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PART I
Montoya and Related Colonial Corals

PART II
Organisms Attached to Montoya Corals

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TEXT SECTION

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PART I

MONTOYA AND RELATED COLONIAL CORALS

Abstract

Twenty-seven species are described from the Montoya group of New Mexico, 17 from the Second Value formation, 6 from the Aleman, and 5 from the Cutter, 1 species being common to the Aleman and the Cutter. Only four species have been described previously; the others are new. Four species are not determined specifically. One Aleman species is tentatively identified in the Cutter; others are distinct for the three formations. Two new genera, *Crenulites* and *Trabeculites,* are described. Species from other regions described and discussed, and in some cases revised, include five species of *Favistina, Protrochiscolithus magnus,* and *Saffordophyllum crenulatum,* three of *Crenulites,* one of *Trabeculites,* and two assigned to *Foerstephyllum.*

Regional analysis strengthens the Red River affinities of the Second Value formation and the Richmond equivalence of the Aleman and Cutter formations, but fuller evaluation must await more precise study of corals of other Ordovician faunas, particularly in western and northern North America.

Revised concepts of morphology and relationship are required, notably the derivation of septa as secondary structures from a primitive wall, and the primitive nature of a simple fibrous wall from which are derived trabecular walls on the one hand and walls with an axial plate on the other, the axial plate developing both into the "primary wall" of the higher Favositidae, and into the epitheca of the rugosan types. The present study fails completely to support division of these corals into Tabulata and Rugosa, but it is felt that alternate proposals would be premature. A new structure, poikiloplasm, is described, which may line corallites, be concentrated as spherical knobs, with or without a thin connection, or form groups of discrete spheres.

A summary is appended, briefly summarizing characters by which the Montoya species can be differentiated readily.

Introduction

This is a study of the colonial corals of the Montoya group. When the Montoya was considered as a formation, the early indications (Richardson, 1908) of the presence of a succession of distinct faunas were largely ignored. With recognition in the Montoya group of several formations, and with reason to believe that a considerable interval of erosion separated the Second Value deposits from overlying Richmond beds, the need to take the stratigraphic range of various fossil groups into account becomes apparent at once. The material on which this study is based is, except for two specimens, of precisely known stratigraphic origin.

Several circumstances have combined to bring attention to the corals. They are locally abundant in several horizons of the Montoya, the large size of the colonies making them conspicuous constituents of the faunas. Some years ago it was generally believed that Ordovician corals involved relatively few species, regarded as having wide, if somewhat vaguely understood, limits of variation; that the species were widely, if erratically, distributed; and that one could hardly hope that their study would result in conclusions particularly meaningful faunally or stratigraphically. With more precise and more recent work, it has come to be realized that this view involves specific concepts that are much too broad. Dorothy Hill (1951) was able to summarize the significant sequences of Ordovician coral faunas on a worldwide basis.

Bassler (1950) brought together faunal lists, with necessary taxonomic revisions, clarifying some of the older species and adding some new ones, and this work did much to alleviate the confusion that has surrounded many of the American Ordovician corals. Dorothy Hill (1959) presented a careful and accurate study on some corals from the Montoya group. The main basis for this study was a coral collection made from an outlier of the Montoya, the presence of which had not been suspected previously, near Morenci, Arizona. Some additional material from our collections from the typical Montoya of New Mexico was included, but there was little reason to hope that the few specimens were representative taxonomically, and they were not particularly well preserved. The study served to emphasize the need for more information on the Montoya corals, and to this end a special effort was made in further collecting to obtain more and better material.

When such material was at hand, it remained to find someone to study it. Dr. Hill was then engaged on other studies and could not give these specimens early attention. Further, colonies were large and heavy, and sending them to Queensland for study posed some vexing problems. I next turned to Miss Helen Duncan, whose knowledge of the corals of western North America is probably unequaled. Other duties have prohibited her from undertaking the study of the colonial forms, but she hopes to include the solitary forms with others from western North American occurrences in a work of wider geographic scope. Both Miss Duncan and Dr. Hill suggested that I undertake the study of the colonial forms myself. It is in the Ordovician that the corals first develop diversity and become significant constituents of the faunas. Not very many species have been described, and I accepted the suggestion, thinking that these forms could not be very complicated. How wrong I was is shown by the various devious byways into which this study digressed.

The local aspects of the study could be accomplished without great difficulty. The material on which it was based was of precisely known stratigraphic origin. Although some 400 thinsections were made before the study was completed, with a view toward exploring variation within colonies and among different colonies of a species, the recognition of species and determination of the contrasts among the corals of the three main formations involved was not in itself a very difficult matter.

A study of this kind is expected to yield more than information on the local species and their stratigraphic ranges. One would hope to make significant comparisons with corals in contemporaneous or supposedly contemporaneous formations in other regions. Suitable comparative material from such sections is lacking, and published information has proved largely inadequate. For some sections, as those of the Fremont and Bighorn formations, the only available information is in faunal lists. One can never be sure that such lists were based upon collections in which the corals were properly represented, particularly since for years the corals were considered "no good" in the Ordovician, and even the collecting of specimens was regarded as an act of pure virtue from which no material benefit could evolve, rather like visiting an ailing poor relation. Determinations in such lists are often casual, as shown by the frequent citation of species that cannot be identified with certainty. For some formations, collections were made without adequate stratigraphic control. Sadly, the most thorough study of comparable corals, that of Troedsson (1929) for the Cape Calhoun formation, contains no indication of ranges of species within that interval. If significant comparisons cannot be made in the present work, it is some consolation that when closer studies are made of the corals of related formations and faunas, the present work may make such comparisons possible.

The main difficulties in the present study were encountered in the investigation of previously described species. A generation ago it was possible to "know" all the described species of the Ordovician, at least of North America. The convention exists that before a new species is described it be compared with every known species in the genus. In the corals, one is confronted by a considerable number of species described long ago, defined only in the most general terms, and so poorly known that the specific characters are doubtful and questions exist even as to their generic position. In the strict sense, the description of new materials should be preceded by proper investigation of these earlier described species. This can be done only from a restudy of types or, where types have been lost, by the study and designation of neotype material. At the very least, this would have required the borrowing of types, with permission to study them by sections, and would have extended the present study by 3 or 4 years. But it is rarely that simple in practice. Some institutions refuse to lend types, and the types involved are in repositories located in Washington, New York, Ottawa, London, Bonn, Copenhagen, and possibly Chicago and Berlin; moreover, examination of additional material in Oslo and Stockholm would have been helpful. Even had such travel been practical in terms of time and expense, there was no assurance that the results would have been successful.

