epitheca.

Small, interseptal spaces are formed when the septal dilation is lessened. Other spaces in the corallum interiors of the two hypotypes are formed by two small, alar fossulae and a prominent cardinal fossula which, as Duncan (1957, p. 612) said, "is deep and its sides are essentially parallel until it flares out axially around the base of the columella." The columella in one hypotype (UND Cat. No. 13613), consists of the axially extended and dilated counter septum flanked on both sides by the first counter lateral septa. Both the holotype (USNM 127574) and this hypotype have the remaining counter lateral septa in a pinnate arrangement, producing two alar pseudofos-Minor septa in the hypotype are short, immersed in the septosulae. theca formed by the dilated peripheral ends of the major septa, and are best developed on the counter side of the corallum. Septal microstructure is trabeculate and the flanking sclerenchymal layers contain fibers that are the extensions of fibers in the lateral portions of the trabeculae.

Tabulae are present only on the counter side of one hypotype corallum (UND Cat. No. 13614) as small, peripherally inclined, slightly convex tabellar plates 0.4 to 0.6 mm apart.

Types and specimens. -- Hypotypes, UND Cat. Nos. 13611-13614, 13693-13695; catalogued specimens UND Cat. Nos. 13690 (14 individuals), 13691 (2 individuals).

Occurrence.--The species is restricted to exposures of the Rock Creek and Hunt Mountain beds. Duncan (1957, p. 613) reported the occurrence of the holotype (USNM 127574) and paratypes (USNM 124801, 127575-127577) from the top Rock Creek beds on the south fork of Rock Creek, eastern flank of the Bighorn Mountains, Johnson County, Wyoming (USGS locality Nos. 1262-CO and 68-SD). The specimens referred to in this study were collected at the following localities.

Hypotypes, UND Cat. Nos. 13611, 13693, 13694; and specimen UND Cat. No. 13690; from the Hunt Mountain beds on the north side of Shell Creek Canyon, Bighorn County, Wyoming (Appendix A, locality A531).

- Hypotypes UND Cat. Nos. 13612, 13614, 13695; and specimen UND Cat. No. 13691; from 1.6 meters (5.2 ft) below top, Hunt Mountain beds, east of Hunt Mountain, Sheridan County, Wyoming (Appendix A, locality A539).
- Hypotype UND Cat. No. 13613; float, Hunt Mountain beds (Appendix A, locality A543).

<u>Discussion.--Bighornia parva</u> (Duncan) is a markedly triangulate species of <u>Bighornia</u> closely related to <u>B. patella</u>. The counter flattening restricted to the apical region of <u>B. patella</u> is extended along the entire length of the corallum, and the rounded cardinal-alar regions of coralla of <u>B</u>. <u>patella</u> are modified into longitudinal planar surfaces extending the length of the coralla.

More septa commonly occur in ephebic regions of <u>B</u>. parva than in comparable specimens of <u>B</u>. patella. These are commonly less dilated in the corallum interiors than in <u>B</u>. patella.

<u>B. bottei</u> and <u>B. parva</u> are the only two species of the genus <u>Bighornia</u> in the Hunt Mountain beds on the western side of the Bighorn Mountain. Ross (1957, plate 37, figures 3, 5-7) illustrated a coral (USNM 124801) subsequently designed as a paratype of <u>B. parva</u> and illustrated by Duncan (1957, p. 613, plate 70, figures 14-18) which appears identical to <u>B. patella</u> in the Gunn Member of the Stony Mountain Formation.

This paratype (USNM 124801) occurred on the eastern side of the Bighorn Mountains in the Rock Creek beds and may represent the southwesternmost limit of corals assignable or comparable to <u>B</u>. <u>patella</u>. <u>Bighornia parva</u> may represent a southwestward transition within the genus <u>Bighornia</u> toward a distinctly triangulate corallum shape.

Bighornia bottei Nelson, 1963

Plate 21, Figures 8-13

<u>Bighornia</u> sp. Nelson, 1959, Jour. Alberta Soc. Pet. Geol. v. 7, no. 3, pl. 4, figs. 3a-d.

Bighornia bottei Nelson, 1963, Geol. Soc. America, Mem. 90, p. 41,

pl. 5, fig. 6; pl. 9, figs. 5, 6a-d; pl. 11, figs. 5a-b, 6a-c, 7, 8; pl. 12, figs. 1, 2a-g, 3a, b, 4a-c.

Species diagnosis.--Small calceolid and medium sized (commonly up to 50 mm length) ceratoid coralla with apical region flattened in the plane of the alar septa; prominent circular or spoon-shaped depression on cardinal side in apical region of corallum; counter side of corallum convex. Cardinal side straight or concave; corallum width to height ratio decreasing from 5:1 at apex to 1:1 about 20 mm from apex. Corallum nearly circular more than 20 mm from apex; calyx deep; up to 57 major septa, buried in septal stereozone with thickness approximately 0.25 times corallum radius; prominent columella formed by merging of axial ends of major septa with counter septum.

Description of material.--Four hypotype coralla at hand assignable to <u>Bighornia bottei</u> Nelson (UND Cat. Nos. 13604, 13605, 13672, 13673) are calceolid. The smallest (UND Cat. No. 13673) is 11 mm long (measured along the trace of the counter septum) and the largest (UND Cat. No. 13572) is 34 mm; its calceolid form is modified by a transition toward a circular transverse outline at the calyx rim.

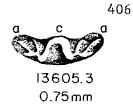
The circular apical depression on the cardinal side of the largest hypotype is 8.7 mm in diameter and 0.5 mm deep. Transverse profiles in the apical region are influenced by this depression (Figure 55), and by the flattening of the apex parallel to the alar septa. The resultant profiles of one hypotype (UND Cat. No. 13605) frequently have the lateral margins elevated above the margins of the cardinal region due to the influence of the depression. Corallum height, measured between the traces of the cardinal and counter septa on the corallum exterior, shows a relatively uniform rate of increase. The resultant average for the hypotypes shows that the

404

corallum angle between the cardinal and counter septal traces is 40 to 50 degrees. Width/height ratios for these specimens (UND Cat. Nos. 13604, 13605, 13672, 13673) decrease continually (from w/h=5.0 at apex to w/h=1.3 at 25 mm) with increasing corallum length, illustrating the approach of the corallum outline toward a circular type with increasing coral age and corallum length.

The calyx on one hypotype (UND Cat. No. 13604) is 3.5 mm deep within a corallum of 13.5 mm long. Depth/length ratio for this hypotype is 0.26 times the length. The calyx on the largest hypotype (UND Cat. No. 13672) is 5.1 mm deep within a calyx 34 mm long. Depth/length is 0.15 for this corallum. Thus a trend seems to exist in which calyx depth ratios decrease with increasing corallum length. Transverse calyx profiles are broadly V-shaped with a prominent columella which, in the largest hypotype projects 2.4 mm above the calyx floor, approximately 0.5 times the calyx depth. The columella is a broad, moundlike projection which, in one hypotype (UND Cat. No. 13605), is formed by the fusion of the axial ends of the dilated major septa with the counter septum.

Up to 57 major septa occur at the calicinal rim of the largest hypotype (UND Cat. No. 13672). Septal insertion as a function of corallum length occurs at a rate of 10 per millimeter corallum length within 4 mm of the apex for one hypotype (UND Cat. No. 13605). At distances greater than 4 mm, the rate of insertion in this specimen decreases to one per millimeter. The largest hypotype at hand shows a rate of insertion from 2 per millimeter near the apex, which decreases to a rate of less than 1 per millimeter in the mature portions of the corallum. Major septa in one hypotype (UND Cat. No. 13605; Figure 55),





13605.4 1.0 mm



13605.2

0.5mm

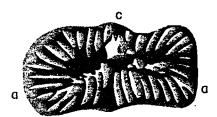
13605,5 1.25 mm



13605.6 1.5 mm



2.0mm



13605.10 3.0 mm

Fig. 55.--Serial peel tracings of <u>Bighornia bottei</u> (UND Cat. No. 13605). Counter septum in six o'clock position; c, cardinal septum; a, alar septum; k, counter septum. Distance from apex given for each peel, approx. X4.

are dilated to such a degree that they are in lateral contact with each other. In the hypotype in question, the region of complete or partial lateral contact occurs at distances greater than 1 mm from the apex up to 10 mm at the floor of the calyx. Transverse sections of the same hypotype show the minor septa to be buried between the sclerenchymal layers of adjacent major septa. In the largest hypotype (UND Cat. No. 13672) the minor septa cannot be traced closer than 7.5 mm to the apex. A transversely sectioned hypotype (UND Cat. No. 13605) has minor septa in the flattened counter portion of the corallum 4 mm from the apex. None occurs in the cardinal-alar regions of the corallum at that level, however.

Major septal microstructure is trabeculate. A longitudinal section of one hypotype (UND Cat. No. 13604) cuts the central plane of a major septum and exhibits trabeculate bundles radiating from the septal point of origin. Transverse thin sections of another hypotype (UND Cat. No. 13605) shows the septal structure to consist of a central, fibrous dark layer flanked by two fibrous sclerenchymal layers. Fiber orientation in this section is normal to the septal plane, which does not seem to be reflective of a structure composed of parallel bundles of radiating fibers. The central layer's border with the adjacent sclerenchymal layers are diffuse and gradational, possibly indicating that the layered structure is illusory.

No clearly defined transverse structures attributable to tabulae occur in the sectioned hypotypes (UND Cat. Nos. 13604, 13605).

Types.--Hypotypes UND Cat.Nos. 13604, 13605, 13672, 13673.

Occurrence.--Nelson (1963, p. 41-42) collected the holotype and paratypes from the following Ordovician strata and regions in the lowlands near the southwestern shore of Hudson Bay:

- Member No. 3 of the Chasm Creek Formation on the Churchill River; holotype, GSC No. 10898, and paratype GSC No. 10875.
- Member No. 2 of the Chasm Creek Formation on the Churchill River; paratype GSC No. 10877.
- Member No. 1 of the Chasm Creek Formation on the Churchill River; paratypes, GSC Nos. 10881, 10882.
- Chasm Creek Formation on the Nelson River; paratype, GSC No. 10879.

The hypotypes studied were collected in the Hunt Mountain beds, Bighorn Mountains, Sheridan County, Wyoming, east of the Hunt Mountain.

- Hypotype, UND Cat. No. 13604; 0.12 meter (0.4 ft) below the top of the beds (Appendix A, locality A549).
- Hypotype, UND Cat. Nos. 13605, 13673; 1.6 meters (5.2 ft) below the top of the beds (Appendix A, locality A539).

Hypotype, UND Cat. No. 13672; float from the beds (Appendix A,

locality A542).

<u>Discussion</u>.--Comparison of the four hypotypes of <u>Bighornia</u> <u>bottei</u> from northern Wyoming with the holotype and paratypes show that the most significant difference in specimens of the two regions is corallum size. Nelson (1963, p. 42) stated that most of the Hudson Bay lowland specimens were about 50 mm long with one paratype (GSC No. 10879) being 80 mm long. The largest northern Wyoming hypotype (UND Cat. No. 13672) by contrast is only 34 mm long, and the shortest hypotype (UND Cat. No. 13673) is only 8 mm long.

Thus it appears that the sparse Hunt Mountain bed specimens representing the population never attained maturity and size of that the Hudson Bay specimens.

Nelson (1963, p. 42-43) gave extensive data on corallum height, width, and major septal counts that permit comparison with the biometrics of the hypotypes.

age.

Comparison of corallum height indicates that the Hudson Bay specimens are higher as a function of distance from the apex than are the northern Wyoming hypotypes.

Corallum width for the Hudson Bay specimens is greater per unit distance from the corallum apex than is the width for the hypotypes. Therefore, it appears that the specimens representing the Hudson Bay assemblage of <u>B. bottei</u> are characterized by greater rates of lateral growth per unit of corallum length than were the hypotypes of the species.

Width/height ratios of the Hudson Bay specimens and the hypotypes are almost identical. Only the apical portions (less than 16 mm from the apex of GSC Nos. 10875 and 10879) are wider per unit height at comparative distances from the apex (w/h=2.5 at 6 mm) than are the remainder of the two populations of the species (w/h=1.6 at 6 mm). All specimens show a trend toward circularity (w/h=1.0) with increasing corallum length.

The rates of insertion of major septa per unit length are comparable for the two groups of specimens. Both groups show a general tendency for the rate of insertion to decrease with increasing coral

Comparison of the two groups of <u>B</u>. <u>bottei</u> on the basis of size indicate that the Hudson Bay group was characterized by individuals that lived longer than those in the northern Wyoming group. This implies that Ordovician marine environmental conditions were more favorable in the area of the Hudson Bay population than in the northern Wyoming region of the Ordovician epeiric sea.

The serial acetate peel sketches of hypotype UND Cat. No. 13605 show the progressive increase in number of major septa, septal dilation, and migration of the alar septa toward the flattened counter side of the corallum (Figure 55). The cardinal septum remains as a small, aborted structure throughout the life of the hypotype. Septa in the cardinalalar quadrants are generated at the cardinal septum which undergoes planar fission to produce two septa flanking the cardinal fossula. Migration of these is toward the alar septa. Septa in the counteralar quadrants are generated at the alar septum and migrate toward the counter septum.

Septal microstructure in transverse thin sections of the same hypotype does not show the degree of trabecular development shown in the schematic of a paratype (UND Cat. No. 13606; Figure 54) of <u>Big</u>-<u>hornía cvancari</u> n. sp. The hypotype of <u>B</u>. <u>bottei</u> does not contain the lateral expansions of the central septal layer that the paratype of <u>B</u>. <u>cvancari</u> does. No well developed "bursts" of the central layer occur in concentric patterns in <u>B</u>. <u>bottei</u> whereas in <u>B</u>. <u>cvancari</u> n. sp., they are well developed. A longitudinal thin section of a hypotype of <u>B</u>. <u>bottei</u> (UND Cat. No. 13604) does, however, show well developed trabecular bundles radiating axially and distally from the region of origin

of the septum. Therefore, like <u>B</u>. <u>cvancari</u> n. sp., septa in <u>B</u>. <u>bottei</u> are characterized by discernible trabeculae.

Nelson (1963, p. 41) noted the occurrence of a hypotype (GSC No. 10870) of <u>Bighornia solearis</u> (Ladd) from the Member No. 1 (lowermost) of the Chasm Creek Formation in the Hudson Bay lowland. It is similar to <u>B</u>. <u>bottei</u> by possessing a spoon-shaped cardinal-apical depression, but has a size more comparable to <u>Bighornia patella</u>. The hypotype (U. of Iowa No. 2-051) and paratypes (USNM No. 71926, U. of Iowa 2-052) occurred in the Fort Atkinson Member of the Maquoketa Formation in northeastern Iowa, making this the only reported occurrence of a species of <u>Bighornia</u> outside the Ordovician equatorial realm.

<u>Bighornia solearis</u> differs from <u>B</u>. <u>bottei</u> in the character of the axial structure. That of <u>B</u>. <u>solearis</u> is a prominent palicolumella (Nelson, 1963, p. 41) formed by the axially extended counter septum whereas the columella of <u>B</u>. <u>bottei</u> is formed by the dilated axial ends of the major septa in conjunction with the counter septum.

According to Nelson (1963, p. 41) <u>B</u>. <u>solearis</u> is a transitional form between <u>B</u>. <u>patella</u>, whose size and type of columella it possesses, and <u>B</u>. <u>bottei</u> whose apical depression and flattened apex it possesses. Therefore, <u>B</u>. <u>solearis</u> may have arisen from <u>B</u>. <u>patella</u> with <u>B</u>. <u>sole-</u> <u>aris</u> in turn giving rise to <u>B</u>. <u>bottei</u> (Figure 52).

Suborder COLUMNARIINA Rominger, 1876

Family STAURIIDAE Milne-Edwards and Haime, 1850

Genus Crenulites Flower, 1961

Type species (by original designation).--Crenulites duncanae Flower, 1961, New Mexico Bureau Mines and Min. Resources, Mem. 7, p. 84.

Diagnosis.--Large, cerioid coralla with thin-walled, polygonal corallites; walls of central axial plate flanked by fibrous sclerenchymal layers--"rugosan" type; nine to 12 major septa with equal number of minor septa; major septa exhibiting amplexoid retreat; peripheral margins of the major septa continuous or discontinuous between levels of adjacent tabulae; minor septa short; peripheral margins of tabulae crenulate with distal apices of folds coincident with location of septa (adapted from Flower, 1961, p. 84).

<u>Discussion</u>.--Flower (1961, p. 84) stated that <u>Crenulites</u> "grades into" the genus <u>Favistina</u> (=Favistella Dana) through <u>C</u>. <u>rigidus</u> because of amplexoid septa in both genera. He (1961, p. 76) proposed the name <u>Favistina</u> and rejected the name <u>Favistella</u> Dana, which was based upon the species <u>Favistella alveolaris</u> Van Cleve, <u>nomen nudum</u>, an unpublished description of lost specimens. He proposed that <u>Favistina</u> be used with the scope of Favistella of Bassler, which is diagnosed as;

. . . compound tetracorals composed of polygonal, usually continuous corallites united by their walls, without mural pores but with septa well developed as thin lamellae arranged in primary and secondary rows extending nearly to center of calyx, with complete horizontal tabulae and finally with no columella, dissepiments, or interstitial tissue (Bassler, 1950, p. 271).

Crenulites rigidus (Billings), 1858

<u>Columnaria rigida</u> Billings, 1858, Canadian Naturalist and Geologist, v. 3, p. 421; Billings, 1858, Canada Geol. Survey Rept. Prog. for 1857, p. 167; Foerste, 1924, Canada Geol. Survey, Mem. 138, p. 68, pl. 4, fig. 1 (?), pl. 5, fig.1.
[?]Columnaria alveolata rigida (Billings), Foerste, 1924, Canada Geol.

Survey, Mem. 138, pl. 5, fig. 1.

Favistella alveolata rigida (Billings), Bassler, 1950, Geol. Soc. America, Mem. 44, p. 273.

Crenulites rigidus (Billings), Flower 1961, New Mexico Bureau Mines and Mineral Resources, Mem. 7, p. 85-86, pl. 29.

<u>Diagnosis</u>.--Cerioid corallites up to 6 mm in diameter, with 9 to 11 major and minor septa; major amplexoid septa on distal tabular surface extend approximately six to seven-tenths of distance from corallite wall to center; major septa continuous along corallite wall between tabulae; minor septa short, occurring throughout corallite length.

Description of material. -- The massive cerioid coralla (UND Cat. Nos. 13707-13716) have corallites on the periphery obliquely oriented, inclined outward, from the corallum center. Corallites in the central portion of the coralla are parallel and vertical. Corallites are large, and the hypotype colonies (UND Cat. Nos. 13707-13710) have mean diameters of 3.7 to 4.4 mm (Appendix B, Table 35). Corallites are polygonal, ranging in form from trapezoidal to septagonal. Walls are thin, with an axial plate separating layers of fibrous sclerenchyme composed of upwardly inclined fibers diverging away from the axial plate, which is continuous around and interconnects adjacent corallites (Figure 56a). Two orders of septa occur. Minor septa are short, maintaining a nearly constant length throughout the corallite (Appendix B, Table 35). In rare cases, these septa extend up to half the distance toward the corallite center. This occurs in one fragment of a colony where a transverse section revealed the minor septa extending onto the surface of a tabula, illustrating a rare example of minor septa present in an amplexoid condition, whereas all major septa show the amplexoid condition. Mean septal extension range for the hypotype coralla is 0.44 to 0.97 times the

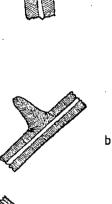
mean corallite radius (Appendix B, Table 35). All major septa viewed in tangential sections show complete continuity between tabulae, indicating that complete amplexoid retreat does not occur in the species.

The microstructure of minor and major septa shows that they are most commonly constructed of fibers diverging outward from a central plane of fiber abuttment (Figure 56b). Exceptionally long major septa extending onto a tabular surface have a rare axial plate composed of dense, non-fibrous skeletal material with the same appearance as the axial plate of the corallite wall (Figure 56c).

The axial plate of these long, major septa seems, under high magnification, to connect with the axial plate of the wall. Flower (1961, p. 85) in describing <u>C</u>. <u>duncanae</u>, noted that the rare examples the major septa in a paratype seemed to be extensions of the axial plate.

Tabulae are complete, planar, and downturned at their peripheral margins, giving the line of tabular intersection with a wall a sawtooth or crenulate character (Plate 21, Figure 15). Major septa, longitudinally continuous along the corallite wall, intersect the tabulae at the distal apex of each crenulation. Orientation of the tabulae parallels the presumed sediment surface in both vertically and obliquely oriented corallites, indicating that the basal disc paralleled the surface of the substrate and that the polyp body column may have been oriented normal to that surface.

Spacing of tabulae within the fragmental hypotypes show varied types of spacing (Appendix B, Table 35). Coralla not showing spacing zonation exhibit extensive, transverse zones of corallite crushing, possibly obliterating any indication of spacing zonation.



a



Fig. 56.--Representations of wall and septal microstructure of <u>Crenulites rigidus</u>, approx. X20.

(a) Fiber orientation and axial plate in corallite wall, longitudinal section.

(b) Fiber orientation in a minor septum, transverse section.

(c) Fiber orientation and axial plate in a major septum and corallite wall, transverse section.

Coralla with tabulae segregated into zones of widely and closely spaced tabulae contain zones paralleling the upper corallum surface.

Types. -- Hypotypes, UND Cat. Nos. 13707-13710, 13716.

Occurrence.--The hypotypes (GSC No. 8438, USNM 81976), one of which Flower (1961, p. 85) based his description on (USNM 81976) were collected from Ordovician strata on Snake Island in Lake St. John, Quebec. Hypotypes (UND Cat. Nos. 13707-13710) and specimens (UND Cat. Nos. 13711-13715) were collected from quarry exposures of the Selkirk Member near Garson, Manitoba (Appendix A, localities A530, A884, A889, A891).

One hypotype (UND Cat. No. 13716) came from 12.2 meters (40 ft) above the base of the Bighorn Formation on the western flank of the Bighorn Mountains, Wyoming (Appendix A, locality A532).

Discussion.--The occurrence of scalloped and downturned tabulae between major septa, plus amplexoid major and minor septa, serves to place the southern Manitoba cerioid coralla with large, prismatic corallites in the genus <u>Crenulites</u> Flower. Absense of amplexoid septa and scalloped, marginally downturned tabulae would result in the colonies under discussion being assigned to the genus Favistina Flower.

Table 35 (Appendix B) shows that corallite diameters, septal counts, and tabular spacing are similar for the hypotypes; and major septa are continuous between tabulae. There are slight differences pertaining to the number and length of the major septa. Nine to 11 major septa are present in the Selkirk hypotypes, whereas the hypotype described by Flower has 11 to 12.

Crenulites duncanae Flower, 1961

Crenulites duncanae Flower, 1961, New Mexico Bur. Mines and Mineral Resources, Memoir 7, p. 84-85, pl. 16, fig. 1 (in part); pl. 19; pl. 20, figs. 1-5.

Diagnosis.--Small corallites 1.8 to 4 mm in diameter with ten major and ten minor septa; amplexoid, major septa commonly extending to center of corallite with peripheral edges continuous between adjacent tabulae; minor septa short or absent, commonly amplexoid when of maximum length.

Description of material.--All hypotypes and catalogued specimens (UND Cat. No. 13717-13727) are fragments of massive, cerioid coralla with a planar, distal surface in the center of the corallum with corallites normal to it. Peripheral corallites radiate from the center. Mean corallite diameter for three hypotypes from the Selkirk Member (UND Cat. No. 13717-13719) is 2.6 mm. The range of diameter for these hypotypes is 1.8 to 3.5 mm (Appendix B, Table 36). Corallite walls have a central axial plate between two fibrous sclerenchymal layers. Each layer gives rise to septal structures within a corallite of the pair sharing the wall. Fibers within each sclerenchymal layer are oriented in the same manner as those in the walls of <u>Crenulites rigidus</u>. In both <u>C. rigidus</u> and <u>C. duncanae</u>, sclerenchymal fibers in each layer are oriented obliquely upward and outward from their origin at the axial plate.

Ten major and an equal number of minor septa occur in each corallite, rarely 11 of each type occur (Appendix B, Table 36). Major and minor septa commonly appear to be outgrowths of, or

directly related to the sclerenchymal wall layers. Transverse sections show that the fibers within observed septa diverge from a central plane of origin similar to those in <u>Crenulites rigidus</u> (Figure 56b). In most cases, the central plane in these septa is not a structural entity like the axial plate of the intercorallite wall but is simply a plane of abuttment of two sets of fibers.

However when major septa are sectioned at their point of maximum extent across a tabula, a three layered structure, similar to the rugosan wall, occurs at the level of maximum septal length and width--with a central layer or axial plate bounded on each side by the sclerenchymal layers (Figure 56c). Poor preservation prevents observation of the relation of this septal structure to the corallite wall, so no conclusion can be made as to whether this type of structure arises from the wall axial plate. Often, at the level of a tabular surface, two major septa on opposite sides of the corallite are in contact, or nearly so, at the corallite center. This seems to define a cardinalcounter plane, lending an aspect of bilateral symmetry to the corallite. Apparent alar and counter-lateral septa often merge with the cardinal and counter septa.

The columella (Hill, 1956, p. F242), formed by the merging of these septa, exists only at the level of intersection on a tabular surface, and is not continuous with those on adjacent tabulae.

Tabulae are all complete and downturned at their peripheral margins. Those in inclined corallites are normal, approximately parallel or subparallel to the presumed sediment surface. Tabulae intersecting the corallite wall and the peripheral end of major septa are deeply depressed between the septa, forming a crenulate

or zig-zag line of intersection. Tabulae intersect the major septa at the distal apex of each crenulation.

Hypotypes often show strongly developed segregation of zones of closely and widely spaced tabulae (Appendix B, Table 36). These zones are parallel to the corallum growth surface. Tabulae within zones of widely spaced types often show weak development of septa on tabular surfaces, whereas the zones of closely spaced types contain the most strongly developed septa in terms of thickness and degree of extension onto the tabular surface. Tangential sections through both regions show that the peripheral margins of the major septa are continuous from tabula to tabula. Variations in tabular spacing affect the septa in terms of the amount of axial extension and septal thickness but do not affect longitudinal, intertabular continuity.

Types.--Hypotypes, UND Cat. Nos. 13717-13719, 13725.

Occurrence.--The holotype (NMBM No. 571) and paratypes (NMBM Nos. 672, 673) occured in the upper part of the Second Value Formation of the Montoya Group near El Paso, Texas (Flower, 1961, p. 85). Most hypotypes (UND Cat. Nos. 13717-13719) and other catalogued specimens (UND Cat. Nos. 13720-13724) occurred in quarry exposures of the Selkirk Member, Garson, Manitoba (Appendix A, localities A530, A884, A889, A892, A893). One hypotype (UND Cat. No. 13725) occurred 40.6 meters (133 ft) above the base of the Bighorn Formation and specimen UND 13726 occurred 15.2 meters (50 ft) above the base of the unit, in Bighorn County, Wyoming (Appendix A, localities 534 and 532).

Discussion. -- Criteria used for assignment of the hypotypes and specimens to C. duncanae are corallite diameter, septal count,

and amount of extension of major septa onto tabular surfaces. The corallite diameter of the northern Wyoming and southern Manitoba hypotypes are in close agreements with values expressed by Flower (1961, p. 84) for the holotype and paratypes (Appendix B, Table 36).

Septal counts for the hypotypes are within the range of Flower's types, 8 to 12 of each type per corallite, and are consistent in the occurrence of 10 major and 10 minor septa in most corallites. Flower (1961, p. 84) stated that minor septa are not visible in the holotype and paratypes, but his plate 19, figure 5 shows structures that may be minor septa, attached at their peripheral margins to the corallite wall.

Minor septa in the southern Manitoba hypotypes vary from not visible to those extending up to one-fifth of the distance from the corallite periphery to the axis (Appendix B, Table 36). Minor septa are poorly developed in portions of corallites where tabular spacing is greatest and are best developed in regions of closely spaced tabulae. Major septa, particularly the cardinal, counter, and others, commonly merge at the distal tabular surface. This characteristic approaches that in the cerioid rugosan genus <u>Cyathophylloides</u> Dybowski. In <u>Cyathophylloides</u>, major septa meet at the corallite axis but have a greater number of septa and upwardly arched tabulae. The tendency toward bilateral symmetry in <u>Crenulites duncanae</u> indicates an affinity with evolutionarily advanced colonial and solitary rugose corals characterized by such symmetry.

Flower (1961, p. 85) stated that the holotype and paratypes of <u>C</u>. <u>duncanae</u> do not have major septa with intertabular continuity. However, an illustration of one of the paratypes NMBM No. 672;

Flower, 1961, plate 20, figure 5) shows complete, and nearly complete, intertabular continuity of the major septa. The hypotypes also have major septa continuous between tabulae.

Several silicified corallum fragments were collected from the lower, massive portion of the Bighorn Formation. Lack of preservation of wall structures prohibits delineation of the wall microstructure. Sections of the largest fragment (UND Cat. No.13725) cut the basal periphery of a corallum. Corallites closest to the basal surface are different from those in the interior and distal portions of the corallum. Those near the basal surface exhibit an alveolitid outline, with the convex wall directed toward the corallum interior. These corallites are usually inclined to the corallum growth surface, and are oblique to the tabular and the closely and zones of widely spaced tabulae. Septal development in these corallites is poor, with both major and minor septa being vestigal or absent. Due to the lack of well developed septa, no crenulation occurs at the tabular margins.

Suborder COLUMNARINA

Family STAURIDAE

Genus Cyathophylloides Dybowski, 1873

<u>Type species</u> (by subsequent designation, Sherzer, 1891, p. 278).--Cyathophylloides kassariensis Dybowski, 1873, p. 379.

Diagnosis.--Cerioid, the major septa extending almost onto the axis; minor septa vary in length from short to long; marginarium absent; tabulae highly variable, being transverse and having slightly downturned edges, centers transverse, depressed or domed, and incomplete (Browne, 1965, p. 1186).

Discussion. -- Cyathophylloides is very similar to Favistina Flower (=Favistella Dana). It differs from Favistina in having a

greater number of major septa that are longer than those in <u>Favistina</u>. Browne (1965) emended the diagnostic characters of <u>Cyathophylloides</u> to include corals with major septa extending close to or to the corallite axis and minor septa varying from short to long. The emended diagnosis recognizes the possibility of amplexoid retreat of major septa within the genus. Flower (1961, p. 83) suggested an evolutionary lineage of <u>Favistina</u> to <u>Cyathophylloides</u> through increasing septal length and downturning of tabular margins.

Cyathophylloides hollandi n. sp.

Plate 22, Figures 6, 7

Diagnosis.--Large sub-globose corallum with corallite diameters of 1.7 to 5.8 mm with mean of 3.6 mm; corallites radiating from growth center of colony, those in basal peripheral portion of colony with alveolitid outline, and those in central and distal portions of colony having a polygonal outline; scattered corallites projecting less than 3 mm above the corallum growth surface, retaining polygonal outline; ten to 16 major septa per corallite, with a mean of 13 major and 13 minor septa per corallite; major septa long, commonly extending nearly to corallite axis; major septa showing slight amplexoid retreat above tabular surface; minor septa short, length averaging 0.1 times mean corallite radius, spinose on axial margins; tabulae complete, normal to corallite axis, in zones of closely and widely spaced types, commonly downturned at periphery, planar tabulae less common.

<u>Description of material</u>.--The large, cerioid, sub-globose holotype (UND Cat. No. 13727) adheres at its proximal surface to a small favositid corallum. Corallites in the mature portions of the corallum

are polygonal whereas those in the basal and peripheral portion of the holotype corallum have an alveolitid outline, which is formed by the upper arched wall of the corallite being supported by the arched walls of the underlying corallites.

The corallites radiate from the point of origin of the colony. Immature corallites alter their outline with increasing diameter, from subtriangulate to rectangular or trapezoidal, and to polygonal with maturity. Scattered, mature corallites project from the corallum growth surface and exhibit longitudinal, septal furrows on the corallite walls.

Corallite diameters are 1.7 to 5.8 mm with a mean of 3.6 mm (Appendix B, Table 37). Corallite walls are uniformly thin and transversely crenulate, with an amplitude no greater than 0.5 times the wall thickness. The uniformly thin and continuous axial plate is flanked by fibrous sclerenchyme.

Ten to 16 major and an equal number of minor septa are present in each corallite. Major septa are longitudinally continuous along the corallite wall and often merge in adjacent pairs at or immediately above a tabular surface. Scattered corallites show one or two exceptionally elongated septa opposite each other, which tend to merge with each other or other septa, giving the appearance of a cardinal-counter plane. Above the tabular surface, major septa exhibit a restricted type of amplexoid retreat (Figure 57) with maximum retreat resulting in lengths ranging from approximately 0.4 to 0.9 (mean=0.7) times the mean corallite radius. They remain uniformly thin save for a slight thicknening at their peripheral edges. Axial deflection of these septa is shown as a right or left twisting, symmetrical about the

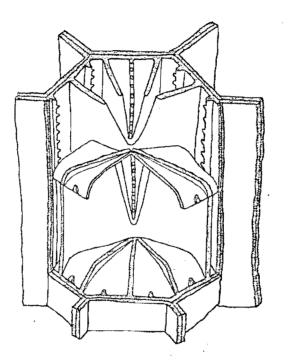


Fig. 57.--Portion of corallite of <u>Cyathophylloides hollandi</u> n. sp. Cut-away shows disposition of amplexoid major septa, minor septa, and tabulae, approx. X25.

counter-cardinal plane. Minor septa, where developed extend 0.06 to 0.14 times the corallite radius (mean=0.09). They are longitudinally continuous between tabula, and bear short spines on their margins (Figure 57).

All tabulae are complete and transverse to the corallite axis. Those in the central and upper portions of the corallum are predominantly downturned at the edges or have a raised central platform with a planar or slightly depressed center. Planar types are uncommon. Tabulae are grouped into indistinct zones of crowded and widely spaced forms. Mean spacing values for the crowded and widely spaced tabulae are 0.83 mm and 1.37 mm (Appendix B, Table 37).

Type.--Holotype, UND Cat. No. 13727.

Occurrence. -- The holotype of <u>Cyathophylloides hollandi</u> was collected as float about 4 meters (13 ft) above the top of the Hunt Mountain beds, Bighorn Range, northern Wyoming (Appendix A, locality A545).

<u>Discussion</u>.--Browne (1965) described several individuals of <u>Favistina</u> from the Richmond Group of north-central Kentucky west of the Cincinnati Arch, and assigned them to <u>Cyathophylloides</u> because of an emended diagnosis of that genus. Her biometrics of the North American species of <u>Cyathophylloides</u> (Brown, 1965, table 2) permit comparison with the Wyoming holotype. <u>Cyathophylloides crenulata</u> (Flower), from Kentucky, most closely resembles <u>C. hollandi</u>; however, the following differences exist:

> <u>C. crenulata</u> has parallel corallites, whereas the corallites of <u>C. hollandi</u> are radiating, reflecting a differing mode of budding and a differing corallum form.

2. Corallite walls of <u>C</u>. <u>crenulata</u> are distinctly crenulate and thicker than those of C. hollandi.

3. Tabular spacing differs.

<u>Cyathophylloides burksae</u> Flower is the only representative of the genus that has been noted (Flower, 1961) in the Montoya Group. It occurs in the Aleman Formation in New Mexico. Together, <u>C. hollandi</u> and <u>C. burksae</u> are the only two representatives of the genus in the New Mexico-Greenland belt of Ordovician strata. Comparison of the two species shows the following differences:

- <u>Cyathophylloides</u> burksae has generally parallel corallites, whereas those of <u>C</u>. hollandi are radiating.
- 2. <u>Cyathophylloides burksae</u> has smaller corallites and consistently fewer septa than does the other species.
- Corallite walls of <u>C</u>. <u>burksae</u> are thicker than those of
 c. hollandi.
- 4. Major septa of <u>C</u>. <u>burksae</u> are long and thick, frequently merging at the axis. The major septa of <u>C</u>. <u>hollandi</u> are long but thinner, and exhibit lengthening of the cardinal and counter septa.
- 5. Minor septa of <u>C</u>. <u>burksae</u> are up to half the length of the major types. <u>C</u>. <u>hollandi</u> has minor septa up to 0.2 times the length of the major septa.

The Wyoming holotype of <u>Cyathophylloides hollandi</u> is named for Dr. F. D. Holland, Jr., Professor of Geology at the University of North Dakota, Grand Forks.

A notable character of the holotype is projection of the polygonal corallites a short distance above the corallum surface. Free

standing corallites occur singly or in adjacent pairs and do not seem to have resulted solely from post-death reworking, or diagenetic or weathering processes, although silification has occurred on the surfaces of the projecting corallites. Another feature of the species is the wide range of septal counts within corallites (Appendix B, Table 37).

Suborder CYSTIPHYLLINA

Family TRYPLASMATIDAE

Genus Tryplasma Lonsdale, 1845

<u>Type species</u> (by subsequent designation of Etheridge, 1907, p. 42).--<u>Tryplasma aequibile</u> Lonsdale, 1845, pp. 613, 633, pl. A, figs. 7-7a. Silurian; River Konka, east side of northern Ural Mountains, Russia (Stumm, 1952, p. 842).

<u>Diagnosis</u>.--Short or long, simple subcylindrical; or compound, loosely dendroid or phaceloid rugose corals with septa composed of vertical rows of spines. Tabulae complete, relatively horizontal, moderately to widely spaced. Dissepiments absent (Stumm, 1952, p. 842).

<u>Discussion.--Tryplasma</u> is the only tryplasmatid in the Ordovician System in strata peripheral to the Williston Basin. It is also unique in that it is the second phaceloid coral species seen during this study, the first being <u>Palaeophyllum argus</u>. Unlike most other genera, <u>Tryplasma</u> has no apparent ancestor in the Ordovician System in the Basin.

Tryplasma gracilis (Whiteaves), 1904

Plate 22, Figure 3

Aphyllostylus gracilis Whiteaves, 1904, Ottawa Natur., v. 18, no. 6, p.

113; Whiteaves, 1906, Palaeozoic Fossils, Geol. Survey Canada,

v. 3, pt. 4, p. 279.

<u>Tryplasma gracilis</u> (Whiteaves) Stumm, 1952, Jour. Paleontology, v. 26, no. 5, p. 843, pl. 125, figs. 16, 17; Stearn, 1956, Geol. Survey Canada, Mem. 281, p. 91, pl. 6, figs. 1, 8.

<u>Diagnosis</u>.--Phaceloid, fasciculate corallum with radiating and parallel cylindrical and subcylindrical corallites averaging 3.0 mm in diameter; no interconnecting tubules; tabulae concave to convex, in poorly defined zones of closely and widely spaced tabulae.

Description of material .-- The two, fragmental, hypotypes (UND Cat. Nos. 13635, 13636) contain cylindrical and subcylindrical corallites averaging 3.0 and 2.1 mm in diameter. The corallites are parallel in the mature portions of the coralla and radiate outward from the corallum point of origin. No interconnecting tubules or stolons are present between corallites. Mean center-to-center corallite spacing, in one hypotype, averages about 3.9 mm and is 1.3 times the mean corallite diameter. The number of longitudinal rows of septal spines per corallite are indeterminable due to incomplete preservation, but longitudinal septal spine spacing for the two holotypes is 0.4 and 0.26 mm. Tabulae are predominantly complete, transverse to the corallite axis, and are concave to convex. Tabulae are grouped into zones of closely and widely spaced types that are continuous between adjacent mature corallites along poorly defined levels which parallel the corallum growth surface.

Types.--Hypotypes, UND Cat. Nos. 13635, 13636.

Occurrence.--Both coralla of <u>Tryplasma gracilis</u> (Whiteaves) were collected from the Stonewall Formation. Hypotype UND Cat. No. 13635 occurred between 1.4 to 1.7 meters (4.5 to 5.5 ft) above the base of the unit and hypotype UND Cat. No. 13636 occurred 5.2 meters

(17 ft) above the base. Both were collected at the type locality of the formation, near Stonewall, Manitoba (Appendix A, localities A554, A555). Stearn (1956, p. 91) stated that the species is an index fossil to the Stonewall Formation and is found at the type locality and to the north of it.

Discussion. -- The hypotypes from the type locality are completely dolomitized and fragmental so extensive biometrical comparisons are not possible. Stearn (1956, p. 91) described two hypotypes (GSC Nos. 10409, 12866) from the type locality and gave some biometric data. The hypotypes described in this study compare favorably with those described by Stearn. Both fall within the range of corallite diameter (Appendix B, Table 38) and each shows corallites in parallel and radiating orientation that compare to the hypotypes in Stearn's work.

One hypotype (GSC No. 10409) described by Stearn possesses small corallites that radiate from the point of origin of the colony and subsequently turn to become parallel to each other and, in doing so, increase in diameter. One hypotype (UND Cat. No. 13636) has small, cylindrical corallites, approximately 2 mm in mean diameter, arranged in radiating fashion. This appears to represent an immature form of <u>T</u>. gracilis and is similar to the basal portion of a hypotype figured by Stearn (1956, plate 6, figure 8). The other hypotype (UND Cat. No. 13635) is a mature colony. Differences in longitudinal spacing of septal spines and tabulae in the two hypotypes may be due to (1) different rates of upward growth as influenced by environmental factors, or (2) varying rates of upward growth due to physiological changes between the immature and mature stages.

Figs. 1, 2, 4, 7.--Trabeculites maculatus Flower (UND Cat. No. 13 1. Transverse section showing crenulate corallite walls, p replaced trabeculae (clear wall sections), and septal s X4.2.

- 2. Longitudinal section showing septal spines, crenulate t zoned tabular spacing, and tabular spines, X4.7.
- 4. Longitudinal section of the trabecular corallite wall s the axial rod (clear central portion) and the flanking sclerenchymal layers. Faint lineations within the laye represent fiber orientation (shown by arrows), crossed X150.
- Transverse section of the corallite wall showing axial and plates (clear central portions). Trabecular bounda shown by arrows, crossed nicols, X47.
- Figs. 3, 5, 8.--Trabeculites manitobensis n. sp. (UND Cat. No. 13
 - 3. Transverse section showing corallite walls with trabecu expanded at their central regions. Septal spines are s as lateral expansions of wall trabeculae, X4.7.
 - 5. Longitudinal section with tangentially sectioned wall trabeculae shown by dark, vertical lines, X7.3.
 - 8. Longitudinal section through corallite wall trabecula, rod shown as clear central area, fiber orientation show arrows, septal spine is an extension of sclerenchymal f crossed nicols, X150.

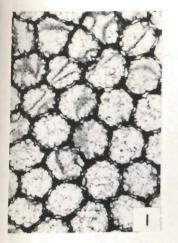
Fig. 6.--Nyctopora fissisepta n, sp. (UND Cat. No. 13703).

6. Longitudinal section with wall trabeculae cut tangentia shown by dark, vertical lines, X6.

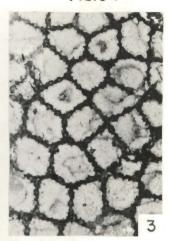
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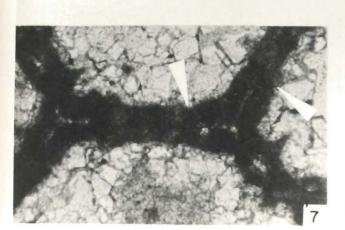
Plate I



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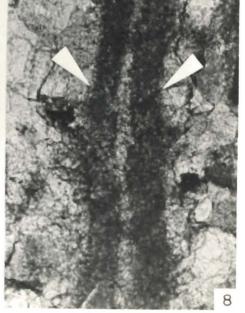
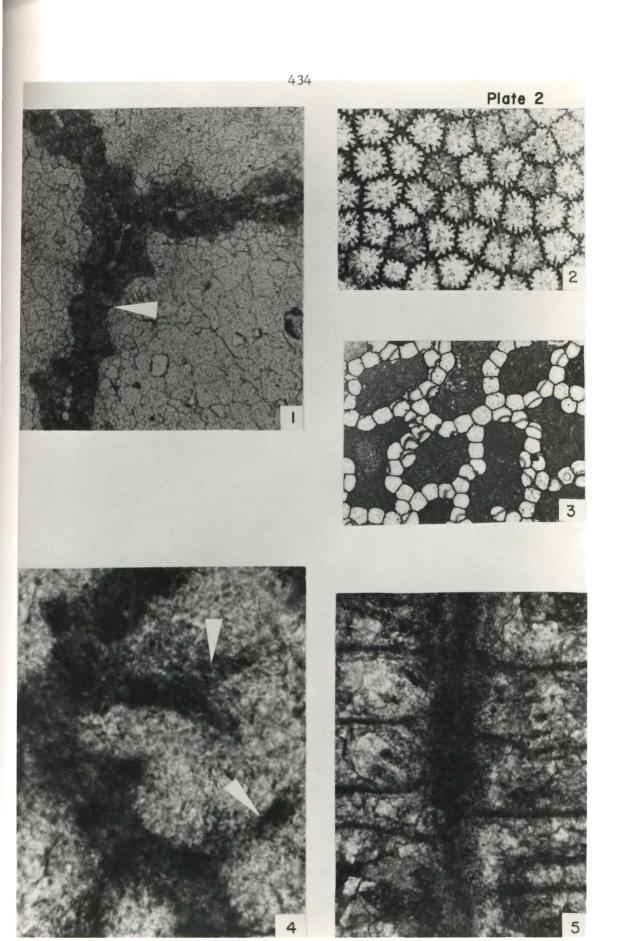


Fig. 1.--Trabeculites manitobensis n. sp. (UND Cat. No. 13561).

- 1. Transverse section of trabeculate corallite walls showing axial plates at trabecular centers. Arrow illustrates boundary between a trabecular pair, crossed nicols, X47.
- Figs. 2, 4, 5.--Nyctopora fissisepta n. sp. (UND Cat. No. 13703).
 - Transverse section showing walls and prominent septa. Trabeculae within walls distinguishable by variations in shading, X6.9.
 - 4. Transverse section with corallite walls and bifurcated septa (shown by arrows), X150.
 - 5. Longitudinal section through a wall trabecula with closely packed septal spines having the same orientation as trabecular fibers, crossed nicols, X47.

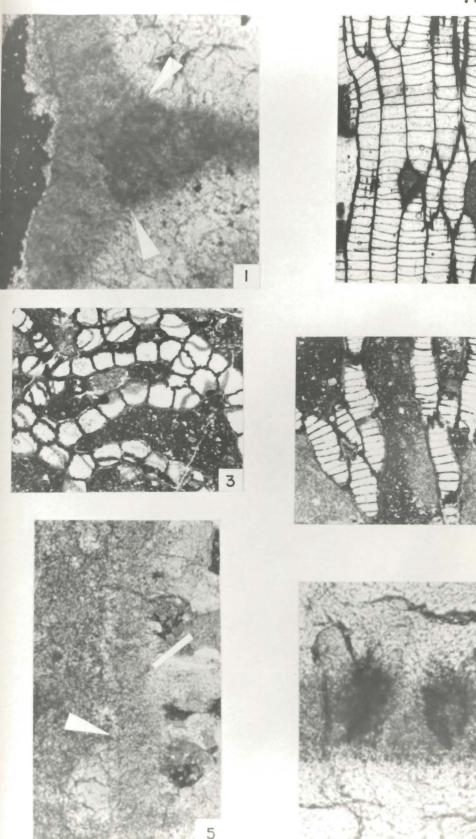
Fig. 3.--Manipora amicarum Sinclair (UND Cat. No. 13765).

3. Transverse section showing uniserial cateniform ranks, biserial agglutinative patches, slightly crenulate common walls, and convex lateral walls, X2.8.

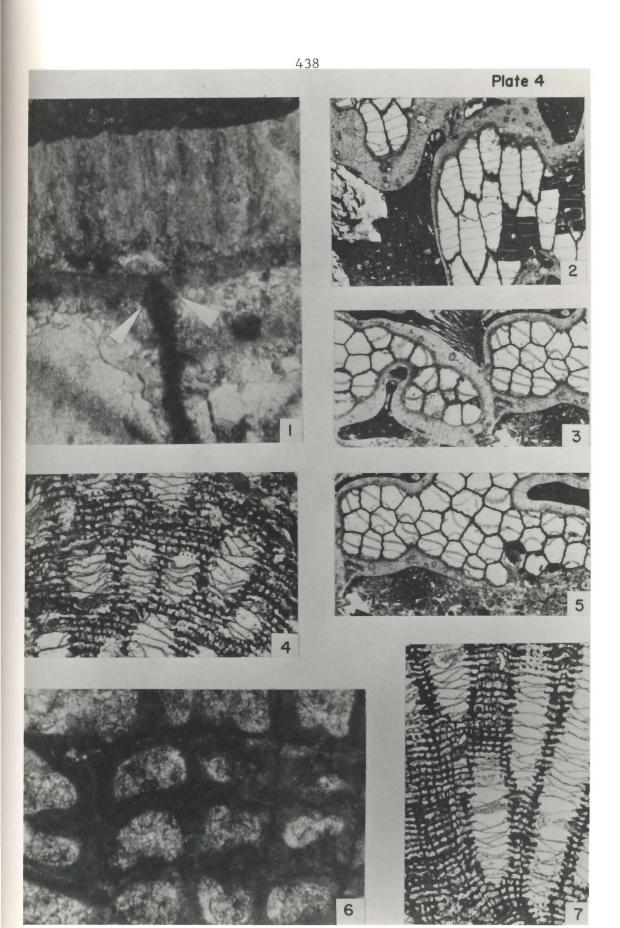


- Figs. 1, 2, 5.--Manipora amicarum Sinclair (UND Cat. No. 13765).
 - Transverse section through the common and lateral walls showing sutures between the two wall types (shown by arrows), crossed nicols, X47.
 - 2. Longitudinal section, X17.
 - Longitudinal section with holotheca (shown by arrow) and fibrous layer of lateral wall (orientation shown by broad line), crossed nicols, X150.
- Figs. 3, 4, 6.--Manipora garsonensis n. sp. (UND Cat. No. 13766).
 - 3. Transverse section showing septate common walls, and convex lateral walls, X3.1.
 - 4. Longitudinal section with crenulate common walls shown by zig-zag pattern, X3.0.
 - 6. Longitudinal section with tabular spines set in tabular stereozone, X150.