In connection with the investigation of cephalopod types, the writer has found two major institutions that decline to lend types; they had, moreover, at least at the time of inquiry, no facilities for making the requisite sections, and it was even impossible to obtain photographs of the types. In some ways it would be simpler were the types irretrievably lost, for then one could proceed with neotype material; with known types extant but shielded from proper investigation, one can only wait for improved facilities or a reversal of the policy forbidding the loan of such material.

The type specimens would not have been necessarily an end; comparative material from type and other localities would have been required, and the end result would have been an extension of the present study into something very close to completing the revision of the North American Ordovician corals already so ably begun by Bassler (1950). Proper regard for priority would dictate such extension of the present work, or else delay publication on the Montoya corals until such work had been done by others. It is questionable, however, whether such strict regard for priority of names advances or retards paleontology.

Although the proper names to be applied to species may be dependent upon types, correlation is still possible, wherever comparative material is available, and such material will show whether, for example, our Montoya *Favistina* is distinguishable from one at Madison, Indiana, which has been called *F. stellata,* even though there may be some question as to the proper scope of that species. Thus, in a sense, meaningful comparisons with actual material, or with adequate descriptions and figures, such as are presented by Troedsson (1929) or Stearn (1956), are possible, while at the same time the nomenclatorial chaos in which some of the species are involved is bypassed. Vexingly, almost every one of the older, long-accepted species to which attention was directed in the present work yielded some perplexing problem. *Foerstephyllum,* in the Black River, is generally accepted as one species, but comparative material suggests that at least three are present there. The *Favistella* of the Richmond of the Cincinnati region possibly contains two species. The types of *Favistella alveolata interventa* contain representatives of three genera and three species. Saki (H. H. Munro, Viking Press, New York, 1930) in his "Discourses of Moung Ka" draws a distinction between what is a democracy and what is called a democracy. We have been forced to approach many of the older coral species in the same spirit; we cannot, for example, know what *Columnaria franklini* of Salter is without restudy of the type, but we do know what Troedsson (1929) described and figured under that specific name, and can, from this, make meaningful comparison with a species, whether properly named or not, in the Cape Calhoun faunas. Many other generally accepted specific determinations require treatment with similar reservations.

In the early stages of this investigation, it was resolved to confine attention at the specific and generic level to local materials, but this resolve crumbled gradually under repeated temptations. Recognition of poikiloplasm, a material formed within corallites and distinct from the fibrous walls, required extensions of the study to note and illustrate the material in some forms outside the Montoya group. Indeed, were it not for practical difficulties, such illustrations would have been carried farther; they were not, simply because when it was finally resolved to include such figures, the needed slides in the U.S. National Museum could not be identified with certainty, and I hesitated to ask for the loan of extensive material of this sort in view of its fragility. Need for more information on the structure of *Protrochiscolithus* led to the examination of sections of a specimen of *P. magnus* (Whiteaves) from Manitoba, which I had happened to collect merely because it was encrusting a cephalopod, and the results were too significant to be omitted, contributing as this form did to the recognition of vesicular columellas in some species and bacular columellas in others.

The new genus *Crenulites* was first known from two species from the Second Value formation. Examination of sections in the U.S. National Museum confirmed the previous suspicion that *Cyathophylloides ulrichi* was a member of the genus, and brought to light two other occurrences, previously unsuspected, one from Snake Island, Lake St. John, Quebec, and one from Akpatok Island, Ungava Bay, about 200 miles south of Baffin Island. It seemed desirable to add descriptions and figures of these forms, but each was involved in problems. The Lake St. John form is probably what Billings (1858) described as *Columnaria rigida,* and I have assigned it to that species; however, without sections of the original types, one cannot be certain that the assignment is correct. The other form, from Akpatok Island, was represented in the National Museum collection by only two thinsections; although these were adequate for recognition of the species, it seemed desirable to have something more for the type of a new species. A little detective work in the literature revealed that a possible source of this material was a collection made in 1931 on the Oxford Expedition to the Arctic Straits, and that the collections from Akpatok Island were not at Oxford, as one might expect, but in the Sedgewick Museum at Cambridge. Inquiry concerning this form and some other matters directed to Dr. O. M. B. Bulman resulted in almost astonishingly prompt and extensive cooperation. Selected specimens of *Calapoecia,* which had been studied by Cox, were sent. All unworked cerioid corals were sectioned, thus reducing the labor involved in their investigation, and lent for study, together with all possible information as to horizon, locality, and associated faunas at the various horizons. The material yielded adequate material of the new *Crenulites,* and indicated most strongly that the two slides of the U.S. National Museum were made from two different colonies in this material. The collection also yielded a second specimen of the new genus *Trabeculites,* and two additional forms strengthening the already indicated close connection between *Foerstephyllum* of the *vacuum* type and species, typical and atypical, that have been included in the genus *Paleofavosites.*

It was this last discovery that made it necessary to abandon the original determination that the present investigation would avoid questions of fundamental fine structures and relationships. It was felt that with practically no previous experience on these corals, the writer could hardly expect to evaluate fine structures with certainty or to pronounce upon relationships from the observation of materials limited in geographic and stratigraphic scope. These questions, however, could not now be avoided.

Discovery of pores in *Saffordophyllum* had indicated that it was a member of the Favositidae; further, as the oldest genus of the family, it might well be the archaic radical of the family from which more advanced types evolved. However, transitional forms now seemed to connect *Paleofavosites* with *Foerstephyllum.* Both origins could hardly be true, unless the favositids were morphologically convergent forms of two distinct lineages. Investigations of wall structure were required, and had, indeed, been necessary for some other problems, notably the distinctions between the fibrous *Saffordophyllum,* the trabecular *Nyctopora,* and the intermediate condition found in *Trabeculites.* The end result was development of a concept of relationships of these genera, presented in detail below.

This matter had still further implications, for if the present conclusions are at all correct—and I would suggest that they be tested with much additional material—there is no possible division of the genera involved into two natural groups, the Tabulata and Rugosa, though such a division has long been accepted. Clearly, the present findings are far from complete, but it was felt that progress would best be served by presentation of the evidence and the conclusions, if only that others may be stimulated to further investigations of these matters in the light of additional material.

In the end, illustration and description of material were extended from the limits of the Montoya to various significant species from other parts of the American Ordovician; in particular, significant attention was given to corals of such outliers of the Montoya group as the Richmond of Cincinnati and the Ordovician section of Akpatok Island.