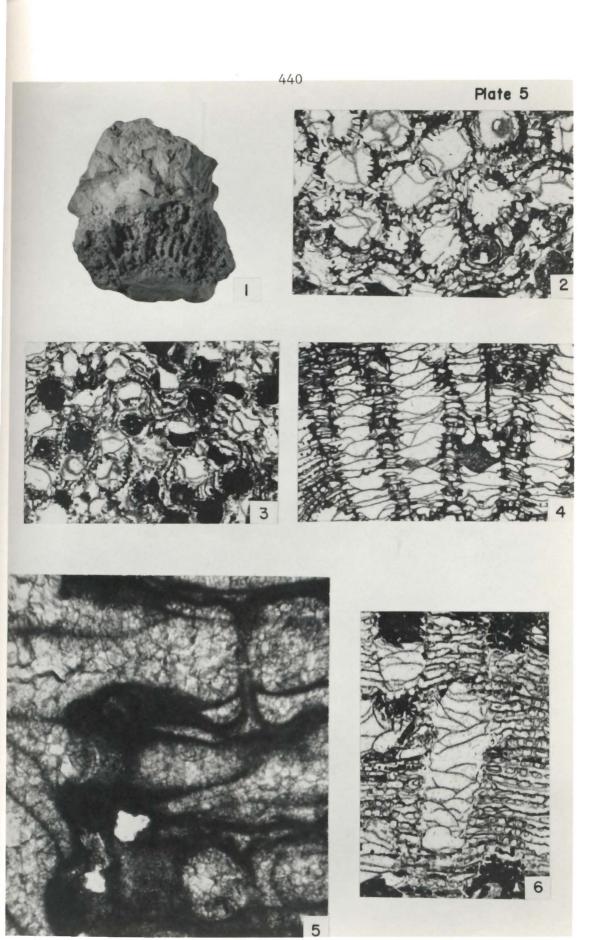
Plate 3



- Figs. 1-3, 5.--<u>Manipora bighornensis</u> n. sp., encrusted by <u>Coccoseris</u> sp. (UND Cat. No. 13662).
 - Transverse section cutting common and lateral walls of M. bighornensis, and trabeculae of <u>Coccoseris</u> sp. Suture between common and lateral walls shown by arrows, crossed nicols, X47.
 - 2. Longitudinal section, X3.5.
 - 3, 5. Transverse section, X3.5.
- Figs. 4, 6, 7.--<u>Calapoecia</u> <u>anticostiensis</u> Billings (UND Cat. No. 13565). 4. Oblique section, X3.7.
 - 6. Longitudinal section showing mural pores formed by intersection of vertically oriented wall trabeculae intersecting with horizontally oriented coenosteal plates. Plates terminate in septal spines at left hand side of illustration, crossed nicols, X47.
 - 7. Longitudinal section, intersected septal spines shown as rows of dots in corallite lumina, X4.1.



- Fig. 1.--<u>Calapoecia</u> sp. cf. <u>C. anticostiensis</u> Billings (UND Cat. No. 13567).
 - 1. Fragmental specimen, X0.55.
- Figs. 2, 4, 5.--Calapoecia arctica Troedsson.
 - 2. Transverse section showing tabulae extending into coenenchymal region (light gray lines; UND Cat. No. 13570), X3.4.
 - 4. Longitudinal section (UND Cat. No. 13570), X3.5.
 - 5. Longitudinal section showing tabulae extended into coenenchymal region through mural pores. Corallite on the left side of the illustration (UND Cat. No. 13569), X47.
- Figs. 3, 6.--Calapoecia ungava Cox (UND Cat. No. 13571).
 - 3. Transverse section with tabulae (light gray lines) in coenenchymal region, X3.5.
 - 6. Longitudinal section, tabulae extruded through mural pores into coenenchyme, X5.8.

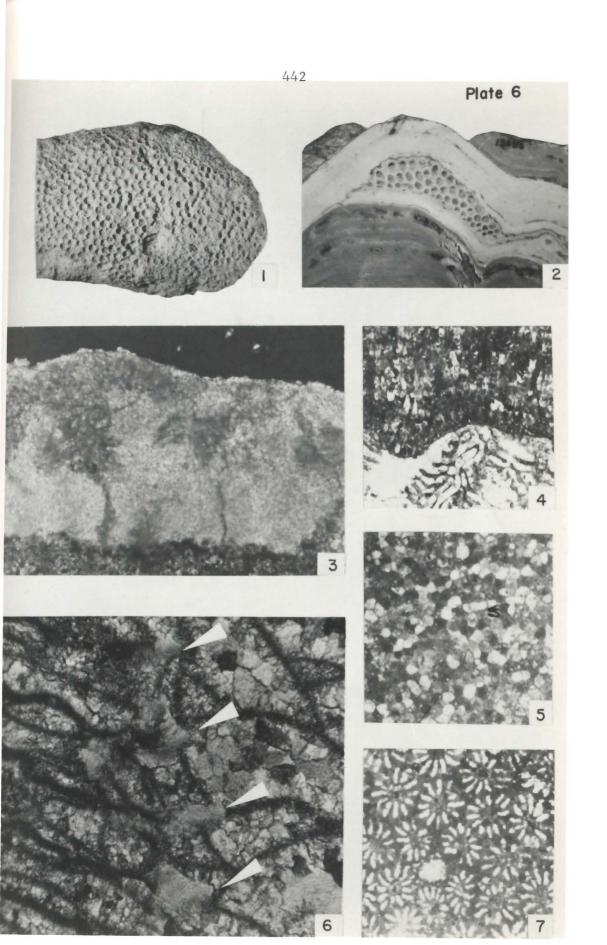


Figs. 1, 6.--Calapoecia ungava Cox (UND Cat. No. 13571).

- 1. Distal surface of corallum, X0.65.
- 6. Longitudinal section through portions of corallite wall, septal spines indicated by arrows. Coenenchymal region to left of wall, crossed nicols, X47.

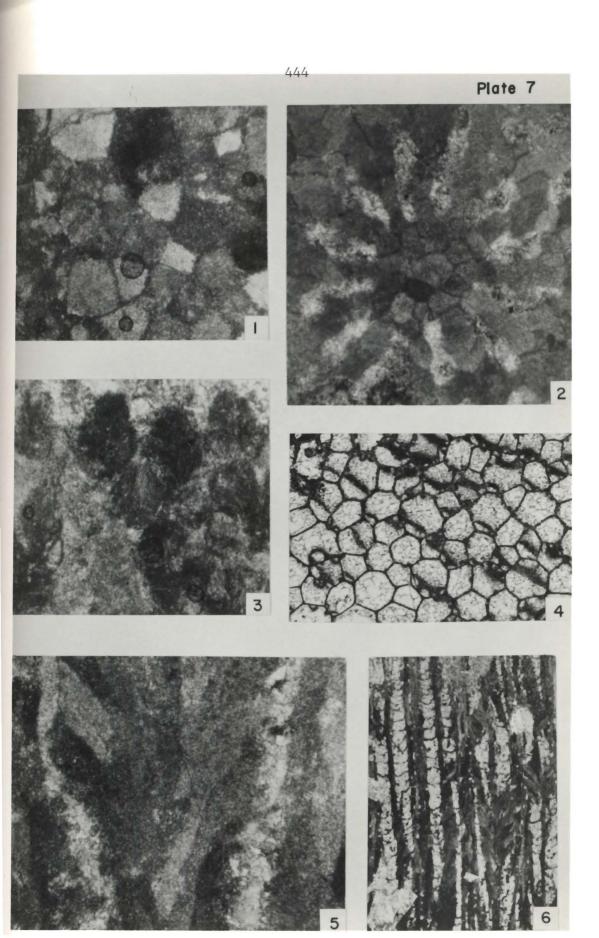
Fig. 3.--Protarea sp. cf. P. cutleri Leith (UND Cat. No. 13651).

- 3. Longitudinal section with three trabeculae arising from corallum attachment surface, crossed nicols, X150.
- Figs. 2, 4, 5.--Coccoseris astomata Flower (UND Cat. No. 13653).
 - Polished longitudinal section of a stromatoporoid coenosteum (dark gray) covered by <u>C</u>. astomata, which is covered in turn by a colony of <u>Calapoecia arctica</u>. Both overlain by another layer of C. astomata, X0.67.
 - 4. Longitudinal section showing relationship between <u>C</u>. <u>astomata</u> and Calapoecia arctica, X6.2.
 - 5. Transverse section showing close-packed polygonal baculae, X9.
- Fig. 7.--<u>Protrochischolithus magnus</u> (Whiteaves) (UND Cat. No. 13663). 7. Transverse section, X8.4.

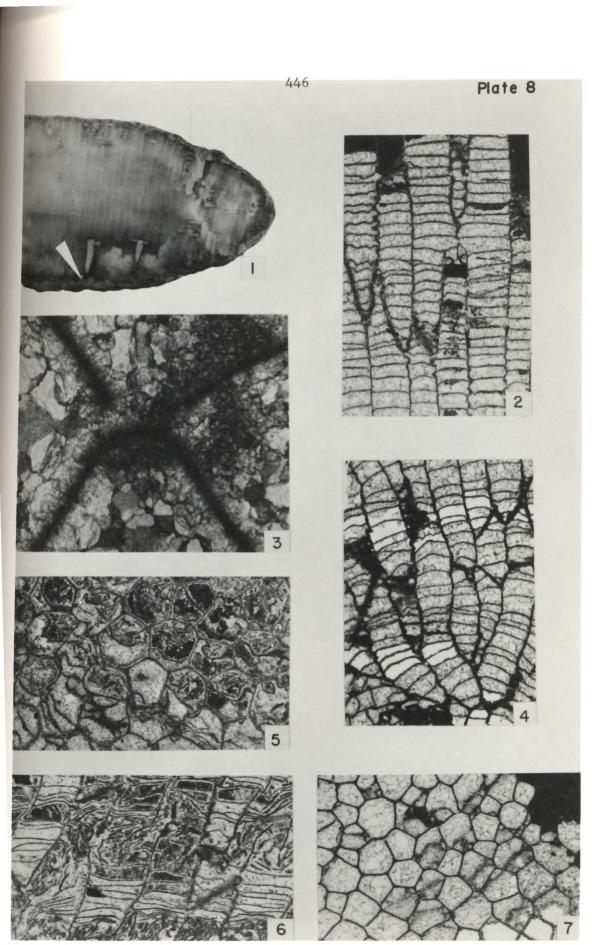


Figs. 1, 3.--Coccoseris astomata Flower (UND Cat. No. 13653).

- 1. Transverse section, polygonal baculae, X47.
- 3. Longitudinal section showing trabecular baculae with coneshaped pustules at their distal ends, crossed nicols, X47.
- Figs. 2, 5, 6.--Protrochischolithus magnus (Whiteaves) (UND Cat. No. 13663).
 - 2. Transverse section showing polygonal baculae in columella, septa, and walls. Septal interspaces represented by clear regions, crossed nicols, X47.
 - 5. Longitudinal section showing trabecular baculae originating in and diverging from the corallite wall. Interseptal spaces represented by clear regions, crossed nicols, X47.
 - 6. Longitudinal section showing divergent baculae in walls, clear interseptal spaces transversed by concave tabulae, and parallel baculae within columellae, X6.
- Fig. 4.--Paleofavosites kuellmeri Flower (UND Cat. No. 13729).
 - 4. Transverse section showing rounded corallite walls and crenulate tabulae, X9.



- Figs. 1-3.--Paleofavosites kuellmeri Flower (UND Cat. No. 13729).
 - 1. Longitudinal polished section showing parallel corallites resting on argillaceous substrate (arrow), X0.95.
 - 2. Longitudinal section showing crenulate tabular margins, crenulate walls, and mural pores, X4.9.
 - 3. Transverse section showing curved walls and gaps where section plane cuts two mural pores, crossed nicols, X47.
- Figs. 5, 6.--<u>Paleofavosites</u> sp. cf. <u>P. kuellmeri</u> Flower (UND Cat. No. 13730).
 - 5. Transverse section, X4.3.
 - 6. Longitudinal section, X5.5.
- Ags. 4, 7.--Paleofavosites mccullochae Flower (UND Cat. No. 13731).
 4. Longitudinal section showing crenulate walls and mural pores, X4.
 - 7. Transverse section showing curved walls and pore gaps at corallite corners, X4.1.



- 1. Longitudinal section, X7.6.
- 2. Transverse section, X6.2.

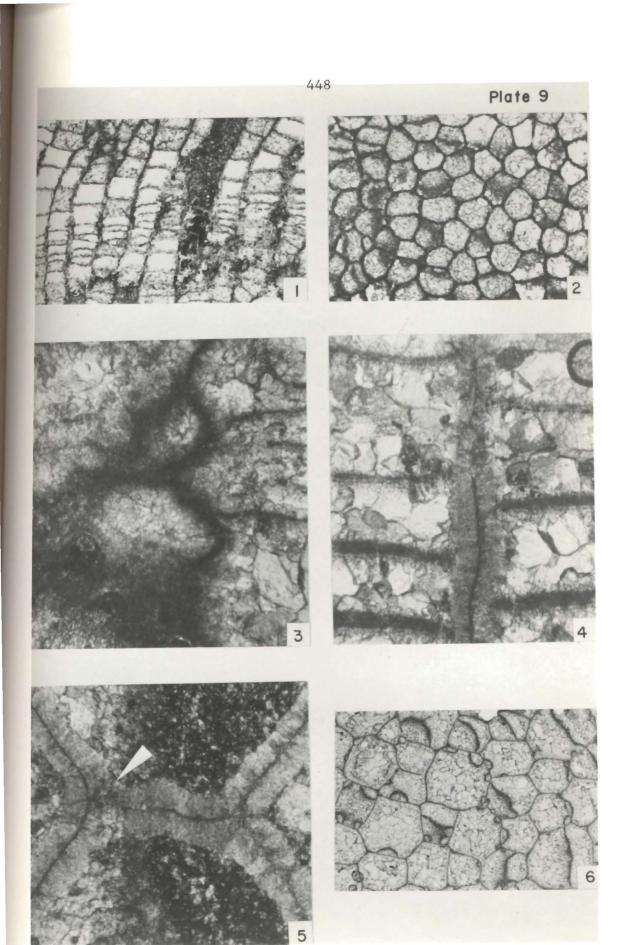
Fig. 3.--Paleofavosites mccullochae Flower (UND Cat. No. 13731).

3. Longitudinal section showing crenulate wall with a mural pore, crossed nicols, X47.

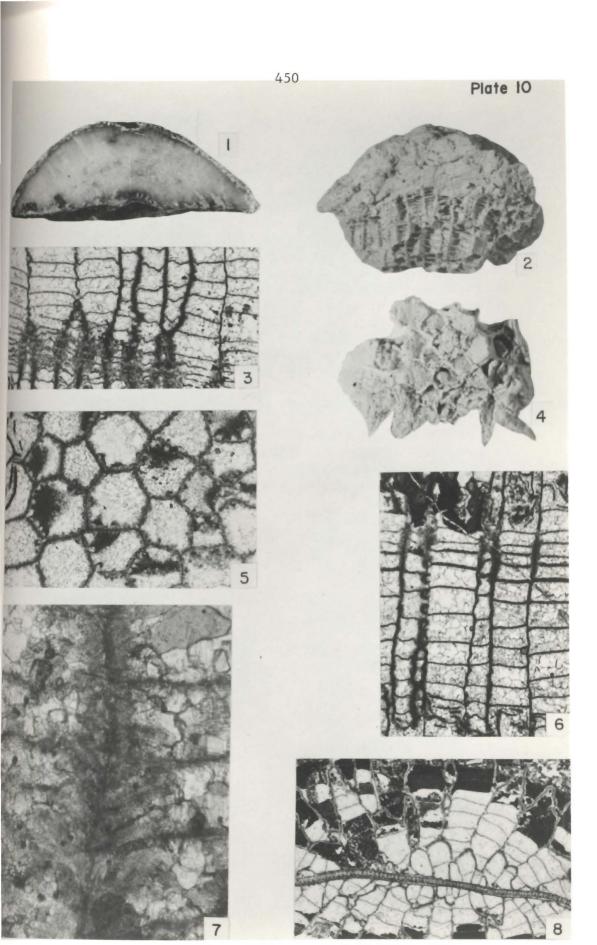
Figs. 4-6.--Paleofavosites prolificus (Billings).

- Longitudinal section showing fibrous sclerenchymal wall layers, variations in wall thickness and its association with tabular spacing, UND Cat. No. 13735, crossed nicols, X47.
- 5. Transverse section showing thick walls, wall curvature, and a tunnel formed by a mural pore (arrow), UND Cat. No. 13735, crossed nicols, X47.
- Transverse section showing curved corallite walls and crescentic dark lines representing tabular crenulation, UND Cat. No. 13734, X5.6.

Figs. 1, 2.--Paleofavosites sp. cf. <u>P. prayi</u> Flower (UND Cat. No. 13733).

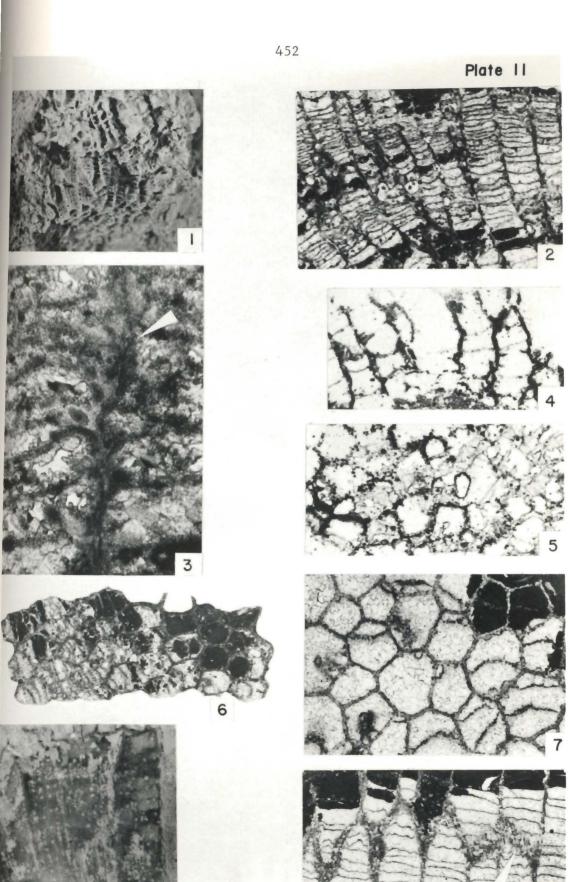


- Figs. 1, 6.--Paleofavosites prolificus (Billings).
 - Longitudinal polished section bisecting the corallum, calices 1. filled with sediment, UND Cat. No. 13734, X0.72.
 - 6. Longitudinal section showing thickened walls associated with closely spaced tabulae, crenulate wall and a row of mural pores partially enclosed by poral processes, UND Cat. No. 13735, X5.7.
- Figs. 2, 3, 5, 7, 8.--Paleofavosites okulitchi Stearn.
 - Fragmental corallum with some pores in walls, UND Cat. No. 2. 13745, X1.6.
 - 3. Longitudinal section showing crenulate walls, walls expanded into septa associated with closely spaced septa, and crenulate tabular margins, UND Cat. No. 13741, X4.3.
 - 5. Transverse section showing wail sclerenchymal layers expanded into septa in regions of closely spaced tabulae, UND Cat. No. 13741, X4.9.
 - 7. Longitudinal section showing septa, UND Cat. No. 13741, crossed nicols, X47.
 - 8. Longitudinal section showing adherance of corallum to skeletal fragment, UND Cat. No. 13742, X3.7.
- Fig. 4.--Paleofavosites sp. A (UND Cat. No. 13750). 4. Fragmental corallum, X2.4.



- Fig. 1.--<u>Angopora manitobensis</u> Stearn (UND Cat. No. 13751).

 Fragmental corallum showing mural pores at corallite corners, vertically directed, lamellar septa, and tabulae, X3.1.
- Figs. 2, 3, 6.--Angopora wyomingensis n. sp. (UND Cat. No. 13754).
 - 2. Longitudinal section showing closely spaced tabulae, X7.3.
 - 3. Longitudinal section with crenulate wall, septal spines, and lamellar septa (arrow), crossed nicols, X47.
 - 6. Oblique section, X7.1.
- Figs. 4, 5.--(?) Angopora sp. (UND Cat. No. 13755).
 - 4. Longitudinal section with prominent spines, X7.5.
 - 5. Poorly preserved transverse section, X7.2.
- Figs. 7-9.--Favosites manitobensis n. sp. (UND Cat. No. 13751).
 - 7. Transverse section, X4.8.
 - 8. Corallite wall on basal surface of corallum, rows of mural pores shown by rows of light gray dots, X4.0.
 - 9. Longitudinal section with trabeculae in obliquely cut walls (arrow) and crenulate tabular margins, X3.9.



Figs. 1, 3, 5.--Favosites manitobensis n. sp. (UND Cat. No. 13751), crossed nicols, X47.

- 1. Longitudinal section with trabecular expansions of axial plate (light gray regions within wall).
- 3. Transverse section at intersection of four corallites. Trabeculae represented by light gray regions within walls.
- 5. Longitudinal section obliquely cutting wall plane with three trabeculae (outlined in black).

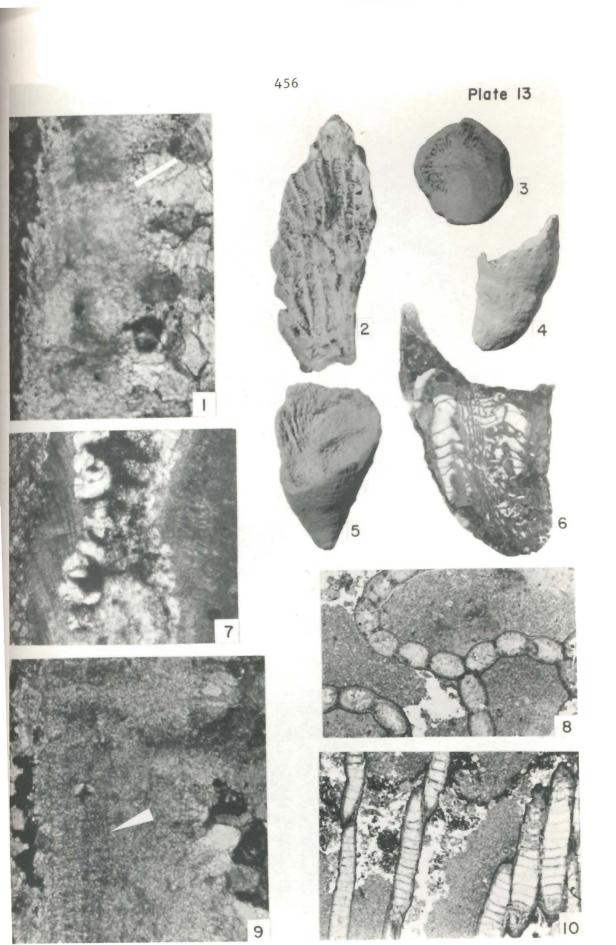
Figs. 2, 4, 6.--Catenipora robusta (Wilson).

- 2. Transverse section through common wall showing three sutures between common wall trabeculae and lateral wall, UND Cat. No. 13761, crossed nicols, X47.
- 4. Transverse section, UND Cat. No. 13759, X3.1.
- 6. Longitudinal section plane normal to cateniform rank cutting two common wall trabeculae and flanking portions of the lateral walls, UND Cat. No. 13761, crossed nicols, X47.

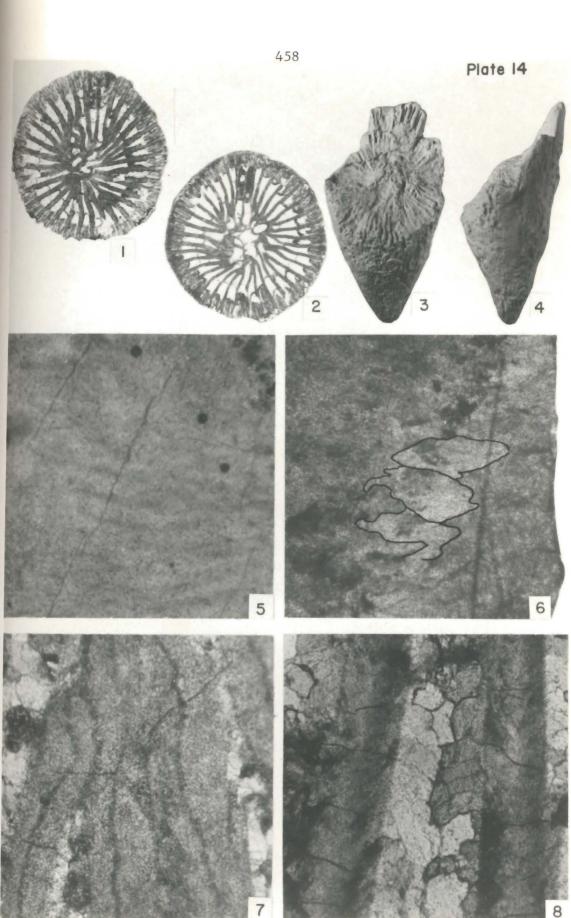
Plate 12

Figs. 1, 7.--Catenipora robusta (Wilson).