The Montoya materials brought attention to one more devious byway of investigation quite outside the original limits of the study. A number of thinsections showed some peculiar organic remains attached to the outsides of a number of the cateniform and phaceloid corals. No comparable fossils have been described; yet apparently these forms were wide ranging, for sections of the U.S. National Museum collections reveal similar organisms attached to corals in the Ordovician of Oslo, Norway, Gaspé, and Utah. In spite of wide solicitation for suggestions, including appeals to specialists in most major fossil groups, these forms remain of uncertain position, even as to phylum. They are described in Part II of the present memoir, as a separate paper, largely in order that they may not remain buried in the literature. The two studies are illustrated by a combined series of plates, for the photographs showing these strange organisms also show some significant morphological features of the corals to which they are attached.

Like so many other investigations, this one refused to come to any logical end. Before it was finished, I looked with envy upon James Thurber, who states in the preface to his "Thirteen Clocks" how in the end he was making countless small changes in the text, until his editors took it away from him on the grounds that it was finished anyway, and he was only tinkering with clocks and running up and down secret staircases. In bringing the present work to something that might be called completion, I was in need of similar help.

Acknowledgments

Without encouragement, and much constant advice and help, from others more experienced in the study of Ordovician corals, the present work would possibly not have been undertaken and would certainly never have been brought to completion. In particular, I am deeply indebted to Miss Helen Duncan, whose contributions have been so material that I feel she should have been named as a joint author, though I am uncertain that she would endorse some of the present conclusions. The help and guidance provided included information on the scattered coral literature, descriptions of obscure species, information on ambiguities of morphology and morphological terminology, discussion of specific and generic problems, and questions of fine structure and relationships. Such discussion involved voluminous correspondence, and several conferences, and when opportunity came for the writer to visit the National Museum and compare thinsections with those in the collections there, Miss Duncan gave generously of her time and joined me in making the requisite comparisons, a task that consumed a little better than a week of concentrated effort.

For additional aid I am indebted to Dr. Dorothy Hill and Dr. J. W. Wells; such aid ranged from information on some obscure literature that I might otherwise have overlooked, to discussion of matters of relationship, morphological and taxonomic terminology, and interpretation of fine structures.

On two visits to the National Museum, of which the second was devoted to a week of examination of coral materials, I was granted the fullest and most willing cooperation by everyone concerned with the present investigation: Dr. G. A. Cooper and various members of the Museum staff, as well as members of the U.S. Geological Survey, in particular Miss Jean Berdan, Dr. William Oliver, and Dr. Robert Neumann.

Much of the Montoya material that formed the nucleus of the present study was of my own collecting. A large part of the material came from the southern extremity of the Franklin Mountains, at the edge of El Paso, where my wife aided materially in collecting. Dr. Lloyd Pray, who first called attention to the significant coral zone of the Aleman (1958), contributed a significant collection largely of material from that horizon. Dr. Frederick Kuellmer called my attention to the Tank Canyon section at the northern end of the Black Range, and in our joint examination of the section, the rich and unique coral assemblage in a black dolomite of the Cutter was discovered. The specimen that served here as the type of *Protrochiscolithus alemanensis* was lent from the collections of the U.S. Geological Survey, and was first brought to my attention by Miss Duncan.

Without access to the collections of the U.S. National Museum, proper specific comparisons, so necessary for the present work, would not have been possible. When subsequent events indicated the need to figure such material and study it further, the required specimens were lent through the courtesy of Dr. G. A. Cooper.

I have already mentioned the circumstances that led to the inquiry concerning Akpatok Island materials, and the prompt and generous response in lending the needed materials and providing all possible relevant information from records, for which I must express my thanks to Dr. O. M. B. Bulman, to whom my initial inquiry was addressed, and Dr. C. L. Forbes, on whom devolved the responsibility of having sections prepared, lending materials, and supplying the needed additional information from records in the Sedgewick Museum.

Many of my friends and colleagues have generously supplied badly needed comparative materials. Dr. G. M. Kay sent material of *Lichenaria* and *Billingsarea* from the Chazyan of the Champlain Valley. Dr. J. W. Wells contributed some Black River *Foerstephyllum*. Dr. Madeleine A. Fritz sent some material from the significant coral assemblage of Streetsville, Ontario, as well as material from the Lowville of Ottawa that formed the basis for the description and illustration of *Favistina paleophylloides*. Dr. J. J. Galloway, of the University of Indiana, contributed material from the Ordovician of both New York and the Cincinnati region. Other material from Cincinnati was sent from the University of Cincinnati Museum. Badly needed material from the coral beds in the Liberty at Bardstown, Kentucky, was generously sent by Mrs. Ruth Browne, of the University of Louisville. Material from Madison, Indiana, originally from the collection of James Hall, and possibly involved in his description of *Favistella stellata*, was lent from the American Museum of Natural History.

There are many who have made valuable suggestions, either in regard to the corals or to the attached organisms, or both. A full list would probably include most of those concerned with paleontological problems in the National Museum, and should include, in addition to those already mentioned, Dr. Harry Ladd, Dr. Ruth Todd, Dr. Frederick Bayer, Dr. Ray S. Bassler, Dr. Ellis Yokelson, Dr. Robert Neumann, and Dr. R. S. Boardman. Additional suggestions were made by Dr. J. J. Galloway, Dr. K. E. Caster, Dr. E. R. Cumings, and Dr. J. W. Wells. Dr. Alice Wilson provided most generous assistance relating to some of the Ordovician corals from Canada.

For faithful and painstaking assistance in the task of preparing some 400 thinsections involved in the present work, acknowledgment is made to Robert Gale Hicks, for 2 years my student assistant.

One of the great vexations surrounding the study of such corals as those included in the present work is limitation of illustrations, largely induced by considerations of expense. The resultant works necessarily fail to include full discussion or illustration of the variations that may occur within a species. It is, then, the more appropriate to thank Dr. E. J. Workman, president of the New Mexico Institute of Mining and Technology, and Mr. A. J. Thompson, director of the State Bureau of Mines and Mineral Resources, for the encouragement of full illustration rather than the more usual administrative efforts to limit needed illustrations for reasons of economy. Both have given the fullest support to the present investigation.

Dr. E. H. Kase, Jr., in the checking and rechecking involved in editing, has corrected many errors, though our skirmishes as to whether idiosyncrasies of style should reflect the taste of the author or editor have taken a great deal out of both of us. Further editing was done by Dr. John McKee with the assistance of Mrs. Glenda Niccum. The editors are responsible for the form of the bibliography.