- 1. Longitudinal section through lateral corallite wall showing annulated holotheca, steeply inclined growth increments and orientation of inner layer fibers parallel to white line, UND Cat. No. 13761, crossed nicols, X150.
- 7. Longitudinal section cutting two lateral corallite walls, section normal to cateniform rank. Growth increments shown as curved, steeply inclined, dark lines, UND Cat. No. 13758, crossed nicols, X47.
- Figs. 8-10.--<u>Catenipora rubra</u> Sinclair and Bolton (UND Cat. No. 13764). 8. Transverse section with layered, spinose lateral walls, X3.5.
 - 9. Transverse section of lateral wall showing banded growth increments (arrow). Corallite center toward right, X150.
 - Longitudinal section with spinose, layered lateral walls, X2.4.
- Fig. 2.--Catenipora sp. (UND Cat. No. 13752). 2. Fragment of corallum, X1.3.
- Figs. 3-6.--Streptelasma poulseni Cox.
 - 3. Calicinal view, cardinal septum at top, UND Cat. No. 13609, X1.
 - 4. Longitudinal view, cardinal side on right, UND Cat. No. 13608, X1.
 - 5. Longitudinal view showing deep calyx, cardinal side toward left, UND Cat. No. 13609, X1.
 - 6. Longitudinal section showing septa and tabulae cardinal side toward left, UND Cat. No. 13609, X1.75.

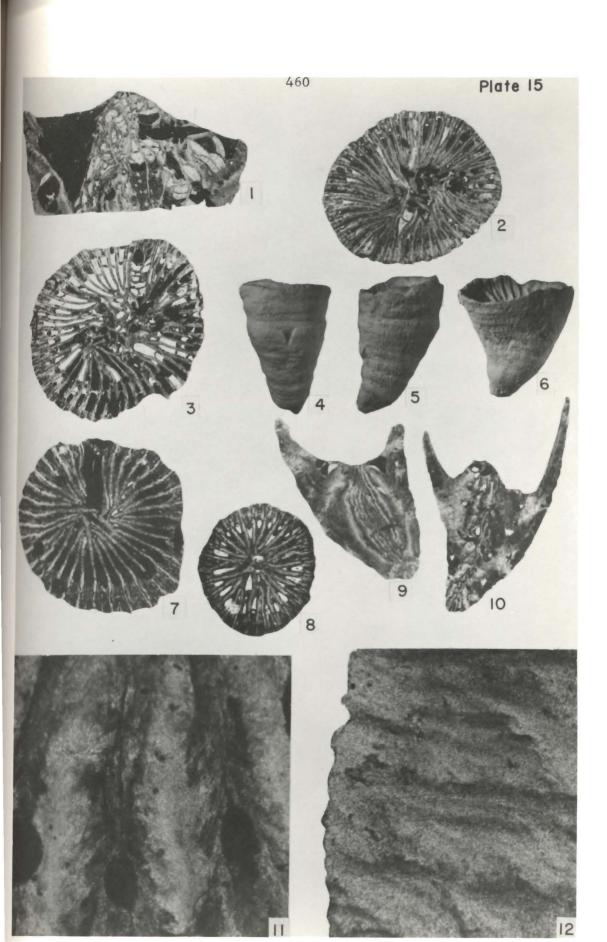


- Figs. 1, 2, 5. 7.--Streptelasma poulseni Cox.
 - 1. Transverse section 10 mm from apex, cardinal septum at twelve o'clock, UND Cat. No. 13608, X3.3.
 - 2. Transverse section 13 mm from apex, cardinal septum in same position as above, UND Cat. No. 13608, X2.8.
 - 5. Longitudinal section cutting central region of a major septum, showing fibers in parallel groupings. Corallum axis toward left, UND Cat. No. 13608, crossed nicols, X47.
 - 7. Transverse section of three major septa showing faint V-shaped fiber orientation opening toward corallum axis (toward top of illustration), UND Cat. No. 13609, crossed nicols, X47.
- Figs. 3, 4, 6, 8.--Streptelasma sheridanensis n. sp. (UND Cat. No. 13634).
 - 3. Counter side and portion of inclined calyx, portion of calicinal rim remains on cardinal side, X1.
 - 4. Alar side, cardinal portion of calicinal rim, and mound-like columella, X1.
 - Longitudinal section cutting the axial portion of a major septum showing three probable trabecular boundaries (black lines), crossed nicols, X47.
 - 8. Transverse section of two major septa (axis toward top of figure) showing V-shaped fiber orientation and zonation of fiber textures in trabeculae, crossed nicols, X47.

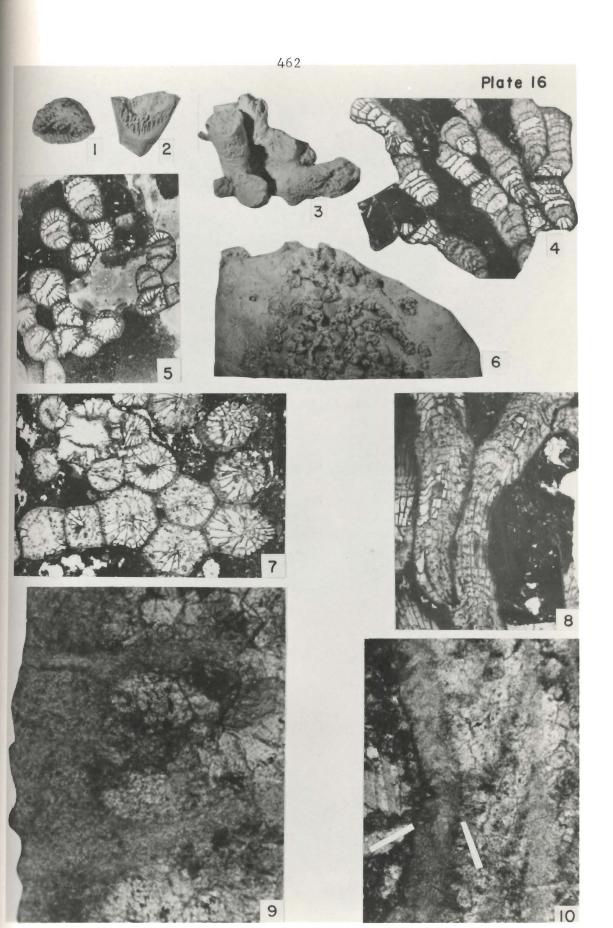


Figs. 1-3.--Streptelasma sheridanensis n. sp. (UND Cat. No. 13634).

- 1. Longitudinal section with deeply depressed tabulae in cardinal fossula on left side of columella, X2.6.
- 2. Transverse section, 10 mm from apex, with slight flattening in alar plane, cardinal septum at twelve o'clock, X2.9.
- 3. Transverse section, 25 mm from apex, with pronounced axial vortex, cardinal septum at one o'clock position, X2.3.
- Figs. 4-12.--Streptelasma kelpinae n. sp.
 - 4. Cardinal side of corallum (UND Cat. No. 13697) with notch on cardinal side of former position of calicinal rim, X1.
 - 5. Alar side of UND Cat. No. 13697, X1.
 - 6. Alar side of UND Cat. No. 13699, X2.
 - 7. Transverse section of UND Cat. No. 13620 with prominent cardinal fossula, 13 mm from apex, X3.9.
 - Transverse section of UND Cat. No. 13615, 8 mm from apex, X4.2.
 - 9. Longitudinal section of UND Cat. No. 13617, with section plane eccentric to axis, X1.9.
 - 10. Longitudinal section of UND Cat. No. 13618, with deep calyx, X2.6.
 - 11. Transverse section of three major septa of UND Cat. No. 13620 showing textural differentiation between trabeculate centers of septa and septal margins, crossed nicols, X47.
 - 12. Longitudinal section of the central portion of a major septum of UND Cat. No. 13617. Trabeculate bundles shown by dark streaks, corallum axis toward right, crossed nicols, X47.



1.	2 <u>Streptelasma</u> sp. (UND Cat. No. 13702). Calicinal view with cardinal side at right, Xl. Alar view of corallum with cardinal side at right, Xl.
	Palaeophyllum argus Sinclair (UND Cat. No. 13704). Fragmental corallum, X1.3.
4.	5 <u>Palaeophyllum pasense</u> Stearn (UND Cat. No. 13705). Longitudinal section showing tabulae with elevated central platform, amplexoid septa, X2.3. Oblique section showing semi-cateniform habit, X2.2.
6. 7. 8. 9.	D <u>Palaeophyllum sinclairi</u> n. sp. (UND Cat. No. 13706). Portion of corallum showing cateniform arrangement of corallites, X1.3. Transverse section showing cateniform and cerioid corallites, X3.3. Longitudinal section showing tabulae with elevated central platform, X3.8. Transverse section through corallite wall, and major and minor septa showing insertion of septa in corallite wall, axis toward right, crossed nicols, X150. Longitudinal section of corallite wall showing two-layered fiber orientation (white lines parallel fiber direction),
	crossed nicols, X47.

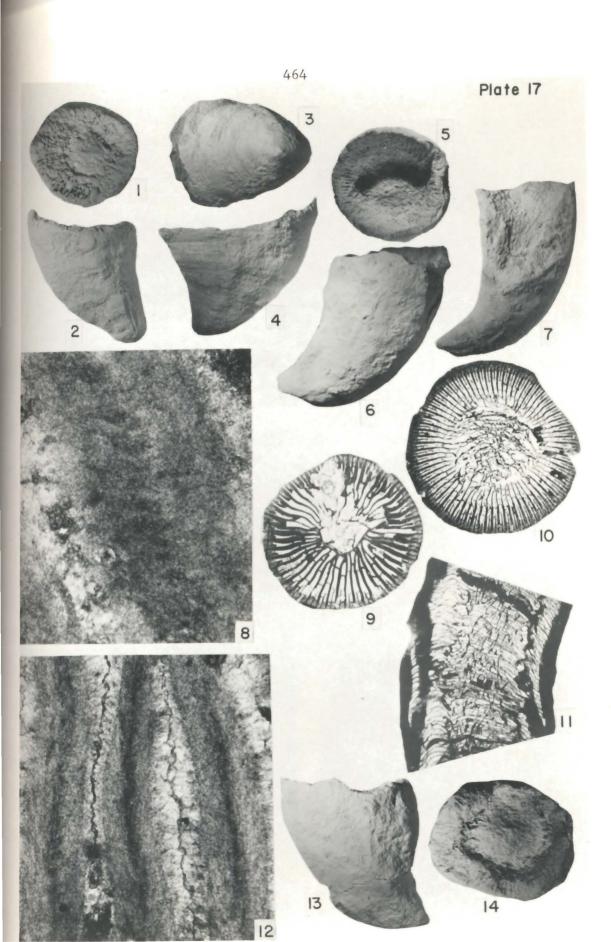


Figs. 1-12.--Grewingkia robusta (Whiteaves).

- Calicinal view, cardinal side toward left, UND Cat. No. 13642, X1.
- 2. Alar view, cardinal side toward left, UND Cat. No. 13642, X1.
- 3. Apical view showing cardinal angulation on right side of corallum, UND Cat. No. 13632, X1.
- 4. Alar view, UND Cat. No. 13632, X1.
- 5. Calicinal view, with low columella, cardinal side at right, UND Cat. No. 13639, X0.75.
- Alar view of corallum, cardinal side at right, UND Cat. No. 13639, X0.75.
- 7. Alar view showing deep calyx, UND Cat. No. 13640, X0.5.
- 8. Longitudinal section plane cutting the central plane of a septum showing faint extinction banding representing bundles of parallel fibers, UND Cat. No. 13644, crossed nicols, X47.
- 9. Transverse section, 27 mm from apex, UND Cat. No. 13646, cardinal septum at twelve o'clock position, X2.
- 10. Transverse section, UND Cat. No. 13649, cardinal septum in same position as above, X1.1.
- 11. Partial longitudinal section, UND Cat. No. 13649, cardinal side toward left, X1.
- 12. Transverse section through three cardinal septa with fibers arranged in V-shaped patterns, X47.
- Figs. 13, 14.--Grewingkia goniophylloides (Teichert) (UND Cat. No. 13647).

13. Alar view, cardinal side toward left, X1.

14. Calicinal view cardinal side toward left, X1.



- Figs. 1, 4.--<u>Grewingkia goniophylloides</u> (Teichert) (UND Cat. No. 13648).

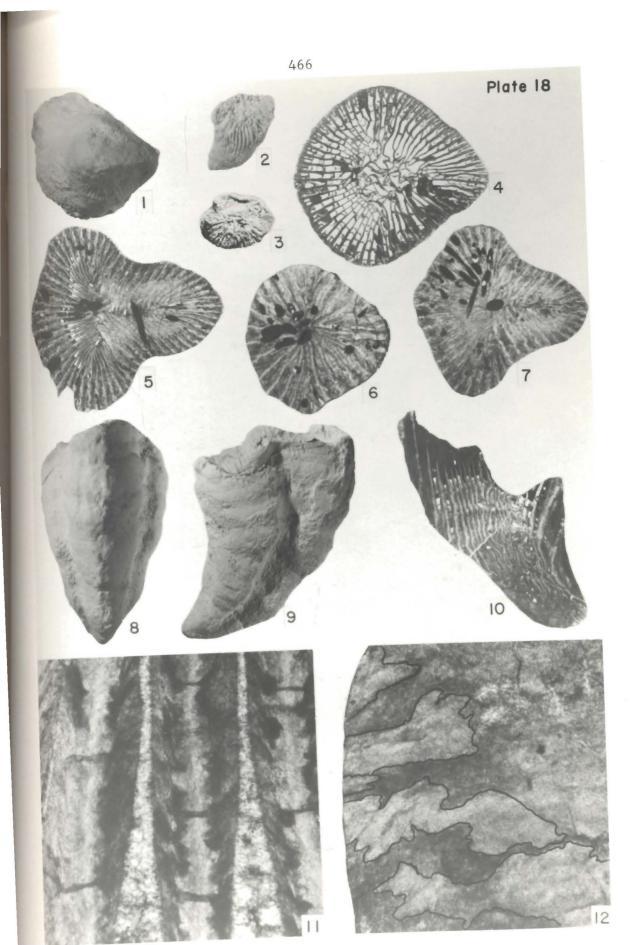
 Apical view with slight cardinal-alar concavity in two and four o'clock positions, X1.
 - 4. Transverse section with a cardinal-alar concavity at four o'clock position, 25 mm from apex, X1.7.
- Figs. 2, 3.--Grewingkia sp. (UND Cat. No. 13701).

2. Longitudinal view, cardinal side toward right, X1.

3. Calicinal view, cardinal side toward right, X1.

Figs. 5-12.--Lobocorallium trilobatum (Whiteaves).

- 5. Transverse section, 33 mm from apex, UND Cat. No. 13597, with skeletal burrowings, X1.8.
- 6. Transverse section, 5 mm from apex, UND Cat. No. 13597, X4.2.
- 7. Transverse section 15 mm from apex, UND Cat. No. 13597, X2.1.
- 8. Longitudinal view, cardinal side at center, with pronounced cardinal and counter-alar lobation, UND Cat. No. 13587, X1.
- 9. Longitudinal view, cardinal side toward right, with prominent alar furrow, UND Cat. No. 13587, X1.
- Longitudinal section eccentric from corallum axis, UND Cat. No. 13588, X1.5.
- Transverse section of three major septa showing textural difference between central trabeculate and flanking nontrabeculate regions, UND Cat. No. 13597, crossed nicols, X47.
- 12. Longitudinal section through central portion of a major septum of UND Cat. No. 13588, trabeculae shown by outlined regions, crossed nicols, X47.



Figs. 1-11.--Dieracorallium manitobense (Nelson).

- 1. Calicinal view, cardinal side at twelve o'clock position, UND Cat. No. 13574, X2.
- 2. Alar view, cardinal side toward left, UND Cat. No. 13579, X2.
- 3. Apical view, cardinal side at twelve o'clock position, UND Cat. No. 13756, X2.
- Alar view with cardinal side toward right, UND Cat. No. 13577, X2.
- 5. Apical view with cardinal side in same position as above, UND Cat. No. 13580, X2.
- 6. Alar view of UND Cat. No. 13580, with cardinal side toward left, X2.
- Longitudinal section showing deep calyx, UND Cat. No. 13603, X4.8.
- 8. Transverse section showing prominent cardinal fossula and shortened cardinal septum, UND Cat. No. 13596, X4.3.
- 9. Alar view with cardinal side toward right, UND Cat. No. 13578, X2.
- 10. Alar view, cardinal side toward left, UND Cat. No. 13575, X2.
- 11. Transverse section through calyx, UND Cat. No. 13595, X3.6.

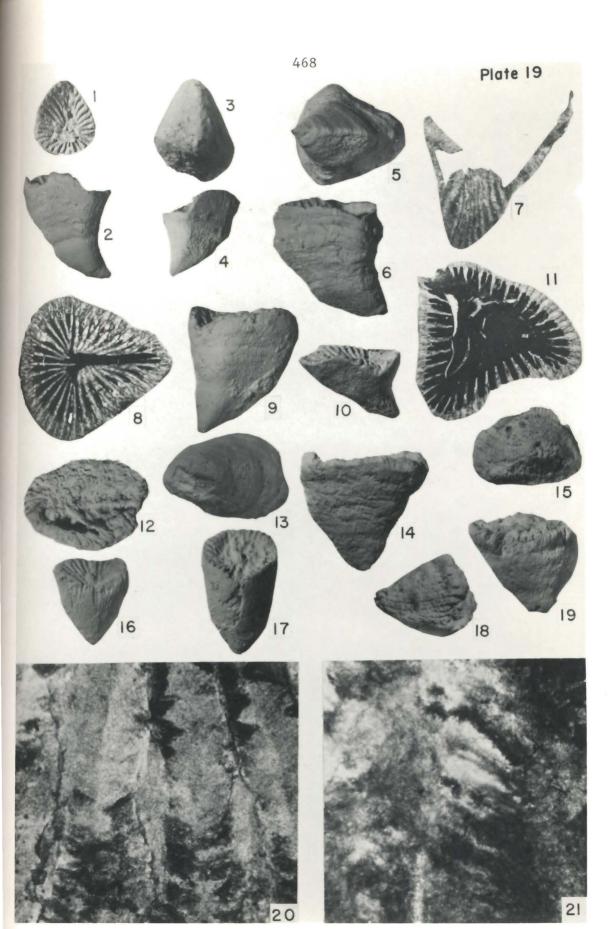
Figs. 12-14.--Dieracorallium sp. (UND Cat. No. 13674), X3.

- 12. Calicinal view, cardinal side toward left.
- 13. Apical view, cardinal side in same position as above.
- 14. Alar view, cardinal side in same position as above.
- Figs. 15, 18, 19.—Bighornia tyndallensis n. sp. (UND Cat. No. 13675), X3.
 - 15. Apical view, cardinal side in twelve o'clock position, alar septa at four and eight o'clock positions.
 - 18. Alar view, cardinal side at top.
 - 19. Cardinal view.

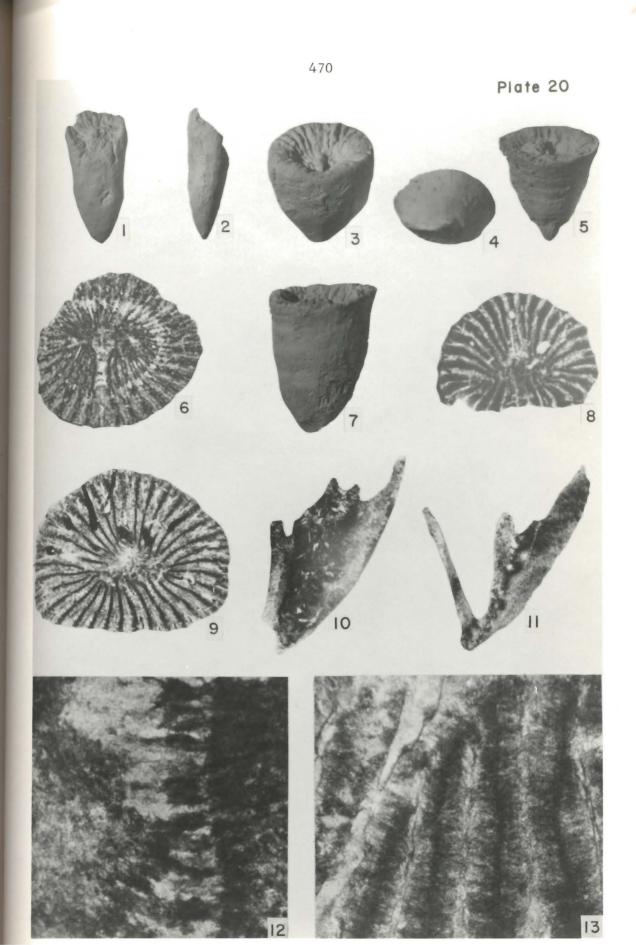
Figs. 16, 17, 20, 21.--Bighornia cvancari n. sp.

- 16. Cardinal-calicinal view, UND Cat. No. 13583, X2.
- Cardinal-calicinal view with prominent columella, UND Cat. No. 13584, X2.
- Transverse section of four major septa showing prominent septal trabeculae (clear regions), UND Cat. No. 13606, crossed nicols, X47.

 Longitudinal section through central portion of a major septum with septal trabeculae shown by parallel dark and light areas, UND Cat. No. 13608, crossed nicols, X47.



- Figs. 1, 2, 6. 10.--Bighornia cvancari n. sp.
 - Cardinal-calyx view with prominent columella, UND Cat. No. 13581, X1.5.
 - 2. Alar view, UND Cat. No. 13581, X1.5.
 - 6. Transverse section, showing prominent counter septum forming columella, UND Cat. No. 13606, X5.2.
 - 10. Longitudinal section, counter side toward right, UND Cat. No. 13608, X4.2.
- Figs. 3-5, 7-9, 11-13.--Bighornia patella (Wilson).
 - 3. Cardinal-calicinal view with prominent columella, UND Cat. No. 13584, X2.
 - 4. Apical view showing flattening on counter side of corallum and lateral elongation in alar regions, UND Cat. No. 13585, X2.
 - 5. Cardinal-calicinal view, UND Cat. No. 13585, X2.
 - 7. Cardinal-calicinal view, UND Cat. No. 13586, X1.25.
 - Transverse section, 8 mm from apex, counter septum in six o'clock position, UND Cat. No. 13631, X3.8.
 - 9. Transverse section, 12 mm from apex, UND Cat. No. 13625, X5.
 - Longitudinal section showing prominent columella arising from counter (right) side of corallum, with prominent trabeculae (arcuate lines) on counter septum, UND Cat. No. 13630, X3.3.
 - 12. Longitudinal section through a major septum with trabeculae shown as dark feather-like features, UND Cat. No. 13626, crossed nicols, X47.
 - 13. Transverse section of four major septa with trabeculae shown as dark feather-like extensions from dark planes at septal centers, UND Cat. No. 13625, crossed nicols, X47.



- Figs. 1, 3-7.--Bighornia parva Duncan.
 - 1. Transverse section, UND Cat. No. 13613, X3.8.
 - 3. Longitudinal section, counter side at bottom, UND Cat. No. 13614, X2.8.
 - 4. Cardinal-alar view, UND Cat. No. 13693, X1.5.
 - 5. Alar view, cardinal side uppermost, UND Cat. No. 13693, X1.5.
 - Apical view showing flattening along counter side, UND Cat. No. 13693, X1.5.
 - 7. Apical view showing planar areas between cardinal and alar septa, UND Cat. No. 13693, X1.5.

Fig. 2.--Bighornia patella (Wilson) (UND Cat. No. 13631).

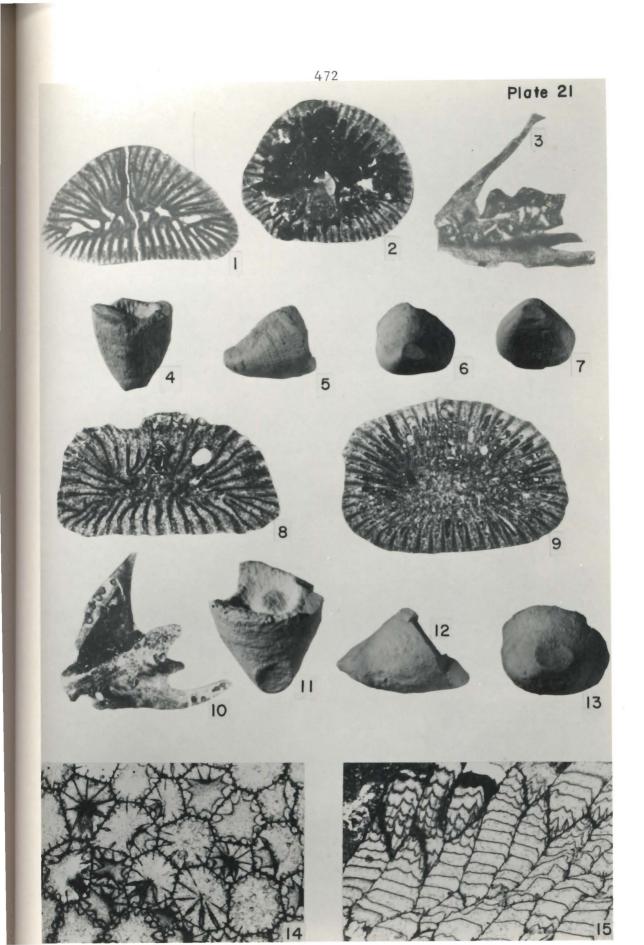
2. Transverse section of calicinal region showing distal extension of columella (oval, translucent area), X3.6.

Figs. 8-13.--Bighornia bottei Nelson.

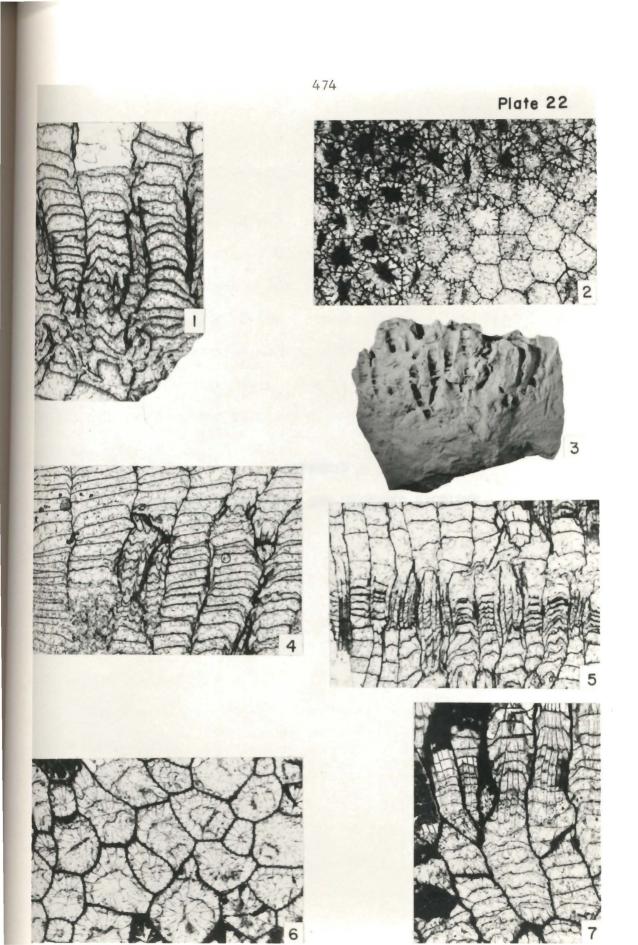
- 8. Transverse section of UND Cat. No. 13605, 4 mm from apex, showing rectangular outline. Alar septa in lower corners, X4.3.
- 9. Transverse section of UND Cat. No. 13605, 18 mm from apex, X3.2.
- 10. Longitudinal section, UND Cat. No. 13604, showing prominent columella, counter side at bottom, X3.
- Cardinal-apical view showing spoon-shaped cardinal-apical depression, and low, broad columella, UND Cat. No. 13672, X1.2.
- 12. Alar view, cardinal side uppermost, UND Cat. No. 13672, X1.2.
- 13. Apical view showing depression, UND Cat. No. 13672, X1.2.

Figs. 14, 15.--Crenunites rigidus Flower.

- 14. Transverse section of UND Cat. No. 13714, showing septa advanced onto tabular surfaces and crenulate tabular margins (arcuate lines at corallite margins), X3.9.
- 15. Longitudinal section, UND Cat. No. 13712, showing intertabular continuity of peripheral margins of septa and crenulate tabular margins, X2.6.



- Fig. 1. -- Crenulites rigidus Flower (UND Cat. No. 13614).
 - 1. Longitudinal section of corallites showing crenulate tabulae and septa continuous between tabulae, X4.
- Figs. 2, 4, 5.--Crenulites duncanae Flower.
 - 2. Transverse section showing a gradation from no septa (lower right corner) to those fully advanced onto tabular surfaces (left side). Tabular surfaces shown as black, star-shaped areas, UND Cat. No. 13717, X4.
 - 4. Longitudinal section showing depressed peripheral margins of tabulae, UND Cat. No. 13720, X4.3.
 - 5. Longitudinal section showing zonation of tabular spacing, crenulate tabulae, and peripheral septal margins continuous between tabulae, UND Cat. No. 13719, X4.1.
- Figs. 6, 7.--Cyathophylloides hollandi n. sp. (UND Cat. No. 13727).
 - 6. Transverse section showing rounded corallite walls, X3.4.
 - 7. Longitudinal section showing amplexoid retreat (upper right corner), X2.4.
- Fig. 3.--<u>Tryplasma gracilis</u> (Whiteaves) (UND Cat. No. 13636).
 3. Corallum fragment with horizontal row of spines, XI.



APPENDIX A

LOCALITY REGISTER AND MEASURED SECTIONS

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LOCALITY REGISTER AND MEASURED SECTIONS

Localities described in this section are sites of fossil and lithologic sample collection. The numbers prefixed by an "A" refer to the Accession Catalogue Numbers of the Geology Department of the University of North Dakota. The use of these accession numbers requires the assignment of a separate number to each locality, stratigraphic horizon, collector, and date of collection. Several numbers are listed for each locality if more than one horizon, collector, or dates of collection were involved.

Localities are arranged in stratigraphic order, and sections are arranged so that the uppermost unit described is at the top of the section. Bed thickness terminology is that of Ingram (1954); grain size terms are those of Wentworth (1922); and color descriptions are those of Goddard and others (1963). All colors stated are for fresh surfaces unless otherwise specified. Thicknesses were measured in feet but are expressed both in feet and meters.

The localities of test holes P-1 and GF-2 are given at the end of this section.

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DOG VIEW BEACH

A902 (locality 1, Figure 1)

Beach at Dog View sledge train base, approx. 2 miles (3.2 km) southwest of West Dog Head Point, T. 32 N., R. 5 W., western shore of Lake Winnipeg; Hecla, Manitoba 1:250,000 quadrangle.

Float from 10 foot (3.1 m) slumped section of the Dog Head Member of the Red River Formation (A902).

NORTH SHORE OF HECLA ISLAND

A905, A907 (locality 2, Figure 1)

Cliffs along north shore of Hecla Island, S¹₂, sec. 26, T. 27 N., R. 6 W., approx. 2 miles (3.2 km) southwest of Gull Harbor Point, Hecla Island, Manitoba; Hecla, Manitoba 1:250,000 quadrangle.

Red River Formation Dog Head Member

Top of exposed section Unit

Thickness

2 Limestone, thick bedded, yellowish gray (5 Y 7/2), microcrystalline, with grayish orange (10 YR 7/4) mottles of saccharoidal dolomitic rhombs; no macrofossils visible (A905).

9.0 ft (2.7 m)+

1 Limestone, finely arenaceous, thin bedded, yellowish gray (5 Y 7/2), microcrystalline, interbedded with fine grained, argillaceous, calcareous sandstone. Bedding plane surfaces undulatory and irregular. Grades downward into white (N 9), medium grained, rounded, quartz sand at top of Winnipeg Fm. (Hecla beds of Fuller, 1961, p. 1346), (A905).

0.4 ft (0.1 m)

Base of Dog Head Member

Total Thickness

Float from Dog Head Member along shoreline (A907).

EASTERN SHORE OF HECLA ISLAND

A909

Bluff along the southeastern shore, NW4, sec. 13, T. 27 N., R. 6 E., approx. 2.5 miles (4.0 km) southwest of village of Gull Harbor, Hecla Island, Manitoba; Hecla, Manitoba, 1:250,000 quadrangle.

Red River Formation Dog Head Member Top of exposed section Unit Thickness 2 Limestone, thin to thick bedded, yellowish gray (5 Y 8/1), microcrystalline, with yellowish gray (5 Y 7/2) saccharoidal dolomitic mottling, bedding planes undulatory, fossiliferous. 12.5 ft (3.8 m)+ 1 Limestone, thinly bedded, light olive gray (5 Y 6/1), argillaceous and fossiliferous, microcrystalline, with interbeds of yellowish gray (5 Y 7/2), burrowed, coarse siltstone along

undulatory bedding plane surfaces.

0.5 ft (0.15 m)

Base of exposed section

Total thickness

13.0 ft (3.9 m)+

HECLA ISLAND CAUSEWAY QUARRY

A965 (locality 3, Figure 1)

NWZ, sec. 23, T. 24 N., R. 4 E., immediately south of Manitoba Provincial Road 332, approx. 3.5 miles (5.6 km) southwest of mainland end of Hecla Island Causeway; Hecla, Manitoba, 1:250,000 quadrangle.

Red River Formation

Cat Head Member

Top of exposed section Unit

Thickness

- Dolostone, thickly bedded (0.5-0.8 ft; 2 0.15-0.24 m), very pale orange (10 YR 8/2), mottled microcrystalline, with crinoid ossicles altered to dolomite. Crystal texture with saccharoidal appearance due to euhedral dolomite rhombs. Mottles light olive gray $(5 \ Y \ 6/1)$, microcrystalline-saccharoidal texture. No sedimentary structures other than thick beds.
- 1 Dolostone, very thick bedded (1.75-to 2 ft; 0.52-6 m), with same composition, color, and texture as above interval. Limonitic pseudomorphs of pyrite 0.6 feet below top of unit.

Base of exposed section

Total thickness

7.2 ft (2.2 m)

3.5 ft (1.1 m)

10.7 ft (3.3 m)

GARSON QUARRY

A884, A886, A897 (locality 8, Figure 1)

Gillis Quarries Ltd., Garson Quarry, NW4, NW4, sec. 3, T. 13 N., R. 6 E., immediately southeast of junction of Manitoba Provincial Highway 44 and Provincial Road 306 on eastern edge of Garson, Manitoba, Canada; Selkirk, East Half, 15 minute quadrangle.

Red River Formation Selkirk Member Top of exposed section

Unit

Thickness

2 Biomicrudite, very thinly bedded (1.6-2.5 ft; 0.5-0.75 m), very pale orange (10 YR 8/12), lutaceous, dolomitic-mottled. Abundant fossil fragments rarely exceeding 1 mm in size, comprising approximately 5-15% of total rock volume. Mottles composed of pale yellowish brown (10 YR 6/2) saccharoidal dolomite in aureole surrounding interconnected network of tubular burrows approximately 2 mm diameter. Abundant stylolitic zones paralleling bedding plane with clays within zones oxidized to a color ranging from moderate yellowish brown (10 YR 5/4) to dark yellowish brown (10 YR 4/2). Massive colonial coelenterates common, large lamellar stromatoporoids, anthozoans (Trabeculites spp., Catenipora spp., Crenulites spp.). Solitary rugosa rare but consist of predominantly Grewingkia; brachiopod valves rare, commonly whole but disarticulated. Castropods most commonly represented by 11.8 ft (3.6 m) Maclurites, large nautiloids common (A886).

Biomicrudite, very thickly bedded (2.2-2.8 ft; 0.7-0.85 m), yellowish gray (5 Y 8/1), lutaceous, dolomitic-mottled. Fossil content same as above. Mottles light olive gray (5 Y 6/1) saccharoidal dolomite same as above. Stylolithic content same as above. Contains thin beds or lens of yellowish gray (5 Y 6/1), coarse crystalline limestone with scattered fossil fragments. Burrows vertical, with small diameter (approximately 4 mm) diameter dolomitic aureole. Possibly recrystallized from fossil coquina (A886).

Base of exposed section

Total thickness

9.0 ft (2.7 m)

20.8 ft (6.3 m)

Fossils collected as float or from unspecified stratigraphic horizon (A884, A897).

TYNDALL QUARRY

A889, A891, A892, A893 (locality 8, Figure 1)

Gillis Quarries Ltd., Tyndall Quarry NW4, sec. 3, T. 13 N., R. 6 E., 0.8 mile (1.3 km) east of center of Garson, Manitoba; Selkirk, East Half, 15 minute quadrangle.

Exposure of Selkirk Member

Fossils collected 0.9 ft (approx. 0.3 m) below top of exposed section (A889).

Fossils collected from bedding plane surface 1.9 ft (0.6 m) below top of section (A891, A893).

Fossils collected from 1.9-3.6 ft (0.6-1.1 m) below top of section (A892).

GARSON OR TYNDALL QUARRIES

A530 (locality 8, Figure 1)

Fossils collected from either quarry where the stratigraphic horizon, collector, or date of collection are unknown.

MULDER QUARRY NO. 12

A850, A851, A853 (locality 6, Figure 1)

Mulder Brothers Construction Co., Ltd., quarry no. 12, SW4, NE4, sec. 27, T. 13 N., R. 3 E., approx. 6 miles (9.7 km) east-northeast of the town of Stony Mountain, Manitoba; Stonewall Manitoba, East Half, 15 minute quadrangle, elevation at top of exposed section approximately 760 ft. Red River Formation Fort Garry Member Top of exposed type section Unit

- 8 Dolostone, thick bedded (1.0-1.7 ft; 0.3-0.52 m), pale yellowish orange (10 YR 8/6), fossiliferous, mottled, micritic. Mottled portions consisting of grayish orange (10 YR 7/4), saccharoidal dolomite with relict burrow structures obliterated. Fossils present as molds of fragments. Dolomite weathered to magnesite (fide N. N. Kohanowski, mineralogist, Dept. of Geology, University of North Dakota). Micritic portion commonly with hairline fractures due to dessication or algal tubules (?).
- 7 Same as above with poorly preserved coralla of <u>Calapoecia</u> sp., and <u>Catenipora</u> sp. (A853), basal bedding surface diastemic.
- 6 Dolostone, thin to medium bedded (0.2-0.25 ft; 0.06-0.08 m), very pale orange (10 YR 8/2) mottled micritic. Mottled portions pale yellowish brown (10 YR 6/2) micritic dolostone, mottling restricted to diameters of original infaunal burrow tubes. Fragmented fossil material commonly restricted to tube fillings. Rare hairline fractures predominantly vertical, exhibiting upward dendritic branching, possibly due to algal tubules (?). Lower bedding plane diastemic.
- 5 Dolostone thin to medium bedded (0.3 ft; 0.09 m), very pale orange (10 YR 8/2), lithographic. Mottles restricted to rare burrow tubes, unfossiliferous small, hairline fractures arranged in reticulate network. Possibly due to compacted pellets or algal tubules (?). Upper and lower contacts undulatory and diastemic.
- 4 Claystone, light greenish gray (5 GY 8/1) to pale reddish brown (10 R 5/4), unfossiliferous with tendency toward fissile shaly cleavage, grading downward into lutaceous dolostone.
- 3 Claystone, thin to medium bedded (0.25 ft; 0.08 m), pale reddish brown (10 R 5/4), dolomitic, grading into lutaceous dolomite breccia with imbricate flakelike, very pale orange (10 YR 7/4), micritic dolomite intraclasts grading downward into lithographic dolostone with clay partings.

Thickness

4.2 ft (1.3 m)

3.2 ft (1.0 m)

0.5 ft (0.15 m)

1.1 ft (0.34 m)

2.0 ft (0.6 m)

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1.2 ft (0.37 m)

- 2 Dolostone, thin bedded (0.2 ft; 0.06 m), moderate orange pink (5 YR 8/4) lighographic, with irregular bedding plane surfaces filled with thin laminae of light greenish gray (5 GY 8/1) clay. Unfossiliferous.
- 0.8 ft (0.25 m)
- 1 Dolostone, thin bedded (0.2 ft; 0.06 m), very pale orange (10 YR 8/2), lighographic, with hairline tubules arranged in reticulate network, possibly due to algal strands. Thickness indeterminable.

0.2 ft (0.06 m)

Base of exposed type section

Total thickness

13.2 ft (4.1 m)

Paleofavosites sp. A collected as float from quarry floor (A850).

MUNICIPALITY OF WINNIPEG ACGREGATE PLANT WEST QUARRY

A576, A584, A585, A841, A896, A969 (locality 7, Figure 1)

West quarry at the Municipality of Winnipeg Aggregate Plant, SE4, SE4, sec. 14, T. 13 N., R. 2 E., approx. 0.7 mile (1.1 km) north-northwest of the center of the town of Stony Mountain, Manitoba.

Stony Mountain Formation Gunn Member

Guin nember

Top of member at type section Unit

Thickness

- 4 Dolostone, pale yellowish orange (10 YR 8/6), argillaceous, finely crystalline, individual dolomite crystals poorly consolidated. Fossils commonly preserved as replacement material (A841, A896).
- 3 Shale, thick bedded (1.0-1.4 ft; 0.3-0.4 m), burrowed, very dark red (5 R 2/6) to pale yellowish orange (10 YR 8/6), calcareous. Fossils preserved in small lenses and laminae of silty biosparite. Finely divided hematite concentrated around perimeter of burrow lends dark color and spotted appearance.

0.6 ft (0.18 m)

4.4 ft (1.3 m)

2 Shale, thick to very thick bedded (2.2-3.6 ft; 0.7-1.1 m), burrowed, pinkish gray (5 YR 8/1) to very dark red (5 R 2/6) calcareous, alternating with thin to medium bedded lenses and beds of pinkish gray (5 YR 8/1) silty biosparite, consisting mainly of fragmented brachiopod valves.

1.8 ft (0.5 m)

1 Burrowed shale, fossiliferous (A969), grades laterally into a structureless, light greenish gray (5 GY 8/1), silty clay with small rare (1.5 mm) pyrite spherules, fossils rare, no trace of organic reworking. Burrowed siltstone and silty biosparites same as in above unit.

6 ft (1.8 m)+

Base of exposed type section

Total thickness

12.8 ft (3.9 m)+

Fossils collected from this locality, horizon unknown (A584, A585, A576).

MUNICIPALITY OF WINNIPEG AGGREGATE PLANT WEST QUARRY A563

A563 (locality 7, Figure 1)

Northeastern corner of west quarry at Aggregate Plant of Municipality of Winnipeg, NE4, SW4, SE4, sec. 14, T. 13 N., R. 2 E., approx. 0.5 mile (0.8 km) north of center of town of Stony Mountain, Manitoba.

Stony Mountain Formation Penitentiary Member Top of member Unit

Thickness

2 Dolostone, pale yellowish orange (10 YR 8/6), thin bedded (0.25-0.3 ft; 0.08-0.09 m), mottled, slightly argillaceous, microcrystalline, with very pale orange (10 YR 8/2) microcrystalline dolostone with burrows outlined by slight concentrations of iron oxide.

0.7 ft (0.2 m)

1 Dolostone, dark yellowish orange (10 YR 6/6) when weathered, pale yellowish orange (10 YR 8/6) to yellowish gray (5 Y 8/1) when fresh, thick to very thick bedded (0.9-1.8 ft; 0.25-0.55 m), argillaceous content variable, alternating with dolomitic siltstone with earthy lustre. Burrowed zones parallel to bedding planes, concentrated in argillaceous portions of unit, moderate orange pink (5 YR 8/4) to pale réd (5 R 6/2), burrows restricted to zones, 1.5-2 mm diameter, parallel to bedding plane. Fossils present as rare shell hash zones of molds of brachiopod and coral fragments (A563).

6.7 ft (2 m)

Base of exposed section

Total thickness

7.4 ft (2.2 m)

MUNICIPALITY OF WINNIPEG AGGREGATE PLANT EAST QUARRY A566

A566, A574, A583 (locality 7, Figure 1)

East wall of east quarry at Municipality of Winnipeg Aggregate Plant, E_{2}^{l} , SW4, SW4, sec. 13, T. 13 N., R. 2 E., approx. 0.7 mile (1.1 km) northeast of center of town of Stony Mountain, Manitoba.

Stony Mountain Formation Penitentiary Member Unit

Thickness

1 Dolostone, grayish orange (10 YR 7/4) on weathered surface yellowish gray (5 Y 8/1) on fresh surface, thick to very thick bedded (2.0-2.6 ft; 0.6-0.8 m), argillaceous, microcrystalline. Fossil content same as Gunn Member, predominantly small solitary rugose corals and articulatic valves of brachiopods, preserved only as molds replicating surficial detail (A574).

Base of member

Total thickness

8 ft (2.5 m)+

MUNICIPALITY OF WINNIPEG ACGREGATE PLANT WEST QUARRY A565, A568

A565, A568 (locality 7, Figure 1)

Southeast corner of west quarry at Municipality of Winnipeg Aggregate Plant, SW4, SE4, sec. 14 (A565); center of west quarry SE4, SW4, sec. 14 (A568); T. 13 N., R. 2 E., 0.5 mile (0.8 km) north-northwest of town of Stony Mountain, Manitoba.

Stony Mountain Formation Gunton Member Top of exposed section Unit

Thickness

10.4 ft (3.2 m)

3.6 ft (1.1 m)

 $3.8 \, \text{ft} (1.2 \, \text{m})$

- 4 Dolostone, thick to massive, very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4), mottled microcrystalline dolostone. Mottle color commonly pale yellowish brown (10 YR 6/2), fossil fragments rare.
- 3 Dolostone same as above with thin (0.1-0.2 ft; 0.03-0.06 m), beds of pale reddish brown (10 R 5/4) argillaceous dolostone and mudstone, burrowed.
- 2 Dolostone, slightly argillaceous, thick bedded, grayish orange (10 YR 7/4), microcrystalline to lighographic, mottle color pale yellowish brown (10 YR 6/2), containing tubular burrows 2 mm diameter.
- 1 Siltstone, dolomitic, thin bedded (0.1 ft; 0.03 m), yellowish gray (5 Y 7/2), burrowed, transition from Penitentiary Member to overlying Gunton Member. 0.1 ft (0.03 m)+

Base of Gunton Member

Total thickness

17.9 ft (5.5 m)+

STANDARD MATERIALS QUARRY

A846, A847 (locality 5, Figure 1)

Aggregate quarry, Standard Cartage, Ltd., NE4, NE4, NE4, sec. 33, T. 13 N., R. 2 E., on south side of east-west section road, approx. 1.0 mile (1.6 km) north-northwest of junction of Manitoba Highways 7 and 67; Stonewall, Manitoba, West Half 15 minute quadrangle.

Stony Mountain Formation Gunton Member Top of exposed section Unit

Thickness

- 12 Dolostone, thin to medium bedded (0.25-0.3 ft; 0.08-0.09 m), very pale orange (10 YR 8/2), micritic to microcystalline, with pale olive (10 Y 6/2) clay laminae. scattered crinoid ossicles on bedding planes. Minor amounts of limonite pseudomorphs of pyrite on fracture surfaces.
- 11 Dolostone, thin bedded (0.25 ft; 0.08 m), yellowish gray (5 Y 8/1), argillaceous, burrowed, with thin laminae of pale olive $(10 \ Y \ 6/2)$ clay.
- Dolostone, thin to medium bedded. 10Same as in unit 12.
- 9 Dolostone, thin bedded, argillaceous. Same as in unit 11.
- Dolostone, thin to medium bedded. 8 Same as in units 10 and 12.
- Dolostone, thin bedded, argillaceous. 7 Same as in units 11 and 9.
- Dolstone, medium bedded (0.4 ft; 0.1 m), very 6 pale orange (10 YR 8/2), micritic or finely crystalline, burrowed portions pale yellowish brown (10 YR 6/2), with thin laminae of light greenish gray (5 GY 8/1) clay. Pyrite crystal aggregations rare, 0.25-1.0 mm diameter. No fossils.

1.8 ft (0.5 m)

3.9 ft (1.2 m)

0.2 ft (0.06 m)

9.1 ft (2.8 m)

0.4 ft (0.1 m)

8.4 ft (2.6 m)

0.6 ft (0.2 m)

5 Dolostone, thin to medium bedded (0.3 ft; 0.09 m), very pale orange (10 YR 8/2), slightly argillaceous, irregular bedding plane surfaces with thin coating of light greenish gray clay (5 G 8/1); alternating with thin (0.2 ft; 0.06 m) beds of pale red (10 R 6/2), burrowed argillaceous dolostone with irregular bedding plane surfaces.

Base of Gunton Member

Total thickness

Penitentiary Member

Top of exposed section

Thickness

3.0 ft (0.9 m)

4.6 ft (1.4 m)

0.5 ft (0.15 m)

5.7 ft (1.7 m)

30.1 ft (9.2 m)

- 4 Siltstone, massive (3.0 ft; 0.9 m), pale red (10 K 6/2), fine grained, dolomitic, burrowed, grades downward into pale red purple (5 RP 6/2).
- 3 Siltstone, massive (4.6 ft; 1.4 m), yellowish gray (5 Y 8/1), fine grained dolomitic, abrupt contact with overlying unit. No borings at top, grades downward to pale pink (5 RP 8/2), burrowed, dolomitic siltstone with grayish red purple oxidation rims (?) around burrow tube. Fossils preserved as calcitic replacements, rare, some small unidentifiable solitary corals.

2 Clay, light greenish gray (5 GY 8/1), silty.

1 Dolostone, massive (4.8->7 ft; 1.5-> 2.1 m), yellowish gray (5 Y 8/1), argillaceous or dolomitic siltstone. Fossiliferous, with fragmented and desarticulated brachiopod valves scattered throughout and concentrated in shell hash zones. Some possible bioturbation.