The Montoya Group

GENERAL DIVISIONS AND CORRELATIONS

Richardson (1908) differentiated the Montoya as a formation, distinguishing these strata of later Ordovician age from the underlying thin-bedded El Paso of Canadian age, and from the overlying massive Fusselman dolomite of Silurian age. The fossils, as interpreted by Ulrich, were regarded as comprising two distinct faunas, a lower fauna of Galena aspect, and an upper fauna of Richmond aspect. Subsequent discussions of the Montoya tended to minimize the lower Galena fauna or to overlook it completely. Some such discussions centered around exposures in New Mexico, where, under advanced dolomitization, the lower calcitic fauna was obscured or destroyed completely, whereas the upper Richmond fauna, represented by silicified shells, remained prominent. Perhaps also an influencing factor was the belief that the Montoya, as a formation, should be a deposit of uniform age; recognition of a lower Galena fauna involved the implication either that intervening Eden and Maysville beds were wanting through a significant break in deposition, or that they were represented by barren strata, the age of which was therefore not clearly evident.

The first attempt at division of the Montoya was that of Entwistle (1945), who distinguished lower massive dolomite with a basal sand as the Second Value member, overlying cherty dolomites as the Par Value member, and light, dominantly noncherty beds as the Raven member. Kelley and Silver (1952) rejected these divisions as based upon faulted sections in which there was also considerable alteration of the beds. They treated the Montoya as a group with formations, of which the Cable Canyon and Upham correspond to the lower sands and overlying dolomites of the Second Value, and the Aleman and Cutter are defined in the same essential lithic terms as the Par Value and Raven of Entwistle. This course would have seemed more justifiable had their divisions not corresponded so closely to those of Entwistle, and had their type sections been less subject to dolomitization, injection of secondary chert, slight faulting, and major slumping. Pray (1953), working in the Sacramento and southern Franklin mountains, retained the lower dark beds in the Montoya, regarding the Upham-Aleman contact as transitional, but distinguished light dolomites as a distinct Valmont formation, regarding it as distinct from the Montoya on lithic and historical grounds, for in much previous work these dolomites had been grouped with the overlying Fusselman rather than with the underlying Montoya.

Use of lithic criteria alone would leave room for almost endless discussion as to the relative merits of these various divisions, for alteration subsequent to deposition produces varied aspects among the various sections, leading to different interpretations. For example, some sections, notably those of the southern Franklin Mountains, Hueco Mountains, Florida Mountains, and Cooks Range, show a marked contrast between the lower limestones (Second Value or Upham) and the overlying cherty dolomites (Par Value or Aleman). In other sections, advanced dolomitization and injection of secondary silica into the higher beds of the Upham may reduce the contrast between Upham and Aleman lithologies to a point at which the contact is no longer obvious, as in the Sacramento Mountains, Caballo Mountains, and Mud Springs Mountains. By reduction of the contrast between the calcareous sediments, the contrast between the Cable Canyon sandstone and overlying dolomites seems the greater; indeed, it is from examination of such sections that the proposal of the Cable Canyon as a formation evolved. Other sections, however, show the Cable Canyon as grading up into the overlying calcareous beds, and its absence in still other sections suggests that it may only be a local, basal sandy facies of the Second Value. Contrast between the dark cherty beds (Par Value or Aleman) and light noncherty dolomites (Raven or Cutter or Valmont) is more general, but faunal evidence suggests that the transition is not everywhere strictly synchronous.

From lithic criteria alone, it would appear that the relative merits of the various systems involve largely subjective elements, and that differences of opinion as to such appraisals might be the subject of almost interminable discussion. Without additional criteria, priority might well be observed; on that basis, the divisions of Entwistle should be preferred, though with the possible reservation that they be considered formations in a Montoya group, and that division of the Second Value formation into Cable Canyon and Upham members might be desirable and convenient in some sections.

If current trends are to be followed, which recommend only the use of lithic criteria in the recognition of stratigraphic divisions, no better solution is possible; to accept, however, only the lithic criteria, and to reject the evidence of the fossils, is to set arbitrary limits on the criteria of stratigraphic investigation and nomenclature. Such a course might be permissible in a profession, but not in a science, in which all avenues of investigation must remain equally valid, their value to be judged solely on their own merits.

Obviously, the only fundamental basis for classification of sedimentary rocks is provided by the history of their deposition, and this in turn involves serious consideration of the faunal evidence. The writer has attempted the application of such principles to the Montoya group (Flower, 1957). Faunal evidence suggests the Cable Canyon to be only the lower basal sand of a unit of Red River age, and therefore the Second Value formation is recognized with the Cable Canyon and Upham dolomite (or limestone), two members that happen to have been distinguished and given names. Choice between the Par Value and Raven of Entwistle and the Aleman and Cutter of Kelley and Silver is indecisive on lithic criteria alone, and priority might be invoked as the deciding factor. The writer, however, has found evidence suggesting that the lithic transition is not everywhere strictly synchronous. Onlap relations of the Cutter on the Aleman surface suggest a minor depositional break, which seems more closely in accord with the transition in the region of the Aleman and Cutter than in the Silver City region, where the Par Value and Raven were recognized. On this basis, the terms of Kelley and Silver seem slightly preferable for general usage, although Par Value and Raven are clearly better expressions of the mappable units in the Silver City region.

The writer has found the Montoya of New Mexico, the Harding and Fremont of Colorado, the Bighorn of Wyoming, and the Ordovician of Manitoba (Winnipeg, Red River, Stony Mountain, and Stonewall formations) to be remnants of essentially uniform history, once continuous. Their present separation is the result of intervening and subsequent periods of uplift and erosion in which connecting strata have been obliterated. Further, the sequences are uniform in showing three significantly distinct periods of sedimentation separated by appreciable intervals of uplift and erosion.

The first period of sedimentation involves the Harding sandstone of Colorado and the Winnipeg sandstone of southern Manitoba. Only thin, scattered remnants are present in New Mexico, and in the Bighorn region there are local remnants of a sandstone which contain some fish plates, as does the Harding. Subsequent uplift and erosion limited the Harding essentially to its present pattern, as shown by Sweet's (1952) isopach map of the formation, and restricted equivalent sands to essentially their present limits of thickness and distribution. The age limits of these sands are not precisely known, but it is evident from the conodonts (Holland and Waldren, 1955) that the strata are no younger than the Black River and no older than the Chazyan.[1]

Return of the seas resulted in widespread deposits of Red River age; such sediments show an amazing general uniformity of faunas from New Mexico and western Texas north not only to Manitoba, but on to Greenland, completely incompatible with any postulation of equivalent deposits in distinct embayments. Elevation and erosion prior to Richmond deposition followed, again limiting the sediments to discrete basins in southern New Mexico and Texas, the Ordovician basin in Colorado, and the Bighorn region; but sediments deeply buried in the Williston basin form an imperfect connection between the Bighorn outcrops and those of southern Manitoba.