12.8 ft (3.9 m)

Base of exposed section

Total thickness

17.9 ft (5.5 m)

WILLIAMS QUARRY

A553-A556 (locality 4, Figure 1)

Type sections of Stonewall Formations and underlying Williams Member of the Stony Mountain Formation, Williams Quarry, owned by Steel Bros. Canada, Ltd., SE¹/₄, sec. 36, T. 13 N., R. 1 E.; pit section of Williams Member, A556; pit section of Stonewall Formation, A554; quarry section of Stonewall Formation, A555.

Stonewall Formation Top of type section Unit

Thickness

8.1 ft (2.5 m)

- 10 Dolostone, thin bedded (0.25 ft; 0.07 m), very pale orange (10 YR 8/2), finely crystalline, mottled, mottle color pinkish gray (5 YR 8/1), burrowed, Paleofavosites spp. rare.
- 9 Dolostone, thin bedded (0.2 ft; 0.06 m), very pale orange (10 YR 8/2), sublithographic (very finely crystalline or fine calcitutite, non-mottled, fine lenticular laminae paralleling bedding planes. Small flecks of limonite pseudomorphs of pyrite along fracture surfaces.
- 8 Dolostone, "nodular", pale red (5 R 6/2), argillaceous, burrowed, localized hematite concretions, grading downward into very pale orange (10 YR 8/2), thin bedded, (0.1 ft; 0.03 m) argillaceous dolostone.
- 7 Dolostone, massive (3.3 ft; 1 m), very pale orange (10 YR 8/2), finely crystalline, pale yellowish brown (10 YR 6/2) mottles, vugular, Paleofavosites sp., Tryplasma sp. rare.
- 6 Dolostone, thick bedded (>0.5 ft;> 0.15 m), very pale orange (10 YR 8/2), finely crystalline, pale yellowish brown (10 YR 6/2) mottles, vugs commonly represented by molds of fossils.
- 5 Dolostone, thin bedded (0.3 ft; 0.1 m), porous, very pale orange (10 YR 8/2), medium crystalline texture with scattered, angular, coarse silt size quartz grains; vugular, pore and vug space occupying approximately 5% of rock volume.

2.0 ft (0.6 m)

1.4 ft (0.4 m)

3.3 ft (1 m)

1.6 ft (0.5 m)

0.6 ft (0.2 m)

4 Dolostone, medium bedded (0.5 ft; 0.15 m), very pale orange (10 YR 8/2) arenaceous, medium crystalline texture, quartz grains angular to rounded, 0.04-0.4 mm diameter.

0.8 ft (0.25 m)

Base of Stonewall Formation

Total thickness

17.9 ft (5.5 m)

Stony Mountain Formation

Williams Member

Top of member in type section Unit

Thickness

3.1 ft (0.95 m)

 $0.4 \, \text{ft} \, (0.12 \, \text{m})$

- 3 Dolostone thick bedded (3.1 ft; 0.95 m), moderate orange pink (10 R 7/4) to spots of grayish red purple (5 RP 4/2), argillaceous to fine arenaceous, finely crystalline carbonate texture, clastic grains ranging in size from 0.04 to 0.18 mm, monomineralic, quartz; angular.
- 2 Dolostone thin bedded (0.3 ft; 0.1 m), pale red (10 R 6/2), argillaceous to arenaceous, finely crystalline carbonate texture. Angular, quartz, detrital grains ranging in size from 0.04 to 0.16 mm. Concentration of hematite pigment delineates planar cross bedding structures inclined about 15 degrees from the bedding plane. Burrowing rare, normal to bedding plane.
- 1 Dolostone, thick bedded to massive () 3.0 ft; >0.9 m), pale red (10 R 6/2), argillaceous to fine arenaceous, finely crystalline carbonate texture. Angular quartz detrital grains ranging from 0.04 to 0.12 mm in size, 3 to 5% of rock volume.

Base of exposed section

Total thickness

6.5 ft (2 m)+

3.0 ft (0.9 m) +

SOUTH SIDE, SHELL CREEK CANYON

A532 (locality 10, Figure 1)

South side of Shell Creek Canyon, SW4, SW4, SE4, sec. 7, T. 53 N., R. 90 W., approx. 4 miles (6.4 km) east of Shell, Bighorn County, Wyoming, Black Mountain Wyoming 7.5 minute quadrangle.

Entire section of lower massive portion of Bighorn Formation exposed in canyon walls, fossils collected (A532).

NORTH SIDE, SHELL CREEK CANYON

A531 (locality 10, Figure 1)

North side of Shell Creek Canyon, SE¹4, NW¹4, SE¹4, sec. 7, T. 53 N., R. 90 W., approx. 4 miles (6.4 km) east of Shell, Bighorn County, Wyoming, Black Mountain Wyoming 7.5 minute quadrangle.

Exposure of Hunt Mountain beds in canyon walls, fossils collected (A531).

HUNT MOUNTAIN LOCALITY

A538, A539, A542, A544-A547, A549 (locality 9, Figure 1)

South-facing cirque wall on an eastwardly extending spur, S_2 , SW_4 , SE_4 , sec. 18, T. 55 N., R. 90 W., overlooking valley of Wallrock Creek, west flank of Bighorn Mountains at approx. 9600' elevation, Sheridan County, Wyoming, Hidden Tepee Creek 7.5 minute quadrangle.

Bighorn Formation

Upper portion; interval overlying Hunt Mountain beds Top of section

Unit

Thickness

6 Dolostone, thin bedded (0.15-0.2 ft; 0.05-0.06 m), grayish orange (10 YR 7/4), medium crystalline, dolomite rhombs up to 0.14 mm in size. Burrows delineated by yellowish gray (5 Y 8/1), finely porous, molds of skeletal debris, comprising up to estimated 5% of rock volume. Massive colonial rugosa, <u>Palaeophyllum pasense</u>, <u>P.</u> <u>sinclairi</u> n. sp., and <u>Cyathophylloides hollandi</u> n. sp.; chert nodules approximately 10 ft (3 m) below top of unit (A546). (Covered interval, described from float.)

- 5 Limestone, thin bedded (0.1 ft; 0.05 m), very pale orange (10 YR 8/2) finely crystalline texture with secondary calcite rhombs approximately 0.04 mm in size. Burrows dolomitized, same color as limestone matrix. Fossil fragments recrystallized to sparry calcite, silicified on weathered surfaces. (Covered interval, described from float.)
- 4 Limestone, very thin bedded (0.05-0.12 ft; 0.01-0.04 m), very pale orange (10 YR 8/2), biomicrite or very finely crystalline texture. Abundant brachiopod and gastropod fragments recrystallized to sparry calcite, silicified on weathered surfaces. Abundant trilobite fragments; <u>Calapoecia ungava</u>, <u>Paleofavosites</u> sp. cf. <u>P. prayi</u>, <u>Lobocorallium trilobatum</u> (A544, A545, A547).
- 3 Limestone, very thin bedded (0.05 ft; 0.01 m), very pale orange (10 YR 8/2), finely crystalline texture, interbedded with pale yellowish orange (10 YR 8/6), calcareous siltstone or mudstone. Fossil content similar to above unit. 3.1 ft (0.95 m)

Base of interval overlying Hunt Mountain beds

Thickness of interval

57 ft (17.4 m)+

Sighorn Formation Hunt Mountain beds Init

2 Limestone, thin bedded (0.1-0.15 ft; 0.03-0.05 m), bioclastic argillaceous, composed predominantly of solitary corals, brachiopod fragments and crinoid ossicles. Interbedded with silty shale, grayish orange (10 YR 7/4), burrowed. Fossil fragments predominantly solitary coralla, brachiopod valves; some recrystallized to sparry calcite, abundant trilobite fragments; <u>Streptelasma</u> sheridanensis n. sp., S. kelpinie n. sp.,

25 ft (7.6 m)+

21.9 ft (6.7 m)

Thickness

Bighornia bottei, Palaeofavosites spp., and others (A538, A539, A542, A549). 15.8 ft (4.8 m) Base of Hunt Mountain beds 15.8 ft (4.8 m) Thickness of unit Bighorn Formation Interval below Hunt Mountain beds Unit Thickness 1 Dolostone, medium to thick bedded (>0.3 ft; >0.1 m), very pale orange (10 YR 8/2), finely crystalline secondary texture (0.04 mm crystal size), unfossiliferous, with some chert nodules very faint vertical structures, possibly burrows. 42.0 ft (12.8 m)+ Base of sampled interval 42.0 ft (12.8 m)+ Total thickness of interval Total thickness of measured section 114.8 ft (35 m)+

EAST FLANK OF BIGHORNS

A534 (locality 11, Figure 1)

NW4, NW4, sec. 28, T. 56 N., R. 87 W., Sheridan County, Wyoming, Road cut along N side of U. S. Hwy. 14 on eastern flank of Bighorn Mountains.

Exposure of complete section of Bighorn Formation, fossils collected (A534).

TEST HOLE P-1

(locality P-1, Figure 1)

SE%, NW%, SE%, sec. 28, T. 164 N., R. 51 W., Pembina County, North Dakota. Ground elevation, 782 ft (248 m); total depth, 505 ft (154 m); total depth logged, 501 ft (153 m); footage cored, 305 ft (93 m; from Anderson and Haraldson, 1968, p. 18).

TEST HOLE GF-2

(locality GF-2, Figure 1)

NW4, NW4, SE¹2, sec. 27, T. 153 N., R. 51 W., Grand Forks County, North Dakota. Ground elevation, 825 ft (252 m); total depth, 320 ft (97.6 m); total depth logged, 317 ft (96.7 m); footage cored, 100 ft (30.5 m; from Anderson and Haraldson, 1968, p. 27).

APPENDIX B

BIOMETRIC DATA OF CORAL MEASUREMENTS

APPENDIX B

BIOMETRIC DATA OF CORAL MEASUREMENTS

Data for each feature are arranged as follows;

range of variability, calculated mean, number of samples.

All expressions of ranges and means are expressed in millimeters unless otherwise stated.

TABLE 6.--Biometrics of the holotype, paratypes, and a hypotype of <u>Trabeculites maculatus</u>

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	Specimen	Holotype, NMBM No. 50687	Hypotype, UND Cat. No. 13560	
		Paratypes, NMBM Nos. 50684-6 Flower (1961)		
	Corallum form, Width	fragmental >55	cerioid, massive, tabular	
	Corallum height	20	>50	
	Corallite diameter	1.9-2.7	1.8-2.45 d=2.08 n=81	
	Trabecular length		0.1-0.42 n=15	
	Trabecular center width	- - -	0.08-0.28 ₩=0.19 n=104	
	Trabecular margin width		0.08-0.28 ₩=0.17 n=104	
	<u>Margin width</u> Center width		0.55-1.6 ₩=0.92 n=104	
	Septa per Corallite		12-17 n=16 n=21 counts	*
	Septal spine		30-106° 0=56° n=107	
,	Major septal length		0.14-0.48 I=0.28 ē=0.27 rad n=78	•

Table 6.--Continued

	• • • •	
Specimen	NMBM Nos. 50684-7	UND Cat. No. 13560
Minor septa length		0.04-0.16 ī=0.1 ē=0.09 rad n=56
Closely spaced tabulae	0.2-0.5	0.14-0.44 \$=0.32 n=30
Widely Spaced tabulae	0.6	0.44-0.8 s=0.56 n=61
Tabular spine length, "close" zone		0.06-0.24 I=0.13 n=86
Tabular spine length, "wide" zone		0.04-0.18 I=0.09 n=62
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TABLE 7.--Biometrics of holotype of <u>Trabeculites</u> manitobensis n. sp.

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Specimen	Holotype, UND Cat. No. 13561	
Corallum form	Massive, cerioid	
Corallum width	> 90	
Corallum height	55	
Corallite diameter	1.6-2.45 d=2.0 n=88	• • •
Trabeculae per corallite	20-24 n=22 n=22	
Trabecular width at margin	0.1-0.32 w=0.18 n=131	
Trabecular width at center	0.13-0.43 w=0.29 n=131	
Margin, width center width	0.33-1.0 $\bar{w}=0.62$ n=131	
Septa per corallite	16-25 n=22 n=49	
Septal spine length	0.04-0.22 1=0.1 ē=0.1 rad n=208	
Septal spine spacing (longitudinal)	0.1-0.42 s=0.19 n=132	
Septal spine orientation	34-90° 0 =68° n=137	

Specimen	UND Cat. No. 13561
Tabular spacing	0.06-1.06 s=0.32 n=169

TABLE 8.--Biometrics of Nyctopora fissisepta n. sp.

······································		
	Specimen	Holotype, UND Cat. No. 13703
	Corallite diameter	1.00-1.80 d=1.36 n=136
	Wall thickness	0.08-0.18 t=0.12 n=90
	Septal spine orientation	$26^{\circ} - 78^{\circ}$ $\overline{0} = 53^{\circ}$ n = 172
	Major septal length (l _l)	0.14-0.5 1=0.37 n=80
	Major septal extension	0.23-0.71 rad ē=0.52 rad n=80
	Minor septal length (1 ₂)	0.06-0.22 1=0.14 n=78
	1 ₂ / 1 ₁	0.17-0.86 $\frac{1}{2}$ / $\frac{1}{1}=0.37$ n=78
	Tabular spacing	0.2-0.8 s=0.46 n=88

TABLE 9. -- Biometrics of holotype, hypotypes, and a specimen of Manipora amicarum

Specimen	Holotype, GSC No. 12382 (Sinclair, 1955)		Hypotypes, GSC Nos. 10373, 10374, 10375 (Nelson, 1963)	Hypotype, UND Cat. No. 13765
Corallum w, 1	fragmental	15 cm	large	28 cm (frag.)
Corallum height	9 cm			13.5 cm
Cateniform rank length				3-15 I=9.4 n=41
Lacuna length			10-40	4-24 1=8.7 n=45
Lacuna width			5-10	3-9 ₩=3.8 n=45
Lacuna w/l				0.16-0.88 w/l=0.38 n=45
Maximum corallite height	E .	40		45-95
Corallite len- gth, cateni- form rank	1.25-1.66	1.25-1.66	1.5-2.0	1.25-2.1 I=1.55 n=84

TABLE 9.--Continued

thickness

Specimen GSC No. 12382 GSC Nos. 10373- UND Cat. No. 13765 NMBM No. 622 10375 Corallite width, 1.4-2.3 cateniform rank w=1.76 n=84 Cateniform coral-0.8-1.57 lite w/l $\bar{w}/I=1.14$ n=84 Agglutinative 1.5-2.0 1.45-2.0 corallite d=1.69 diameter n=91 Width cateniform corallite @ wc=1.76 center (wc) Width cateniform 1.1-1.9 corallite @ wm=1.47 margin (wm) n=84 wm/wc 0.66-1.0 $\overline{w}\overline{m}/\overline{w}\overline{c}=0.83$ n=84 % cateniform 54% 36% 32% corallites Lateral wall 0.09-0.2

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t=0.13 n=84 TABLE 9. -- Continued

Specimen	GSC No. 12382	NMEM No. 622	GSC Nos. 10373- 10375	UND Cat. No. 13765
Common wall length (<u></u> to rank)				0.8-1.7 I=1.27 n=55
Common wall width (to rank)				0.04-0.13 w=0.07 n=55
Common wall width/length (w/l)				0.02-0.1 w/I=0.05 n=55
Fiber orientat- ion in lateral walls				40-83 ⁰ ō=58 ⁰ n=87
Fiber orient- ation in common walls				25-74° ⊕=51° n=88
Tabular spacing, "close"	0.55		0.37-0.5	0.3-0.74 5=0.52 n=98
Tabular spacing, "wide"	· · · · ·	0.71-0.83	0.5-0.67	0.53-1.4 =0.87 n=98

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Table 10.--Biometrics of <u>Manipora garsonensis</u> n. sp., and <u>Manipora</u> <u>bighornensis</u> n. sp.

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Species	<u>M. garsonensis</u> n. sp.	<u>M. bighornensis</u> n. sp.
Specimen	Holotype, UND Cat. No.13766	Holotype, UND Cat. No.13768
Corallum w, 1	120x90	fragmental
Corallum height	25	fragmental
Cateniform rank length	5 to 15]=9.5 n=28	
Lacuna width	3 to 8 w=4.9 n=11	
Lacuna length	8 to 23 1=13.0 n=11	
Lacuna w/1	0.19 to 0.66 w/1=0.4 n=11	
Corallite length cateniform rank	1.9 to 2.8 1=2.3 n=44	
Corallite width cateniform rank	2.05 to 2.7 w=2.36 n=35	
Corallite w/l	0.85 to 1.2 w/1=1.0 n=35	
Corallite dia cerioid portion	2.0 to 2.65 d=2.44 n=17	1.45-2.3 $\vec{d}=1.79$ n=47
Cateniform corallite w at lateral margin (wm)	1.6 to 2.3 wm=1.9 n=34	

TABLE 10. -- Continued

Specimen	UND Cat. No.13766	UND Cat. No.13768	
Cateniform corallite w at center (wc)	2.05 to 2.7 wc=2.36 n=34		
wm/wc	0.66 to 0.93 ^{WM} / _{WC} 0.8		
Lateral wall thickness	<u>0</u> .22 to 0.35 t=0.29 n=28	0.1-0.24 t=0.17 n=32	
Common wall length (1 to rank)	1.2 to 1.84 Ī=1.57 n=25		
Common wall width (to rank)	0.18 to 0.35 w=0.23 n=25	0.06-0.2 t=0.16 n=24	
Fiber orientation in lateral walls	50° to 78° 0 =63° n=27	53-77 ⁰ θ=66 ⁰ n=4	
Fiber orientation in common wall	32° to 66° 0 =46° n=54	41-68° ⊕=54° n=30	
Longitudinal septal spine spacing	0.24 to 0.58 s=0.45 n=12		
Spines per intertabular space	1 to 2		
Spine length	0.1 to 0.3 1=0.17 n=25		
Tabular thickness	0.04 to 0.18 t=0.07 n=106	0.04-0.08 t=0.05 n=29	
Tabular spacing	0.25 to 0.92 s=0.63 n=106	0.3-1.1 s=0.66 n=29	

TABLE 11. -- Biometrics of Calapoecia anticostiensis

	TT . T . b .	·	77
pecimen	Holotype, GSC No. 2267	Hypotypes, GSC Nos. 10502, 10280	Hypotype, UND Cat. No. 13565
	(Cox, 1936)	(Nelson, 1963)
orallum form			globose
orallum w, l	· ·		4.1 cm
orallum height			2.6 cm
orallite iameter	up to 2.5	2 to 3	1.75-3.4 d=2.7 n=64
enter-to-center orallite pacing	"distant"		2.9-5.7 =
eptal umber	20		19-21 n=20 n=23
eptal spine ength	•		0.2-0.8 1=0.45 n=68
eptal spine pacing	0.62		0.2-0.8 š=0.44 n=114
eptal spine rientation			30-110 [°] 9 =67° n=70
oenenchymal late thickness			0.06-0.23 t=0.12 n=92
oenenchymal late spacing			0.28-0.68 s=0.42 n=94

TABLE 11.--Continued

Specimen	GSC No. 2267	UND Cat. No. 13565
Coenenchymal width		₩=1.43 ₩=0.53 dia
Tabular spacing	0.4-0.5	0.1-1.25 s=0.5 n=123

TABLE 12.--Biometrics of <u>Calapoecia</u> sp. cf <u>C</u>. <u>anticostiensis</u>

Specimen	Hypotype, UND Cat. No. 13566	Hypotype, UND Cat. No. 13567
Corallum form	fragmental	frag., hemispherical
Corallum w, 1	2.0 x 2.0 cm	> 8.0 cm
Corallum height	1.0 cm	3.0 cm
Corallite Diameter	1.9-2.4 d=2.23 n=13	2.0-2.8 d=2.34 n=10
Center-to-center corallite spacing	2.7-4.0 s=3.42 s=1.53 dia n=15	
Coenosteal plate spacing	0.4-0.75 s=0.56 n=15	0.4-0.7 s=0.51 n=25
Coenosteal width	0.0-2.0 w=0.82 w= 0.36 dia n=26	

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Specimen	Holotype, RS No. 437 (Troedsson, 1929)	Hypotypes, UND Cat. Nos. 13569, 13570		
Corallum form	fragmental	hemispherical		
Corallum w, 1	>150	73-75		
Corallum height		35		
Corallite diameter	4–6	2.2-4.7 d=3.28 n=90		
Center-to- center corallite spacing	distant	2.5-6.6 s=4.88 n=1.49 dia n=60		
Calice depth	• • •	2.0-4.4 d=2.9 n=16		
Septal count	20	19-20 n=20		
Septal spine '		63-98° 0 =83° n=38		
Septal spine spacing		0.24-1.05 s=0.6 n=104		
Coenosteal plate spacing		0.3-1.04 s=0.6 n=90		
Coenenchymal plate thickness		0.06-0.15 t=0.08 n=131		
Coenenchymal width		₩=1.60 ₩=0.49 dia		
Tabular spacing	· ·	0.1-1.7 s=0.62 n=113		

·			
	Specimen	Hypotype, GSC No. 10503 (Nelson, 1963)	Hypotype, UND Cat. No. 13571
	Corallum form		elongate-tabular
	Corallum w, l		75x145
	Corallum height		32
	Calyx depth		1.3-1.7 d=1.53 d=0.6 dia
	Calicinal rim	circular	elevated above coenenchymal plates
	Corallite diameter	"averages 2mm or slightly less"	2.3-3.1 d=2.6 n=29
	Center-to-center corallite spacing		2.0-4.0 \$=2.88 n=27
	Coenenchymal width	"narrow"	0.0-1.0 ₩=0.33 ₩=0.12 dia n=27
	Septal number	•	19-20 n=13
	Coenenchymal plate spacing		0.2-0.9 s=0.4 n=56
	Septal spine spacing		0.3-0.62 s =0.42 n=47
•	Tabular spacing	•	0.1-1.0 $\bar{s}=0.41$ n=67

TABLE 14. -- Biometrics of hypotypes of Calapoecia ungava

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TABLE 15.--Comparison of biometrics of the holotype of <u>Protarea cutleri</u> Leith with a hypotype of <u>Protarea</u> sp. cf. <u>P. cutleri</u>

	Species	<u>Protarea</u> cutleri Leith	<u>Protarea</u> sp. cf. <u>P. cutleri</u> Leith
	Specimen	Holotype, U. of Manitoba 110 (Leith, 1952)	Hypotype, UND Cat. No. 13651
	Corallum form	encrusting	encrusting
	Corallum w, 1, dia	17 (dia)	> 16 mm; 22
	Corallum height	1.5	0.7
	Calyx diameter		0.7-1.04 d=0.9 n=25
	Center-to- center corallite` spacing	s=1.25	0.8-1.2 s=1.08 s=1.2 dia n=18
	Coenenchymal width		0.2-0.45 w=0.31 w=0.29 dia n=18
	Trabecular wídth		0.18-0.28 w=0.22 n=18
	Columellar tubercle diameter		0.16-0.2 <u>a</u> =0.17 n=5
	Fiber orientation		$23-57^{\circ}$ $\theta=43^{\circ}$ n=31
· .	Septa per corallite	12	10 n=1
•	Width of columella		0.6 0.66 dia n=1

TABLE 16.--Biometrics of species of Coccoseris

Species	<u>C. astomata</u>	<u>C. astomata</u>	C. astomata	<u>Coccoseris</u> sp.
Specimen	Holotype, NMBM No. 670 (Flower, 1961)	Hypotype, UND Cat. No. 13653	Hypotype, UND Cat. No. 13655	Hypotype, UND Cat. No. 13662
Corallum w, h, or dia.	200 (w)x30 (h)	200 (w)x18 (h)	55 (w)x13 (h)	h=2-15
Corallite diameter		1.4-1.9 d=1.68 n=22	1.35-2.0 $\overline{d}=1.63$ n=26	
Center-to-center corallite spacing		1.6-2.4 s=1.97 n=50	1.65-2.2 s=1.92 n=18	
Coenenchymal width		0.3-0.85 ₩=0.51 ₩=0.15 dia n=42		
Trabecular diameter		0.14-0.55 d=0.37 n=200		0.14-0.26 d=0.19 n=41
Trabecular fiber orientation		27-73 ⁰ ∂=52 ⁰ n=61		$16-52^{\circ}$ $\overline{\Theta}=31^{\circ}$ n=30

TABLE 16.--Continued

Specimen	NMBM No 670	UND Cat. No. 13653	UND Cat. No. 13655 UND Cat. No. 13662
Columellar width		0.75-1.1 w=0.94 n=27	
Columella width Corallite dia		⊽=0.56 dia	
Pustules per columella		10-14 n=13 n=18	
Septal number		11-12 n=12 n=23	
Length, inter septal depress- ions	· · ·	0.16-0.44 I=0.31 I=0.37 rad n=72	
Width, inter- septal depress- ions		0.12-0.35 w=0.18 n=72	

TABLE 17biometrics	of	hypotypes	of	Protrochischolithus	magnus
		* * * *			

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Specimen	Hypotypes, U. of Manitoba 111-116 (Leith, 1952)	Hypotype, NMBM No. 733 (Flower, 1961)	Hypotype, UND Cat. No. 13663	Hypotype, UND Cat. No. 13664	Hypotype, UND Cat. No. 13665
Corallum height	90	10	39	2	19
Corallum diameter	190x66	100	103	> 29	> 78
Corallite diameter	₫=2	1.5-1.8	1.0-1.85 d-1.42 n=31	1.1-1.85 d=1.43 n=28	1.1-1.6 d=1.43 n=19
Center-to-center corallite spacing			1.3-1.9 5=1.59 5=1.1 dia n=29	1.25-1.95 s=1.58 s=1.1 dia n=21	1.4-2.1 s=1.62 s=1.1 dia n=13
Wall thickness			0.1-0.3 t=0.17 n=60		
Columella diameter	0.2-0.25 dia	0.33 dia	0.39-0.82 d=0.6 d=0.42 dia n=60	0.55-0.8 d=0.65 d=0.45 dia n=14	0.6-0.9 d=0.76 d=0.53 dia n=19
Columellar bacular diameter			0.08-0.24 d=0.13 n=127		

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Specimen	U. of Manitoba 111-116	NMBM No. 733	UND Cat. No. 13663	
Septal number	12	12	12	
Orientation, septal baculae	•		19-58 ⁰ ō= 39 ⁰ n=88	
Septal width		• •	0.06-0.26 ₩=0.1 n=60	
Tabular spacing		0.29-0.33	0.12-1.52 s=0.45 n=182	

TABLE 18.--Biometrics of the holotype and a hypotype of <u>Paleofavosites</u> kuellmeri and a species comparable to <u>P. kuellmeri</u>

Species	<u>P. kuellmeri</u>	<u>P. kuellmeri</u>	Paleofavosites sp.cf. P. kuellmeri
Specimen	Holotype, NMBM No. 686 (Flower, 1961)	Hypotype, UND Cat. No. 13729	Hypotype UND Cat. No. 13730
Corallum w, l, or diameter	70-100	160x > 105	> 1.5 m
Corallum height	50-80	50	17 cm
Corallum form		elongate-tabul- ar, massive	tabular, massive
Corallite orientation	parallel, subparallel	paralle1	parallel
Corallite diameter	2.0-2.5	1.0-2.9 d=1.98 n=133	2.0-3.5 d=2.8 n=86
Mural pore diameter		0.12-0.3 d=0.21	0.08-0.26 d=0.15 n=38
Pore location	corners only	corners only	corners only
Mural pores, closely spaced		0.32-0.5 s=0.37 n=7	
Mural pores, widely spaced	0.5-1.0	0.54-1.02 s=0.65 n=13	0.38-0.66 $\overline{s}=0.5$ n=6
Wall Crenulat- ion length	1.0-1.5	0.4-0.95 p=0.63 n=105	0.4-1.3 $\vec{p}=0.73$ n=52
Wall crenulat- ion amplitude	strong	(maximum) 0.17-0.37 ā=0.25 ā=0.13 dia n=33	0.18-0.5 a=0.29 n=9

TABLE 18.--Continued

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Specimen	NMBM No. 686	UND Cat. No. 13729	UND Cat. No. 13730
Corallite wall thickness		0.06-0.3 T=0.15 n=150	0.08-0.44 t=0.2 n=52
Axial plate thickness	•	0.02-0.04 t=0.03 n=33	
Wall fiber orientation		26-90 ⁰ Ō =62 ⁰ n=158	4382° 0 ≠63°
Tabulae, closely spaced	0.5-0.55	0.22-0.68 s=0.52 n=77	0.1-0.5 s=0.73
Tabulae, widely spaced	0.62-0.83	0.54-1.02 s=0.72 n=74	0.4-1.35 \$=0.73

TABLE 19.-- Biometrics of primary types and hypotypes of <u>Paleofavosites</u> <u>mccullochae</u>

Specimen	NMBM Nos. 800-805, 569-570 (Flower, 1961)	UND Cat. No. 13731	UND Cat. No. 13732
Corallum w, l	commonly 60x80	68x75	65x35
Corallum height		40	35
Corallum form	hemispherical	elongate- hemispherical	hemispherical
Corallite orientation	radiating	radiating & subparallel	radiating
Max. corallite length		27	

TABLE 19. -- Continued

		· · · · · · · · · · · · · · · · · · ·	
specimen	NMBM Nos. 800-805, 569-570	UND Cat. No. 13731	UND Cat. No. 13732
Offset tubules	0.5	none	none
Corallite diameter	2.5-3.0	0.9-2.9 ₹=2.0 n=110	0.8-3.2 d=1.9 n=60
Mural pore height		0.14-0.3 h=0.2 n=42	0.12-0.3 d=0.18 n=24
Mural pore width		0.12-0.3 w= 0.18 n=42	
Mural pore w/h		0.57-1.66 ₩/Ћ=0.9 n=42	
Wall crenulation length	n "close"	0.3-1.65 1=0.8 n=46	0.7-1.15 1=0.9 n=12
Maximum crenulation amplitude		0.2-0.6 ā=0.28 n=18	0.15-0.4 ā=0.22 ā=0.11 dia n=10
Mural pore spacing	0.8-1.0	0.32-0.82 s=0.53 n=17	
Corallite wall thickness		0.05-0.26 t=0.13 n=47	0.08-0.22 ₹=0.15 n=21
Wall fiber orientation		40-87 ⁰ ō= 64 ⁰ n=46	4388 ⁰ ō= 71 ⁰
Tabular spacing close	0.56-0.62	0.2-0.8 5=0.5 n=49	0.3-0.73 s=0.49 n=26

TABLE 19.--Continued

Specimen	NMBM Nos. 800-805, 569-570	UND Cat. No. 13731	UND Cat. No. 13732
Tabular spac- ing, wide	0.83-1.0 "rarely" 1.25	0.32-1.48 s-1.03 n=50	0.45-1.84 s=0.96 n=30
Tabular form	planar w/ crenulate margins	crenulate	planar w/ crenulate margins
Septal development	none	none	spinose
Maximum spine length		- -	0.2-0.4 1=0.27 n=13
Maximum spine extension	• •		0.2-0.43 rad ē=0.25 rad n=13

Species Paleofavosites Paleofavosites Paleofavosites prayi Flower cf. pravi sp. cf. P. prayi Specimen Holotype, Hypotype, NMBM No. 796, 797 (Flower, 1961) NMBM No. 685 UND Cat. (Flower, 1961) Corallum w, 1 100×50 135x170 (est.) Corallum height 40 mm 12 Corallite length (maximum) <0.5 Offset tubules 0.1 max. dia Corallite 1.5-2.0 0.45-1.8 > 2.0 diameter $\bar{d}=1.3$ n=93 Corallite subalveolitid-outline subpolygonal Corallite radiating and radiating parallel orientation parallel Wall slightly curved and curvature curved straight 0.04-0.17 Mural pore dia d=0.11 n = 32Pore location comers corners corners Mural pore 1.4 0.26-0.6 0.8 - 1.0spacing s=0.35 n=16 Wall 0.4-1.75 crenulation 1=0.83 n=41 length

TABLE 20.--Biometric comparison of holotype of <u>Paleofavosites prayi</u> Flower with comparable forms from Wyoming and Texas TABLE 20. -- Continued

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Specimen	NMBM No. 685	UND Cat. No. 137	33 NMBM Nos. 796, 797
Crenulation amplitude		0.1-0.24 ā=0.17 n=24	
Corallite wall thickness		0.02-0.36 t =0.13 n=29	
Wall fiber orientation	· · · · ·	$\frac{40-92^{\circ}}{6-67^{\circ}}$ n=31	
Tabular spacing, "close"	0.5-0.55	0.22-0.68 s=0.37 n=55	
Tabular spacing, "wide"	1.25	0.42-1.4 s=0.81 n=55	1.25-1.66
Tabular form	transverse or convex, crenulate margins	predominantly planar	crenulate margins
Septal development	none	none	

Species	<u>P</u> . prolificus	<u>P</u> . prolificus	P. prolificus	P. prolificus	Paleofavosites sp. A cf. P. prolíficus	Paleofavosites sp. B cf. P. prolificus
Specimen	Hypotype, GSC No. 10329 (Nelson, 1963)	Hypotypes, GSC Nos. 10410, 11009 (Stearn, 1956)	Hypotype, UND Cat. No. 13734	Hypotype, UND Cat. No. 13736	Hypotype, UND Cat. No. 13739	Hypotype, UND Cat. No. 13740
Corallite orientation			radiating	parallel	subparallel	radiating
Corallite diameter		2.34	$\frac{1.2-3.1}{d=2.25}$ n=32	1.6-2.8 d=2.08 n=48	1.1-2.6 d=2.7 n=42	1.6-2.4 ā=1.92 n=15
Mural pore diameter	0.1		0.1-0.24 d=0.17 n=26	•		0.14-0.28 d=0.18 n=16
Pore location	common in corners	common in corners rare in walls	corners	corners	corners	corners
Pore spacing		abundant	0.3-0.88 s=0.61 n=10	0.36-0.8 s=0.6 n=31		0.38-0.44 s=0.4 n=3

TABLE 21.--Biometrics of Paleofavosites prolificus and hypotypes comparable to it

TABLE 21. -- Continued

Specimen	GCS No. 10329	GSC Nos. 10410, 11009	UND Cat. No. 13734	UND Cat. No. 13736	UND Cat. No. 13739	UND Cat. No. 13740
Wall crenu- lation length			0.35-1.13 I=0.79 n=29			0.64-0.8 1=0.74 n=4
Wall crenu- lation amp- litude		•	0.14-0.35 ā=0.22 ā=0.1 dia n=10			0.2-0.3 ā=0.23 ā=0.11 dia n=9
Wall thickness	thin	thin	0.08-0.24 E=0.13 n=28		•	0.1-0.18 E=0.15 n=15
Septal development	•	rudimentary spines	short spines			
Tabular spacing, "close"	0.25-0.37	0.5	0.2-0.6 s=0.42 n=10	0.34-0.52 s=0.44 n=10	0.26-1.1 s=0.53 n=26	0.25-0.64 g=0.38 n=8
Tabular spacing, "wide"	·		0.6-1.35 s=1.0 n=25	0.6-1.1 s=0.8 n=14		0.55-1.3 s=0.77 n=14

Specimen	Holotype,	Hypotypes,	Hypotype,	Hypotype,	Hypotype,	Hypotype,
	no GSC No. (Okulitch, 1943)	GSC Nos. 10404, 12685 (Stearn, 1956)	GSC No. 10351 (Nelson, 1963)	UND Cat. No. 13741	UND Cat. No. 13742	UND Cat. No 13743
Corallum w, 1	"several inches"	5 cm		7.0x4.5 cm	4.0x3.0 cm	3.0 cm
Corallum height			,	6.0 cm	1.7 cm	1.0 cm
Corallite diameter	23	d=3.73 n=29	2.0-3.5	1.1-3.6 d=2.63 n=49	0.98-3.4 d=2.43 n=31	1.0-4.0 d=2.6 n=46
Pore diameter in corners		0.2	0.2-0.3	0.08-0.22 d=0.16 n=33	0.14-0.28 d=0.21 n=17	0.1-0.18 ā=0.14 n=11
Pore diameter in walls		• • • • •			0.2-0.28 ā=0.23 n=3	• •
Pore spacing in corners		0.7		0.3-1.04 s=0.54 n=21	0.68-1.04 s=0.78 n=5	0.65-1.1 \$=0.86 n=6
Wall crenula- tion length				0.55-1.4 1=1.4 n=19	0.5-1.2 1=0.93 n=10	

TABLE 22.--Biometrics of the holotype and hypotypes of Paleofavosites okulitchi

TABLE 22.--Continued

Specimen	no GSC No.	GSC Nos. 10404, 12685	GSC No. 10351	UND Cat. No. 13741	UND Cat. No. 13742	UND Cat. No. 13743
Wall crenula- tion amplitude			ť.,	0.2-0.36 ā=0.25 ā=0.09 dia n=3		
Corallite wall thickness		0.2-0.3		0.12-0.6 t=0.27 n=19	0.14-0.2 t=0.16 n=12	
Wall fiber orientation				42-90° ō=61° n=19	45-90 ⁰ ō=57 ⁰ n=9	
Septal spines per corallite		"rudimentary to absent"	· · · ·	13-23 or absent	×	
Septal length				0.08-0.25 1=0.19 1=0.14 rad n=22	•	
Tabular spacing, "close"			0.29-0.6	0.12-0.5 $\bar{s}=0.34$ n=28	0.62-0.82 $\bar{s}=0.69$ n=27	0.3-0.7 $\overline{s}=0.58$ n=12
Tabular spacing, "wide"	1.0	"crowded"	0.67-1.0	0.5-1.4 s=0.95 n=37	0.66-1.8 s=1.13 n=27	0.84-1.3 $\bar{s}=1.0$ n=6

TABLE 23.--Biometrics of the hypotype of <u>Paleofavosites</u> sp. cf. <u>P. okulitchi</u>

Specimen	UND Cat. No. 13744
Corallum w, l	4.5; 3.0 cm
Corallum height	3.0 cm
Corallite diameter	0.8-2.6 d=1.5 n=46
Wall and corner curvature	crenulate in transverse section
Corner pore diameter	0.08-0.22 d=0.13 n=15
Wall pore diameter	0.15-0.22 d=0.18 n=15
Wall crenulation length	0.8-0.88 1=0.84 n=3
Septa per corallite	> 13-20
Spine length maximum	0.18-0.4 1=0.3 1=0.4 rad n=26
Spine spacing	0.15-0.38 s=0.22 n=29
Wall thickness	0.12-0.3 t=0.19 n=20
Tabular spacing, "close"	0.22-0.92 s=0.68 n=14
Tabular spacing, "wide"	0.78-2.1 \$=1.37 n=16

Species	Paleofavosites capax	<u>Paleofavosites</u> capax	Paleofavosites sp. cf. <u>P. capax</u>
Specimen	Hypotype, GSC NO. 10493 (Stearn, 1956)	Hypotype, GSC No. 10355 (Nelson, 1963)	Hypotype, UND Cat. No. 13749
Corallum w	8 cm		4.0 cm
Corallum height			2.5 cm
Corallite diameter	d=3.79 s=0.69 n=37	mature; 4-5 immature; 2-3	2.6-4.1 d=3.34 n=7
Corallite outline	six-sided	mature; 6-7 sides immature; 3-5 sides	subpolygonal (?)
Mural pore diameter	0.1	0.2-0.3	0.24-0.35 ā=0.29 n=8
Pore location	corners	corners	corners
Mural pore spacing	abundanť	common	0.48-1.2 s=0.76 n=13
Septal development	absent or short scattered spines		none observed
Tabular spacing, "close"		0.62-0.72	0.35-0.55 s=0.44 n=9
Tabular spacing, "wide"		0.75-1.0	

TABLE 24.--Comparison of biometrics of hypotypes of <u>Paleofavosites</u> capax (Billings) with a hypotype of a comparable form

Table 25.--Biometrics of Paleofavosites spp.

Species	<u>Paleofavosites</u> sp. A	Paleofavosites sp. B
Specimen	Hypotype, UND Cat. No. 13750	Hypotype, UND Cat. No. 13769
Corallum w, 1	2.0 cm x (?)	4.0 x 2.0 cm
Corallum height	1.5 cm	8 cm
Corallite diameter	2.2-3.6 d=2.71 n=15	1.0-3.2 ā=2.49
Mural pore spacing	0.4-0.6 s=0.55 n=4	0.44-1.4 s=0.93 n=25
Tabular spacing	0.22-0.44 s=0.31 n=17	0.26-0.9 s=0.54 n=12

Specimen	Holotype, GSC No. 11048	Hypotype, UND Cat. No. 13751	Hypotype, UND Cat. No. 13752	Hypotype, UND Cat. No. 13753
	Paratypes, GSC Nos. 10407, 11007, 11041 (Stearn, 1956)			
Corallum w, 1	4 cm x (?)	4.5x3.5 cm	3.0 cm x (?)	8.5x6.0 cm
Corallum height		2 cm	0.7 cm	2.5 cm
Corallite orientation		radiating	radiating	radiating, subparallel
Corallite diameter	d=1.89 s=0.23 n=17	1.0-1.9 d=1.33 n=14	1.05-1.95 d=1.36 n=21	1.0-1.9 d=1.28 n=35
Mural pore diameter	0.1	0.1-0.32 d=0.25 n=14	0.08-0.26 d=0.15 n=19	0.08-0.18 d=0.12 n=14
Mural pore spacing	•	0-54-1.6 s=0.91 n=13	0.25-1.0 s=0.49 n=14	0.23-0.55 \$=0.31 n=14
Mural pore location	abundant in corners, rare in walls	corners	corners	corners

TABLE 26.--Blometrics of the holotype, paratypes, and hypotypes of Angopora manitobensis Stearn

Specimen	GSC Nos. 11048 10407, 11007	UND Cat. No. 13751	UND Cat. No. 13752	UND Cat. No. 13753
	11041	· · · ·		
Crenulation length		coincident with mural pores	0.6-0.8 1=0.7 n=2	0.6-0.76 I=0.65 n=7
Crenulation amplitude		indet.	indet.	0.15-0.22 ā=0.21 ā=0.16 dia
Septal length maximum	0.2 maximum	0.24-0.26 1=0.25 n=3	0.1-0.15 1=0.12 n=2	0.2-0.32 I≠0.24 n=5
Septal extension	ē=0.21 rad	ē=0.41 rad	ē=0.18 rad	ē=0.38 rad
Tabular spacing, "close"	0.33-0.5	0.2-0.48 s=0.35 n=15	0.3-0.58 s=0.41 n=18	0.41-0.46 s=0.27 n=26
Tabular spacing, "wide"	•	0.5-1.4 s=0.82 n=17	0.5-0.56 s=0.53 n=4	0.36-0.56 s=0.44 n=6

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TABLE 26.--Continued

	Specimen	Holotype, UND Cat. No. 13754	
	Corallum form	fragmental, cerioid, flattened hemispherical	
	Corallum width	20 mm	
	Corallum height	9 mm	
	Corallite diameter	0.7-1.23 d=0.97 n=34	
	Pore diameter	0.08-0.18 d=0.13 n=12	
· ·	Pore spacing	0.2-0.58 s=0.32 n=7	
	Wall thickness	0.06-0.18 t=0.12 n=20	
	Crenulation length	0.44-0.75 1=0.57 n=5	
	Crenulation amplitude	0.8-1.0 ā=0.09 ā=0.09 dia	
	Septal spines per corallite	12 n=3	÷
	Septal spine length	0.22-0.5 1=0.38 n=11	
	Septal spine extension	0.4-0.96 rad e=0.69 rad n=11	

TABLE 27.--Biometrics of holotype of Angopora wyomingensis n. sp.

TABLE 27.--Continued

Wall fiber orientation	$35-70^{\circ}$ $\overline{\theta}=55^{\circ}$ n=14	
Closely spaced tabulae	0.08-0.26 s=0.15 n=28	•
Widely spaced tabulae	0.26-1.0 $\bar{s}=0.45$ n=14	

Specimen Hypotype, Hypotype, UND Cat. No. 13755 UND Cat. No. 13756 Corallum size > 3 cm indet. Corallite 0.7 - 1.850.8-1.65 d=1.32 d=1.23 diameter n = 2.3n=29 Wall thickness 0.08-0.13 ī=0.11 n=10 Septal length 0.12-0.38 0.14-0.4 ī=0.26 1=0.22 (minimum) n=17 ē=0.36 rad Septal extension ē=0.39 rad (maximum) 0.3-1.2 0.5-1.6 Tabular spacing s=0.67 s=0.88 n=21 n=19 transverse, Tabular transverse oblique orientation

TABLE 28.--Biometrics of two hypotypes assigned to [?] Angopora sp.

	······································	
	Specimen	Holotype, UND Cat. No. 13757
	Corallum diameter	28 cm (estimated)
	Corralum height	> 7 cm
	Corallite diameter	1.8-3.8 t=2.78 n=45
	Corner pore diameter	0.12-0.2 d=0.15 n=17
	Wall pore diameter	0.1-0.24 d=0.16 n=31
	Corner pore spacing	0.3-1.2 s=0.63 n=24
	Wall pore rows	2-4
	Wall pore spacing	0.3-1.4 s=0.74 n=41
	Wall pore row spacing	0.4-1.1 s=0.67 n=22
	Wall thickness	$ \underbrace{\begin{array}{l} 0.16-0.3 \\ t=0.22 \\ n=26 \end{array} $
	Minimum axial plate thickness	0.02
•	Wall fiber orientation	$27-76^{\circ}$ $\overline{\Theta}=52^{\circ}$ n=32
-	Septal ridges	14-20

TABLE 29.--Biometrics of the holotype of <u>Favosites manitobensis</u> n. sp.

TABLE 29.--Continued

Specimen	UND Cat. No. 13757
Tabular spacing, "close"	0.2-1.22 \$=0.59 n=25
Tabular spacing, "wide"	0.35-1.2 s=0.86 n=38

Specimen	Hypotype, UND Cat. No. 13758	Hypotype, UND Cat. No. 13759	Hypotype, UND Cat. No. 13761	Hypotype, UND Cat. No. 13762	Hypotypes, GSC Nos. 10890, 10891, 10368 (Nelson, 1963)
Corallum w, 1			80x120		
Corallum height			70		
Rank length	3-27	2-22	432		
Lacuna width	3-9	2-11		4-7	5
Lacuna length	9- 30	4-24		6-26	15-20, up to 30
Lacuna w/l	0.1-0.81	0.13-1.0		0.57	0.25-0.33
Corallite width	1.4-1.8 w=1.57 n=58	1.0-1.6 w=1.25 n=54	1.4-1.7 w=1.51 n=16	0.98-1.35 w=1.25 n=22	1.2
Corallite length	1.6-2.55 I=2.21 n=58	1.4-2.3 Î=1.8 n=54	1.7-2.2 Ī=1.91 n=16	1.4-1.84 1=1.66 n=22	1.7
Septa per corallite	9(?)-12	8(?)-12	11-15(?)	12(?)-15(?)	
Septal length	0.06-0.3 1=0.19 n=104	0.05-0.24 1=0.14 n=107	0.05-0.15 1=0.11 n=24	indet.	

TABLE 30.--Biometrics of hypotypes of Catenipora robusta

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TABLE 30.--Continued

Specimen	UND Cat. No. 13758	UND Cat. No. 13759	UND Cat. No. 13761	UND Cat. No. 13762	GSC Nos. 10890, 10891, 10368
Septal length lumen width	0.18	0.15	•	· · · ·	
Wall width lumen width	0.2	0.18	0.21	0.19	
Tabular spacing, "close"			0.28-0.66 s=0.47 n=45	0.4-0.96 s=0.75 n=36	0.47
Tabular spacing, "wide"	0.55-1.4 s=0.89 n=98	0.45-1.42 s=0.75 n=82		0.95-1.45 s=1.12 n=12	
Corallite w/l	0.54-0.94 w/1=0.72 n=58	0.5-0.91 w/1=0.7 n=54	0.72-0.94 w/1=0.79 n=16	0.57-0.86 w/l=0.75 n=22	0.71
Corallite width @ margin (wm)	0.96-1.56 wm=1.24 n=51	0.76-1.1 wm=0.9 n=40	1.03-1.3 wm=1.19 n=16	0.8-1.1 wm=0.97 n=23	1.0
Corallite width @ center (wc)	<u>1.</u> 3-2.0 wc=1.6 n=51	0.9-1.42 wc=1.21 n=40	1.4-1.7 wc=1.51 n=16	0.98-1.4 wc=1.25 n=23	1.2
wm wc	0.69-0.91 wm/wc=0.79 n=51	0.6-0.88 wm/wc=0.76 n=40	0.61-0.86 wm/wc=0.77 n=16	0.65-0.91 wm/wc=0.73 n=23	0.83

TABLE 30.--Continued

Specimen	UND Cat. No. 13758	UND Cat. No. 13759	UND Cat. No. 13761	UND Cat. No. 13762	GSC Nos. 10890, 10891, 10368
Wall thickness	0.16-0.26 t=0.21 n=33	0.08-0.24 t=0.16 n=63	$\frac{0.2-0.3}{t=0.22}$ n=21	0.16-0.24 t=0.19 n=17	relatively thick
Lumen width	0.92-1.24 w=1.04 n=33	0.7-1.1 w=0.9 n=36	0.95-1.14 w=1.06 n=13	0.84-1.1 w=1.0 n=11	
Lumen length	1.52-2.2 1=1.88 n=33	1.26-1.92 1=1.5 n=36	1.53-1.9 1=1.69 n=13	1.3-1.64 Ī=1.47 n=11	
Lumen w/l	0.47-0.72 w/1=0.55 n=33	0.44-0.73 w/l=0.58 n=36	0.55-0.73 w/1=0.62 n=13	0.54-0.85 w/l=0.67 n=11	
Common wall width	0.15-0.34 w=0.24 n=28	0.1-0.3 w=0.2 n=34		•	· · · ·

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Specimen	Hypotype, UND Cat. No. 13763	Hypotype, UND Cat. No. 13674	Hypotypes, GSC Nos. 10896, 10897 (Nelson, 1963)
Corallum w, h	>170x >70 (fragmental)	>430x>60 (fragmental)	
Rank length	3-52 I=16.8 n=86	6-78 ·	
Lacuna length	8-40 1=21.9 n=36	9-7100	20; vermiform, 50
Lacuna width	6-17 w=9.86 n=36	3-16	5
Lacuna w/l	$\frac{0.2-1.0}{\omega/1=0.49}$ n=35		
Minimum lacuna width	3-8 w=5.33 n=45	· · · ·	
Corallite . Length	2.4-3.1 1=2.72 n=44		2.2
Corallite wid th	$\frac{1.8-2.2}{w=2.04}$ n=44		1.9
Corallite w/l	$\frac{0.64-0.87}{w/\overline{1}=0.74}$ n=44		0.86
Corallite width @ margin (wm)	1.25-1.7 wm=1.48 n=56		1.6
Corallite width @ center (wc)	1.8-2.2 wc=2.02 n=56		1.9

TABLE 31.--Biometrics of hypotypes of <u>Catenipora</u> rubra

TABLE 31. -- Continued

Specimen	UND Cat. No.	13763	UND Cat. No. 13763	GSC 10896, 10897
wm/wc	0.64-0.88 wm/wc=0.72 n=56			0.84
Lateral wall thickness (wt)	0.24-0.35 $\bar{t}=0.29$ n=34			thin
Lumen width (1w)	1.3-1.6 w=1.46 n=51			
wt/lw	0.2			
Lumen length	2.0-2.8 Î=2.35 n=51		• .	an an an an Arrange. An an Arrange
Lumen w/l	0.5-0.73 w/l=0.62 n=51			
Common wall width (L to rank)	0.48-0.74 w=0.61 n=34			
Common wall length (¦ to rank)	0.3-0.5 1=0.4 n=34			
Common wall 1/w	0.4-0.83 $\overline{1}/\overline{w}=0.65$ n=34			
Septal spine length	0.12-0.4 1=0.27 n=73			
Tabular spacing	0.24-1.5 š=0.9 n=124			

TABLE 32.--Biometrics of two hypotypes of <u>Catenipora</u> sp.