Several important considerations, not fully discussed previously, are involved in the consideration of the age of the Red River beds. The mixture of apparent Black River and Richmond elements in the Red River faunas was long a source of perplexity; it was at length concluded that inasmuch as the Richmond was a recurrent Black River fauna in many respects, the recurring types being modified more or less by evolution, more weight should be given to the new, stratigraphically younger types, and on this basis Richmond age was quite generally accepted (Twenhofel et al., 1954). However, theoretical objections to this course were immediately evident. It was generally recognized that the successions of faunas in the Ordovician of eastern North America were in large part due to alternations of faunas of boreal and austral origin, and that the boreal faunas advanced over that region in Chazy, Black River, and Richmond time. Only much later was the boreal advance in Cobourg time recognized. To be sure, each of these discrete samples of the boreal faunas had its own characteristics, involving the extinction of some stocks and the evolution of others into distinctive generic groups. The later invasions brought about the appearance of some new elements of uncertain origin in eastern regions, others possibly evolving in ways not yet clear, and still others involving new types which, possibly for obscure ecological or paleogeographic reasons, had not been represented in earlier migrations.

Once it is accepted that the faunal elements by which the Richmond is recognized in eastern North America represent a faunal invasion of boreal elements, it is at once evident that their confinement to the Richmond interval in other regions is potentially fallacious. These forms are particularly suspect as criteria of the Richmond in sections to the north and west, which are closer to the reservoir area in which, presumably, Black River types might be found evolving into Richmond types without being displaced by austral faunas. Indeed, one might hope that somewhere to the northwest there might be preserved a section in which the sediments contain fossils showing the gradual evolution of Black River to Richmond types. As yet, no such sequence has been recognized; perhaps none is preserved in the present continental region of North America.

The sections from New Mexico to southern Manitoba present a most incomplete record. The whole region was a positive one, in which long intervals of uplift separated the three periods of recorded deposition, and the intervening periods certainly involved extensive erosion, further limiting the preserved beds in both vertical and horizontal extent.

The implications of faunal migrations seem never to have been fully stated or taken into account in attempts at faunal correlation. It is evident that climatic control is the most logical explanation for the alternation of austral and boreal faunas. The conditions governing their relative distributions are not of a nature that can be deduced from inspection of the sediments themselves, and must relate to physical or chemical conditions that cannot be inferred from inspection of the sediments (Flower, 1946, p. 127). Most such possible controlling factors can be eliminated. Chemical variations are most unconvincing in open and widespread seas; the sediments are obviously all laid down in relatively shallow water, depth is no convincing factor, nor can light, turbidity, or wave action be invoked as probable controlling factors. Temperature remains. Inspection of the faunas shows that the boreal faunas, with abundant corals, large and bizarre cephalopods, large gastropods, large and distinctive brachiopods, exhibit the features that today we find in tropical faunas, in relation to which the smaller, more generalized, less spectacular types of the austral faunas seem, at the best, as temperate. We may go farther and suggest that the oscillations of boreal and austral faunas, formerly explained, though not convincingly, as due to tilting of the continent first to the south and then to the north and west, were the result of general temperature oscillations, the boreal advances marking periods of generally increased temperature. Causes need not concern us here; evidence of such temperature changes in the recent past is clear, and the factors involved are quite possibly astronomical rather than geological. At present, it appears that continental drift, rather than polar shift acting upon a pattern of stable continental relationships, fits the existing distributional pattern of faunal zones.

The situation that one would expect from a succession of faunas involving advances and retreats of a tropical fauna is theoretically simple, but the results are complex and may present intricate patterns in distribution, making ordinary faunal correlations most unsafe.

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[1] It should be noted that Ross (1957) and Sinclair (1959) consider the Winnipeg as only a basal sandstone of the Red River group, rather than as sediments of a materially earlier period of deposition. It is the belief of the writer that two sandstones exist at least locally in that region, and that both have upon occasion yielded fossils. Baillie (1952, p. 27) has listed a fauna from a "northern sandstone" suggesting a collection made from two such sandstones in juxtaposition. The upper sandstone, a basal sandstone of the Red River, is in general comparable to the Cable Canyon sandstone of New Mexico and the Lander sandstone of Wyoming, but there remain elements in the reported Winnipeg sandstone fauna which present anomalies if the whole is interpreted as of Red River age.

Advances would be marked by selection of the hardier, more adaptable elements forming the spearhead of the faunal invasion. Such adaptability is physiological and generally quite erratic among species of a genus; there is no assurance that in several successive advances of the boreal faunas, adaptable strains would be found in the same genera or species groups. Further, if migration was at all gradual, the changing conditions encountered would tend to accelerate rather than retard evolution, and what began as a physiologically adaptive strain in a single morphological species, might end up as a form quite distinctive morphologically from its ancestors. Moreover, in the tenuous region where boreal and austral faunas intermingle, physiological adaptation might permit a stock of boreal origin to become a part of the austral faunas. Evidence of such types is found in the cephalopods. *Deiroceras,* confined to boreal faunas in Black River time, returns in the east in the late Trenton Cynthiana-Catheys faunas of the east-central region, and in the Cobourg and Terrebonne of eastern Canada. In Canada the genus disappeared with the retreat of the boreal faunas, but in Kentucky and Ohio the genus lived on into middle Maysville time. *Faberoceras,* a derivative of *Westonoceras,* evolved apparently in the advance of the boreal faunas in the Cynthiana-Catheys invasion. It became a part of the austral faunas and continued on into the Eden and Maysville, being prolifically developed in the Leipers, modified into *Clarkesvillia* in the early Richmond, where its presence is clearly a survival of austral elements rather than indicative of a new boreal invasion, and continuing even into the early Silurian Brassfield, as the genus *Glyptodendron.*

It can be seen, then, that migrations may result in a peculiar mingling of faunal elements, showing diverse affinities and presenting conflicting evidence when one tries ordinary means of correlation. It is evident that these considerations make unsafe the criteria from which the Red River was judged to be Richmond in age.