S	pecimen	UND Cat. No. 13572	UND Cat. No.	13573
	iameter	1.7-2.7 d=2.26 n=26	1.6-2.5 d=1.97	
	close"	0.3-0.62 s=0.44 n=5	0.4-0.54 s=0.45 n=8	
	wide"	0.56-1.2 s=0.81 n=28	0.55-0.9 $\overline{s}=0.71$ n=26	

TABLE 33.--Biometrics of holotype, paratype, and hypotype of <u>Palaeophyllum</u> argus

Specimen	Holotype, GSC No. 6878	Hypotype, UND Cat. No. 13704
	Paratype, GSC No. 6877 (Sinclair, 1961)	
Corallum width		>3.7 cm (fragmental)
Corallum height	ll cm	>1.5 cm (fragmental)
Corallite diameter	57	7.0-8.3 d=7.7 n=3
Corallite wall thickness		0.2 n=5
Major septa per corallite	20	20-21 n=3
Major septal length	to corallite center	1.65-3.0 1=2.56 n=14
Major septal extension		0.58-0.92 rad ē=0.77 rad n=14
Minor septa per corallite		20 n=1
Minor septal length		0.16-0.2 1=0.18 n=2
Minor septal extension		0.05 rad
Tabular spacing	0.83	indet.

Species	Palaeophyllum pasense	Palaeophyllum pasense	Palaeophyllum sinclairi n. sp.
Specimen	Holotype, GSC No. 10403	Hypotype, UND Cat. No. 13705	Holotype, UND Cat. No. 13706
Corallum form	fasciculate cateniform	cateniform	cateniform
Corallum w, 1	8 cm	14x14 cm (est.)	9x10 cm
Corallum height		5.0 cm	5.0 cm
Corallite diameter (immature)		2.2 n=1	1.7-2.7 d=2.2 n=14
Corallite diameter (mature)	3.0-4.5	2.6-4.6 $\overline{d}=3.44$ n=37	2.46-4.6 d=3.56 n=60
Major or minor septa per corallite	15	13-17 n=15.5 n=16	14-17 n=15.36 n=25
Major septa length, retreated position	not joined at center	0.68-1.9 1=1.25 n=29	0.45-1.8 1=1.06 retreat nearly absent n=10
Major septal extension, retreated position		0.37-0.82 rad e=0.6 rad n=29	0.3-0.92 rad e=0.59 rad n=10
Minor septal length	ridges	0.3-0.7 1=0.41 n=28	0.1-0.5 1=0.32 n=30
Minor septal extension		0.12-0.33 rad ē=0.2 rad n=28	0.03-0.25 rad e=0.15 rad n=30
Outer wall thickness	х - г	0.13-0.3 t=0.2 n=14	0.1-0.35 E =0.2 n=49

TABLE 34.--Biometrics of the holotype and a hypotype of <u>Palaeophyllum</u> pasense Stearn and the holotype of <u>P. sinclairi</u> n. sp.

TABLE 34. -- Continued

Specimen	GSC No. 10403	UND Cat. No. 13705	UND Cat. No. 13706
Epithecal thickness		0.02 n=4	0.02-0.06 t=0.03 n=20
Common wall thickness		0.23-0.32 t=0.26 n=8	0.2-0.35 Ē=0.27 n=16
Axial plate thickness		0.02 n=4	0.02-0.03 n=9
Wall fiber orientation		20°-74° 0 =48° n=20	35 ⁰ 68 ⁰ ⊕=54 ⁰ n=22
Stereoplasm fiber orientation		134 ⁰	119 [°] -161 [°] 0 =138 [°] n=16
Tabular spacing, "close"	0.07(?)	0.32-0.95 s=0.59 n=25	0.16-0.62 s=0.42 n=32
Tabular spacing, "wide"		0.7-1.7 s=1.23 n=21	0.5-1.1 s=0.74 n=28
Tabular form	flat w/down- turned margins	broad, flat central platform	rounded central platform, highly developed
Tabular platform width		1.6-2.1 w=1.86 n=11	0.6-1.7 w=1.35 n=16
Tabular platform width	•	0.4-0.68 dia w=0.52 dia n=11	0.26-0.65 dia w=0.45 dia n=16

Specimen	Hypotype, USNM 81976 (Flower, 1961)	Hypotype, UND Cat. No. 13707	Hypotype, UND Cat. No. 13708	Hypotype, UND Cat. No. 13709	Hypotype, UND Cat. No. 13710
Corallum w, h		150x737 (fragment)	>140x>50 (fragment)	>100x > 60 (fragment)	> 100x > 50 (fragment)
Corallite diameter	4.0, 4.5, rarely 5.0	3.6-5.2 d=4.32 n=41	3.2-5,9 d=4.36 n=39	2.6-5.4 ā=3.87 n=46	2.8-4.4 d=3.66 n=37
Major and minor septa per corallite	11-12	10 n=10 n=11	10-11 n=10.1 n=15	9-10 n=9.9 n=11	10-11 n=10 n=7
Maximum length, major septa	<u><u></u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u>	1.15-1.9 ī=1.49 n=10	1.25-1.35 1=1.18 n=8	0.6-1.0 1=0.8 n=3	1.0-1.9 1=1.68 n=17
Extension of major septa		0.49-0.9 ē=0.7 rad n=10	0.6-0.66 ē=0.62 rad n=8	0.44-0.63 ē=0.54 rad n=3	0.53-0.97 e=0.77 rad n=19
Major septa between tabulae	continuous	continuous	continuous	continuous	continuous
Length, minor septa	very short	0.04-0.11 1=0.11 n=60	0.06-0.3 1=0.14 n=62	0.05-0.22 1=0.11 n=80	0.08-0.34 1=0.19 n=43

TABLE 35.--Biometrics of hypotypes of <u>Crenulites rigidus</u>

TABLE 35. -- Continued

Specimen	USNM 81976	UND Cat. No. 13707	UND Cat. No. 13708	UND Cat. No. 13709	UND Cat. No. 13710
Tabular spacing, non-zoned			0.7-2.0 s=1.25 n=110		
Tabular spacing, "close"	0.8-1.0	0.6-1.8 s=1.47 n=31		0.12-1.16 s=0.53 n=32	0.27-1.2 s=0.67 n=90
Tabular spacing, "wide"	1.4-1.6	1.8-2.8 s=2.26 n=35		0.6-1.95 s=1.39 n=32	0.55-1.6 s=1.12 n=68

TABLE 36 .-- Biometrics of the holotype, paratypes, and hypotypes of Crenulites duncanae

Specimen	Holotype, NMBM No. 671; paratypes, NMBM Nos. 672, 673	Hypotype, UND Cat. No. 13717	Hypotype, UND Cat. No. 13718	Hypotype, UND Cat. No. 13719	Mean of all <u>C. duncanae</u> @ Garson	Hypotype, UND Cat. No 13725
Corallum w, l	12x18 cm			12.5 cm (w)		
Corallum height				4 cm		
Corallite diameter	3.0-4.0	1.8-3.2 d=2.47 n=73	2.1-3.4 d=2.69 n=93	2.1-3.5 d=2.73 n=50	1.8-3.5 d=2.64 n=216	1.4-3.8 d=2.49 n=32
Major septa per corall- ite	8-12	10 n=10 counts	10-11 n=10 n=25 (equal # of minor septa)	10-11 n=10 n=12 (equal # of minor septa)	10-11 n=10 n=47 (equal # of minor septa)	maximum of 10 (equal # of minor septa
Length, major septa on tab- ular surface		0.6-1.38 1=1.0 n=30	Q.84-1.48 1=1.1 n=24	0.66-1.28 1=1.05 n=15	0.6-1.48 1=1.05 n=69	0.55-1.4 1=0.93 n=8
Extension, maj- or septa on tab- ular surface		0.74-1.0 rad ē=0.88 rad n=30	0.6-1.0 rad ē=0.8 rad n=24	0.66-1.0 rad ē=0.84 rad n=15	0.6-1.0 rad ē=0.84 rad u=69	0.42-0.84 ē=0.68 u=8
Length, minor septa on tab- ular surface	"not seen"		0.14-0.55 1=0.35 n=21	0.15-0.26 I=0.2 n=9	0.14-0.55 1=0.31 n=30	

TABLE 36.--Continued

Specimen	NMBM Nos. 671-3	UND Cat No. 13717	UND Cat. No. 13718	UND Cat. No. 13719	<u>C. duncanae</u> at Garson	UND Cat. No. 13725
Extension, minor septa on tabular surface			0.12-0.35 rad ē=0.25 rad n=21	0.11-0.2 rad e=0.16 rad n=9	0.11-0.35 rad e=0.22 rad n=30	
Length, minor septa off tabula surface	r	0.07-0.28 1=0.18 n=73	0.04-0.32 1=0.11 n=65	0.08-0.26 I=0.16 n=61	0.04-0.32 1=0.15 n=199	
Tabular spacing, "close"	0.35-0.5	0.12-0.5 s=0.32 n=32	0.16-0.62 s=0.45 n=54	0.18-0.5 s=0.39 n=32	0.12-0.62 $\overline{s}=0.4$ n=118	0.18-0.65 s=0.34 n=29
Tabular spacing, "wide"	0.5-0.62	0.5-2.1 s=0.75 n=34	0.6-1.7 s=1.13 n=61	0.35-0.95 s=0.66 n=32	0.35-2.1 s=0.91 n=127	0.54-1.9 s=1.09 n=36

 Specimen	Holotype, UND Cat. No. 13727	
Corallum w, 1	11x17 cm	
Corallum height	8 cm	
Corallite diameter	1.7-5.8 d=3.56 n=69	
Major septa per corallite	10-16 n=20	
Minor septa per corallite	10-16 n=20	
Major septa, maxímum retreat	0.42-0.86 rad e=0.7 rad n=36	
Major septa length	0.8-2.3 n=36	
Minor septa extension	0.06-0.14 rad ē=0.09 n=27	
Minor septa length	0.1-0.04 1=0.22 n=27	
Wall thickness	0.14-0.28 E=0.21 n=26	
Fiber orientation	$45^{\circ} - 80^{\circ}$ $\overline{\Theta} = 60^{\circ}$	
Axial plate thickness	0.02-0.04 t=0.03 n=19	
Tabular spacing, "close"	0.5-1.1 s=0.83 n=40	
Tabular spacing, "wide"	1.04-2.3 s=1.37 n=48	

TABLE 37.--Biometrics of the holotype of Cyathophylloides hollandi n. sp.

Specimen	Hypotypes, GSC Nos. 10409, 12866 (Stearn, 1956)	Hypotype, UND Cat. No. 13635	Hypotype, UND Cat. No. 13636
Corallum form	fasciculate w/ radiating corallites	phaceloid w/ parallel corallites	phaceloid w/ radiating corallites
Corallum w, l		3.0x6.0 cm (fragmental)	3.5x2.0 cm (fragmental)
Corallum height		3.0 cm	2.7 cm
Corallite diameter	2-3	1.8-4.4 ā=3.0 n=25	1.6-2.5 d=2.1
Center-to- center corallite spacing		2.4-5.2 s=3.94 s=1.3 dia n=26	· .
Wall thickness		0.12-0.23 t=0.19 n=10	0.14-0.24 t=0.19 n=3
Septal spine spacing		0.25-0.8 s=0.4 n=28	0.2-0.32 s=0.26 n=6
Tabular spacing, "close"	0.71	0.3-1.6 $\bar{s}=1.0$ n=43	0.2-0.8 s=0.52 n=13
Tabular spacing, "wide"	· .	1.2-2.8 s=2.16 n=26	0.6-1.5 s=0.96 n=9

TABLE 38.--Biometrics of hypotypes of Tryplasma gracilis

APPENDIX C

GLOSSARY OF MORPHOLOGICAL TERMS

APPENDIX C

CLOSSARY OF MORPHOLOGICAL TERMS

The following specialized terms are defined in order to minimize confusion as to their usage in this study. For the reader's convenience, definitions of earlier workers are included in cases where I completely agree with their previous usage.

- ACANTHINE SEPTUM: "Type composed of a vertical or steeply inclined series of trabeculae and commonly marked by spinose projections along axially directed margin of septum" (Moore, Hill, and Wells, 1956, p. F245).
- ACCLUTINATIVE PATCHES: Groupings of cerioid corallites in portions of a corallum interconnected by ranks of cateniform corallites. Occurring in Manipora, Catenipora, and Palaeophyllum.
- ALVEOLITID CORALLITE: "Type of reclined corallite having a vaulted convex upper wall and nearly plane lower one parallel to surface of adherance of colony as in <u>Alveolites</u>" (Moore, Hill, and Wells, 1956, p. F245).
- ANGULATE CORALLUM: Keel-like or lobate projection along the traces of cardinal or alar septa on solitary rugose coralla as in <u>Grewingkia</u>, <u>Lobocorallium</u>, <u>Dieracorallium</u>, and <u>Bighornia</u>.

ASEPTATE: Lack of septa within a corallite or solitary corallum.

- AXIAL PLANE: Central plane of sclerenchymal fiber abuttment in a planar structure such as a fibrous corallite wall or septum. "Planes with no real structure and no real thickness. In longitudinal section the change in direction of the fibers marks the plane" (Flower, 1961, p. 26).
- AXIAL PLATE: Central plate at the center of a planar feature such as a fibrous rugosan wall of uncertain microstructure separating two flanking fibrous sclerenchymal layers (Flower, 1961, p. 28), probably homologous to an epitheca.
- BACULUS (pl. BACULI): Closely packed and polygonal, monacanthine, trabecula (Flower, 1961, p. 28) comprising a structural element in the corallite wall of some cerioid tabulate genera.

- BALKEN: Polygonal, monacanthine trabeculae forming the common, intercorallite wall in <u>Catenipora</u>. Buehler (1955, p. 10) said they are "Circular oval rods or 'balken' which occur in the intercorallite walls."
- CALCEOLID: "Solitary corallite shaped like the tip of a pointed slipper, as in <u>Calceola</u> and <u>Bighornia</u> patella with angulated edges between flattened and rounded sides" (Moore, Hill, and Wells, 1956, p. F246).

CALICINAL: Of or pertaining to the calyx.

CALICE: See calyx.

- CALYX (=CALICE): The cup- or bowl-shaped distal surface of a corallite or solitary corallum.
- CATENIFORM: "Corallum with corallites united laterally as palisades which appear chainlike in cross section, the palisades commonly forming a network" (Moore, Hill, and Wells, 1956, p. F246).
- COENENCHYME: "Collective term for both coenosteum and coenosarc" (Moore, Hill, and Wells, 1956, p. F246).

COENENCHYMAL: Of or pertaining to the coenenchyme.

COENOSARC: "Common soft tissue connecting coral polyps in a colony" (Moore, Hill, and Wells, 1956, p. F246).

COENOSTEAL: Of or pertaining to the coenosteum.

- COENOSTEUM: "Skeletal deposits formed between individual corallites of a colony" (Moore, Hill, and Wells, 1956, p. F246).
- COMMON WALL: Trabecular wall between two adjacent corallites in a cateniform rank. Used by Elower (1961, p. 45) to denote the undulate walls flanking cateniform ranks. Flower's common wall is referred to herein as a lateral wall.

CONCAVE: Curved toward the proximal point of a corallum.

CONVEX: Curved toward the distal corallum surface.

CORALLITE CORNER: Angle between two sides of a polygonal corallite in a cerioid corallum.

CORALLUM ANGLE: Angle between the cardinal and counter sides of a solitary corallum.

COSTA (pl. COSTAE): Longitudinal element comparable to a septum but radiating from the corallite into the coenenchymal region in Calapoecia.

- CRENULATION: A rounded projection of zig-zag or undulatory walls in the corallite corners of some species of <u>Paleofavosites</u> and tabular peripheral margins in Crenulites.
- DISTAL: Of or pertaining to the calicinal ("upper") end or surface of a corallite or corallum.
- EPITHECA: "Sheath of skeletal tissue laterally surrounding a corallite or corallum comprising extension of basal plate" (Moore, Hill, and Wells, 1956, p. F247). A homologue of the axial plate, an axial plate, an analogue of the holotheca.
- FIBROUS WALL: Wall in which two sclerenchymal layers abut each other along an axial plane. The most primitive type of wall, as in Lichenaria (the Lichenaria-type wall).
- HOLOTHECA: A layer of skeletal material enclosing an entire halysitoid colony (Flower, 1961, p. 24). Analogous to an epitheca.
- LATERAL WALL: One of two undulatory walls flanking a cateniform rank (Flower's 1961 common wall). Consists of an outer holothecal layer and an inner sclerenchymal layer.

LICHENARIA-TYPE WALL: See fibrous wall.

- LOPHOPHYLLIDIID COLUMELLA: A columella, as in Lophophyllidium, formed by dilation of the axial end of the counter septum.
- MAJOR SEPTUM: "One of the protosepta or metasepta" (Moore, Hill, and Wells, 1956, p. F248).
- MINOR SEPTUM: One of the relatively short septa inserted between adjacent major septa.
- MONACANTHINE: Descriptive term for a simple trabecula in which component fibers are centered around one center of formation (Moore, Hill, and Wells, 1956, p. F249).
- MONILIFORM: The resultant outline of a cateniform rank of oval corallites, resembling a string of beads in transverse profile.
- MULTICORALLITE WALL: A cerioid corallite wall extending among several corallites and characterized by rounded corallite corners, gently curved between corners. Represents a frontal advance of several budded polyps during intermural increase (occurring in several species of Paleofavosites).
- MULTITRABECULAR: A term coined by Kato (1963, p. 587) to denote solitary rugosan septa in which numerous trabecular centers are distributed throughout the thickness of the septa.

PLANAR: Lack of curvature in a surface, "flat".

- POIKILOPLASMA: A deposit of light calcitic material filled with tiny, dark granules. It is found attached to the inner surface of walls and septa and on the anterior distal surfaces of tabulae (Flower, 1961, p. 29).
- PORAL PROCESS: Raised rim around a mural pore as in <u>Paleofavosites</u> (Hill, 1959).
- PROTOSEPTUM: "One of six first-formed septa of a corallite" (Moore, Hill, and Wells, 1956, p. F250). "The cardinal and counter septa" (Wright, 1969, p. 1232).
- PROXIMAL: Of or pertaining to the basal or apical ("lower") portion of a corallite or corallum.
- PUSTULE: The rounded-conical, distal, termination of a monacanthine trabecula as in Coccoseris and Protrochischolithus.
- RHABDACANTH: "Trabecula characterized by shifting centers of fibrous growth grouped around a main one" (Moore, Hill, and Wells, 1956, p. F250).
- RUGOSAN WALL: A cerioid corallite wall in which the sclerenchymal fibers of the individual corallites are separated by an axial plate (Flower, 1961, p. 28).

SCLERENCHYMAL: Of or pertaining to the sclerenchyme.

- SCLERENCHYME: A skeletal layer flanking the axial plane and axial plate in walls and septa. Composed of fibers inclined distally and away from the planes and plates.
- SEPTAL TRACE: The longitudinal line on a solitary corallum exterior reflecting the peripheral margins of septa. Principally referring to the cardinal, alar, and counter septa in this study.
- SEPTOTHECA: "Corallite wall formed by thickened outer parts of septa along axis of trabecular divergence" (Moore, Hill, and Wells, 1956, p. F256).
- STEREOZONE: "Area of dense skeletal deposits in a corallite or solitary corallum, generally peripheral or subperipheral in position" (Moore, Hill, and Wells, 1956, p. F250).
- TRABECULA (pl. TRABECULAE): "Pillar or rod of radiating calcareous fibers comprising skeletal element in structure of septum and related components" (Moore, Hill, and Wells, 1956, p. 251).

- TRABECULAR WALL: Cerioid corallite wall composed of parallel, longitudinal monacanthine trabeculae as in <u>Trabeculites</u>, <u>Nyctopora</u>, and <u>Calapoecia</u>.
- UNITRABECULAR: A term coined by Kato (1963, p. 587) to denote solitary rugosan septa in which trabecular centers are situated in the septal plane and the septal sides are planar.

APPENDIX D

BIOMETRIC METHODS AND SYMBOLS

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BIOMETRIC METHODS AND SYMBOLS

To minimize errors from differing methods of measurement it is necessary that the methods be stated. Symbols and biometric terms employed in the systematic descriptions, figures, and biometric tables are defined.

- ABSOLUTE SIZE: The expression of the dimensions of a structure in the metric system.
- CORALLITE DIAMETER: In polygonal cerioid corallites with an odd number of sides, the length of a line measured from the center of a polygonal face, across the corallite axis to the corallite corner. In polygonal corallites with an even number of sides, the length of a line measured from the center of a face across the axis to the center of a face on the opposite side. In cylindrical colonial corallites or solitary coralla with a circular transverse profile, the diameter line.
- CORALLUM HEIGHT: Colonial coralla--the distance from the proximal to the distal surfaces; solitary coralla with noncircular transverse outlines--the distance normal to the substrate when the corallum is in stable rest position. In <u>Grewingkia</u>, <u>Lobocorallium</u>, and <u>Dieracorallium</u>, measured between the traces of the alar septa; in <u>Bighornia</u>, measured between the cardinal and counter septal traces. Expressed in terms of absolute and relative size.
- CORALLUM WIDTH: In colonial coralla; the shortest distance parallel to the substrate surface. In solitary coralla with noncircular transverse profiles; the distance parallel to the substrate with the corallum in stable rest position. In <u>Grewingkia</u>, <u>Lobocorallium</u>, and <u>Dieracorallium</u>; measured between the traces of the alar septa. Expressed in absolute and relative terms.
- CRENULATION AMPLITUDE: The distance between the opposite peaks of a crenulate structure, normal to the direction of the crenulate feature. Expressed in absolute or relative terms.
- CRENULATION LENGTH: The distance between alternate peaks of a crenulate structure, parallel to the trend of the structure. Expressed in absolute terms.

- EXTENSION: The relative length of a radiating structure such as a septum or septa. Expressed in terms of relative measurement, usually radius (rad.).
- FIBER ORIENTATION: The deflection in degrees of the long axis of a skeletal fiber from the corallite axis or plane of the structure.
- HEIGHT (h): The height of a structure, parallel to the corallite axis. Expressed in absolute terms.
- LENGTH (1): The length of a structure, expressed in absolute terms.
- NUMBER OF COUNTS (n): The number of counts taken of a corallum structure in order to establish the characteristics of a taxon.
- RADIUS (rad.): A term of relative measurement in which the dimension of a structure is expressed as a multiple of the corallite or corallum radius.
- RELATIVE SIZE: The size of a structure measured in proportion to a related independent variable.
- SPACING (s): Transverse (center-to-center) spacing of a structure, expressed in absolute and relative terms, longitudinal spacing of structures, expressed in absolute terms.
- TABULAR SPACING: Measured along the central axis of a corallite or solitary corallum. Expressed in absolute terms.
- THICKNESS (t): Thickness of a structure. Expressed in absolute or relative terms.
- WALL THICKNESS: In cerioid corallites measured as the distance from the interior surfaces of the sclerenchymal layer of each adjacent corallite pair. In other colonial corallites and solitary coralla, as the distance between the epitheca and the inner surface of the sclerenchymal layer or stereozone. Expressed in absolute or relative terms.

WIDTH/HEIGHT (w/h): The ratio of width to height of a structure.

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