Further confirmation of this suspicion came when more and more of the supposedly Red River or "Arctic Ordovician" types came to light in the late Trenton, and it became recognized that the late Trenton represented an intermediate advance of the boreal faunas, not recognized until relatively late, when stratigraphic and faunal investigations brought to light the distinctive features of the late Trenton faunas. Many of the Red River cephalopod types were found to penetrate the eastern "Cobourg" faunas. One such arctic faunule was described from the Cynthiana limestone (Flower, 1942), and subsequent study of the Cobourg and Terrebonne faunas yielded many of the Red River genera (Flower, 1952). Further, it became evident finally that only one cephalopod genus, *Schuchertoceras,* was known which was common to the Red River and the eastern Richmond but lacking in the Cobourg invasion. Many Red River genera, such as *Narthecoceras, Kochoceras, Selkirkoceras,* and *Cyrtogomphoceras,* never penetrated the eastern faunas at all. Others, notably *Westonoceras,* which penetrated the Terrebonne of Quebec and the Eden of Cincinnati, and *Winnipegoceras* and *Fremontoceras,* which penetrated the east only in the Cobourg-Terrebonne region in Ontario, New York, and Quebec, are common to the Red River and Cobourg-Eden interval but completely unknown in either the eastern or western Richmond.

Other evidence supporting the pre-Richmond age of the Red River was found in the presence, above typical Red River beds, of a considerable interval of Richmond strata; significant faunal sequences found in such sections suggest that a considerable time interval is involved, quite possibly an interval more closely approximate to the whole of the Richmond than to a small part of it.

An alternative interpretation (Nelson, 1956) requires acceptance of the Red River as Richmond, and the assignment of overlying beds to the "Gamachian," as a potential time interval younger than Richmond but older than Silurian, which was first suggested in relation to the Anticosti section. Faunal evidence of the Richmond age of the Red River is, however, most dubious, as shown here, and the overlying beds fail to supply faunas showing such advances over Richmond faunas as one would expect in a truly post-Richmond interval; rather, many intervals in the Stony Mountain-Stonewall succession suggest equivalence to the type Richmond.

Faunal ambiguities are encountered, but such perplexities must be expected in comparing stratigraphic columns in which faunal migrations are involved. For example, it is in the Red River that one finds many of the cephalopod genera which at Cincinnati are unknown in the Cynthiana, Eden, and Maysville, and which appear in the Richmond not in the lower beds, but in the upper Whitewater division. Many of these genera are unknown in Richmond beds of the west overlying the Red River; these beds do not represent facies favorable for the development of prolific cephalopod associations. Yet the Whitewater contains a bryozoan association most closely duplicated in the Gunn member (Sinclair and Leith, 1958), the lower shaly member of the overlying Stony Mountain formation (Helen Duncan, oral communication), whereas the still higher Penitentiary member contains a brachiopod association that seems most closely similar to that of the Vaureal of Anticosti, and to the Waynesville-Liberty interval at Cincinnati.

The Aleman and Cutter of New Mexico show a succession of faunas that, from their general aspect, suggest the Cutter to be late Richmond, probably embracing beds from Whitewater through Elkhorn. Upper faunas of the Aleman are suggestive of the Liberty and Waynesville; lower faunas are ambiguous in affinities and are dominated by representatives of a few long-ranging genera. One might hope to find in the lower Aleman evidence of Arnheim equivalence, but as yet these lower horizons have yielded forms that might as easily be late Maysville as early Richmond in age.

Sections in New Mexico show evidence of a period of uplift and erosion separating the Red River Second Value formation and the Cincinnatian Aleman. Sections in the San Andres show definite evidence of arching, followed by erosion, producing some sections of anomalous thinness in which the anomaly clearly involves erosional removal of the upper beds.

In Rhodes Canyon the Cable Canyon sandstone is 2 feet thick, and the Upham 119 feet thick; within the latter are lower massive beds, a middle zone of light crinoidal calcarenite, and a succeeding interval of large sphaeroidal chert nodules, 15 feet thick and 24 feet below the contact with the overlying Aleman. Similar chert nodules occur in the upper part of the Upham in the Caballo and Mud Springs Mountains, and can be recognized, though complicated by chert of secondary origin, in the Sacramento Mountains. In Hembrillo Canyon, near the middle of the San Andres range, the Second Value is anomalously thin, and the upper zone of chert nodules is plainly wanting. Here there are 2 feet of Cable Canyon sandstone but only 77 feet of Upham dolomite. Still farther south, at Ash Canyon, the Cable Canyon has thickened to 21 feet and the Upham above is 104 feet thick, thus giving the Second Value a total thickness of 125 feet. Here, again, the upper beds with sphaeroidal chert are evident, though the nodules are slightly smaller, and there is some secondary chert of later origin.

Erosion also supplies a logical explanation for such anomalies in thickness, where zonation within the Second Value is less clear, as in the contrast between the 30 feet of Second Value present in the Florida Mountains and the 85 feet evident in the section in the Cooks Range, about 20 miles to the north. Further, many sections show scoriaceous silica forming irregular patches in the Upham surface and penetrating perhaps 3 to 4 feet down in erratic patches and fissures, a phenomenon suggestive again of uplift and replacement upon and just below an eroded surface. Such patches of silica, replacing calcarenite grains and fossils, are particularly evident in the Hatchet Mountains, the Florida Mountains, the Franklin Mountains, the Hueco Mountains, and Lone Mountain. Absence of comparable features in sections of the northern and northeastern Montoya exposures is explicable in terms of subsequent alteration, involving advanced dolomitization and injection of chert nodules, both of relatively later origin.[2]

Evidence for a similar significant break in deposition is wanting for southern Manitoba, but it must be noted that limited exposures restrict observational possibilities there. The contact between the Red River and the lower Stony Mountain is not shown in any surface exposures, and exposures of limited thickness prevent accurate observation on the thickness of the Red River (Baillie, 1952). More recently work in the Williston basin has permitted the development of isopach maps (Porter and Fuller, 1959), but the available isopach map shows Red River sediments united with those of the Gunn member of the Stony Mountain. Although this pattern is obviously distinct from that shown by the upper Stony Mountain and the Stonewall together, and the sections (fig. 9, p. 140) suggest warping and erosion following Red River deposition, the evidence is possibly somewhat obscured by the intervals selected for the series of isopach maps.

Seemingly, the great objection to a Red River-Richmond erosion interval rests upon our failure to recognize the contact between these formations in the exposed sections in the Bighorn and Fremont "formations." True, upper members have been recognized,[3] characterized by rather thinner bedding, but it appears that these units are probably not equivalent to all of the Richmond, but rather are upper Richmond beds of distinctive lithology, possibly roughly comparable to the Stonewall of Manitoba and the Cutter of New Mexico. There is reason to believe, however, that the Red River-Richmond contact has been obscured in these regions by subsequent events, mainly by dolomitization.

How this can happen is shown by comparison of sections within the Montoya of New Mexico. In sections to the south and southeast, notably in the Franklin Mountains, Cooks Range, and Florida Mountains, the Second Value is relatively free from dolomitization, and its contact with the overlying Aleman shows a strong lithic contrast. However, as one traces sections to the north, increased dolomitization is found, obscuring original lithic differences and resulting in beds that outcrop as massive ledges regardless of original bedding, which also is obscured. Many fossils are destroyed and, with the injection of chert nodules, clearly of secondary origin, the original differences between the Upham and Aleman are reduced and, indeed, all but obliterated. Such extreme conditions are best shown in the sections in the Sacramento Mountains near Alamogordo, and in the Mud Springs Mountains near Truth or Consequences, formerly Hot Springs. In these sections, only careful examination will reveal the exact position of the Upham-Aleman contact, but the change is clearly one produced by alteration, and there is no reason to set aside the evidence of erosional contact shown in other sections of the Montoya, or to believe that the absence of clear evidence of such a break in these sections is due to other than secondary alteration. Indeed, alteration would not have to proceed much farther to conceal the contact completely.

Plainly, these sections show how in the Fremont and Bighorn sections, where dolomitization is advanced, the erosional contact may be hopelessly obscured. Bed-by-bed collecting might yield a solution, but practical difficulties are involved. The Fremont and Bighorn outcrop in regions of considerable relief; exposures are steep, but sections showing extensive exposures of individual beds are largely wanting. Such exposures are needed for adequate faunal sampling. Further, the rocks are massive hard dolomites, and bed-by-bed collection even of many of the observed fossils is virtually impossible. Much of our knowledge of the faunas of the lower massive dolomites of both formations rests upon material collected from loose pieces, for which there is little or no close stratigraphic control.

THE HARDING-WINNIPEG REMNANTS

The writer has found that at the extreme base of the Montoya there are thin remnants of sediments quite unlike those of the Cable Canyon sandstone. In the Mud Springs Mountains there may be locally 1.5 feet of a saccharoidal white sand beneath the Cable Canyon. At Hembrillo Canyon a maximum interval of 3.5 feet was found of gray slightly calcareous silts with a little glauconite; this was exposed on one side of the canyon, but was wanting on the other. Remnants of sand were found in the Black Range and in the section on the west side of the Mimbres Valley not far from the road leading west to Santa Rita. No such remnants were observed in the Florida Mountains, but in the Big Hatchet Mountains, above an uneven surface of the El Paso, on which there was an observed relief of 2.5 feet in a length of 3 feet, there is a slightly arenaceous coarse dolomite with a maximum thickness of 12 feet, and in the Cooks Range a 4-foot interval of quite sandy dolomite with abundant worm borings is commonly present. A similar interval of 4 feet is present in one section at Lone Mountain, but in another section less than an eighth of a mile away the interval is absent. As yet, this interval has yielded no megafossils; not surprising, in view of the character of the sediments and the sparsity of exposures. Samples await proper examination for microscopic materials.

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[2] To a considerable extent, northern dolomitization appears to be regional, but both dolomitization and excessive development of irregular chert nodules are found connected with sections showing close proximity to faults; most of the faults are involved with the development of basin and range structure and are regarded as of middle or late Cenozoic age. At the western extent of the Snake Hills, the Montoya is close to the fault limiting the exposed and elevated Ordovician section. Here dolomitization is advanced; silica occurs erratically in the Upham, in some cases occupying joint cracks, and is excessive in the Aleman, where no silicified fossils are seen. A reasonable explanation is that secondary silica was deposited, centering both upon primary chert nodules and upon the silicified fossils.

[3] The Priest Canyon member of the Fremont and the Leigh member of the Bighorn.

Age reference is admittedly inferential, but these beds are clearly isolated erosion remnants, and we have looked to the north, where correlation of overlying beds is plainly to be found, for possible equivalents. There one finds the Harding sandstone, and the lithic variation found within that formation makes the interpretation of these remnants in New Mexico as relics of the southern continuation of these sediments at least a credible hypothesis. Howe (1959) has ignored previous remarks on this matter, but has found a 1-foot layer of sand at the base of the Montoya developed in the southern Franklin Mountains (he does not so state, but this is extremely local), a similar interval in the Hueco Mountains, and, of less certain interpretation, a 116-foot interval of sand in the Baylor Mountains. All of these Howe suggests as equivalents of the Simpson group of Oklahoma; not a very precise correlation, as the Simpson includes the Joins, certainly as old as the Whiterock and possibly even late Canadian, and succeeding beds range through Whiterock, Chazyan, and beyond, the top being probably as young as Black River.

Of course, these isolated remnants occur between sediments separated by a wide stratigraphic interval, for the highest underlying beds are latest Canadian, and indications are that they are not as young as the Odenville or the highest beds of the Garden City formation. The widespread Red River deposits are of late Trenton (Cobourg in the broad sense) and Eden age. It is not impossible that in the broad interval between there may have been several periods of marine invasion and deposition, and a series of distinct remnants such as are found at the edge of the Llano uplift, but present evidence does not suggest that the parallel applies. Only the sediments of the Hatchet Mountains are startlingly different from the others, and the relative distance separating them from the other remnants, and the greater proximity of this section to the Cordillerian geosyncline, both suggest that the faciological difference may not be very significant.

THE SECOND VALUE FORMATION

In general, the Second Value formation consists of massive-weathering, poorly bedded strata. Thus far only two members have been recognized, the Cable Canyon sandstone and the Upham dolomite. The Cable Canyon has yielded only a very few observed fossils, large *Maclurina,* rare endoceroids, and a bit of a *Receptaculites.* The sparse fauna is hardly surprising in view of the extremely coarse-grained nature of the sediments, but the few forms known are genera and apparently species of Red River aspect occurring in the overlying Upham limestone, and fail to suggest a material break in deposition between the two lithic units. Regional variations in the thickness of the Upham and Cable Canyon, though caused in part by post-Second Value erosion, appear less extreme when the thicknesses of the two members are combined in a single figure for the Second Value formation. Some sections show a sharp contact between the Cable Canyon and the Upham; as already noted, where dolomitization obscures lithic differences in the carbonate rocks, the contrast between the Cable Canyon and the Upham seems greatly increased. However, other sections show apparent gradation between the two members. Indeed, some sections, notably those at Rhodes and Hembrillo Canyons in the San Andres Mountains, though the top of the sandstone occupying the basal 2.5 feet of the Second Value is set off by a conspicuous bedding plane, contain sandy stringers in the lower 15 feet of the overlying dolomite.

Where the calcareous beds of the Upham remain relatively free from dolomitization, there are apparent lithic differences within these sediments, potential members fully as significant as the Cable Canyon sandstone. At El Paso the lower 70 feet consists of a mottled dolomitic limestone remarkably similar, except for a slightly darker color, to the Chaumont of New York. The Selkirk limestone of Manitoba is again remarkably similar, differing primarily in the lighter color of the sediments, for in it the mottlings are in shades of white, gray, and light tan. Such sediments represent an environment particularly favorable to the cephalopod facies, in which the fauna consists largely of cephalopods and gastropods, usually of large size, with corals, pelecypods, and trilobites common, but in which brachiopods and bryozoa are at best minor constituents. The mottled beds grade up into a clean, light crinoidal calcarenite member, in which are found numbers of brachiopods, mainly small forms. The upper beds contain poorly sorted mixtures of calcarenite and calcilutite, some chert, not common in the lower beds, and patches of scoriaceous silica, particularly abundant at the top, the last being regarded as formed during post-Second Value uplift and erosion. The section does not extend high enough to show the beds with sphaeroidal cherts noted in other sections in the San Andres, Sacramento, Caballo, and Mud Springs Mountains. As far north as Rhodes Canyon, the light crinoidal calcarenite can be recognized, even though dolomitization is fairly advanced there.

The Cooks Range section, which is exceptionally free from dolomite, shows 12 feet of Cable Canyon and a 2-foot transitional zone into dark calcilutites. These beds grade up into a middle calcarenite zone, but here the sediments are dark, and the zone has yielded a large assortment of fair-sized shells, mainly brachiopods. Higher in the section, a gradation back to calcilutites is encountered, and in the upper part are spheroidal chert nodules. At the top of these dark calcilutites there is an abrupt change to 12 feet of white calcarenite, here named the Cooks Range member. Lithically it is distinct from both the Upham below and the Aleman above, and only faunal evidence indicates its affinities with the Second Value. Those who deny the use of fossils in making stratigraphic decisions will properly consider this a distinct formation. Most shells have obviously been ground to a lime sand, but collecting has yielded an assortment of brachiopods that are clearly Second Value species.

At Lone Mountain the section is quite similar except that it shows more advanced dolomitization, which has tended to obscure the middle brachiopod-bearing calcarenites. Sphaeroidal cherts occur a little below the top of the member, and there is from 1 to 5 feet of the white calcarenite of the Cooks Range member. At this locality the calcarenite has so far yielded few fossils, and the only recognizable types are small *Zygospira* and *Cornulites.* These genera are common in the first faunal zone of the Aleman, but were, when found here, unknown in the Upham. For this reason, even though correlation with the Cooks Range member was obvious from lithology, position, and proximity, the possible interpretation of these beds as Aleman required review. The possibility was rejected. The situation is, however, worth noting as an example of possible errors. The genera involved are long-ranging types, within which species are quite similar; indeed, to judge from the shells, it is possible that the species are at present rather too broadly interpreted. Certainly there is a great temptation to base correlations on similarities that reflect generic rather than specific identifications. That *Zygospira* and *Cornulites* characterize a zone low in the Aleman is a local phenomenon. Paleogeographic and ecological factors are probably involved, but they are difficult, if not impossible, to estimate; we may, for all practical purposes, regard such concentration as fortuitous, and a lucky accident that such a zone prevails over much, though not all, of the Aleman in a single horizon. Another and more serious danger is involved, the temptation to base correlations on superficial identifications at the specific level. It is feared that Howe's (1959) assertion that a number of brachiopod genera are represented by the same species in the Upham and Aleman faunas may rest upon such superficial identifications, and his further conclusion that no significant time break separates the two formations is the more fallible. He cites with equal confidence *Paleophyllum thomi* as common to these two formations. *P. thomi* is confined to the Aleman. In the Upham, *P. margaretae* is superficially similar in corallite size and general aspect, but shows differences in septal and tabular features, indicating that the resemblance is most superficial.[4] My own observations on rather extensive brachiopod collections from both formations suggest the brachiopod species to be distinct. In some genera, distinctions are difficult to recognize, comparable to the contrast between the superficially similar Eden and Richmond species of *Dalmanella* (*Diceromyonia*) and *Sowerbyella* (*Thaerodonta*) in the Cincinnati region.

As yet the complete fauna of the Second Value is not known, and necessarily intermittent collecting continues to add to the new forms. Because of the scarcity of good available exposures and the hardness of the strata, it will be long before collections will approach the real limit of variety of the species. It appears, however, that there is no great significant difference between the faunas in the lower and upper divisions. Such differences as exist seem rather to suggest ecological control. At El Paso the lower mottled limestones contain a scattering of large cephalopods, gastropods, and corals, as well as occasional trilobites, but with brachiopods and bryozoans relatively scarce. It is evident, however, that the lithology here, shared by the Selkirk member of the Red River and the Chaumont limestone of the Black River, is an environment particularly favorable to the development of these types. The overlying crinoidal calcarenite has yielded nothing but small brachiopods, but the preservation of only small shells may indicate merely that here wave action ground all larger forms to unrecognizable fragments. Some brachiopods present in the overlying impure dark massive layers are unknown below, but the difference may be due to insufficient collecting rather than to a real zonation. Certainly many of the corals, gastropods, and cephalopods here are conspecific with those in the basal beds.

At or just above the zone with the sphaeroidal cherts, the Upham shows silicified fossils, cup corals, *Clitambonites*, *Rhynchotrema*, and *Sowerbyella*, but again this is due more to the fact that these fossils tend to silicify in this part of the section than that there is a demonstrable zonation of significance.

The Second Value faunas, as yet incompletely known, may be summarized as follows:

PORIFERA, real and supposed. *Receptaculites;* sponge spicules and fragments.

STROMATOPORIDA: *Labechia* sp. and a new species currently being described by Galloway, who assigns it tentatively to *Rosenella*, a genus not otherwise known in the American Ordovician.

CORALS: Colonial forms are listed elsewhere in this work and need not be repeated here. Solitary forms are few, now in process of study by Miss Helen Duncan, but it is evident that *Grewinkia* and *Streptelasma* are involved; *Bighornia* is possibly a member of this association, but the few known specimens from the Montoya lack accompanying data.

BRACHIOPODA: There is a large brachiopod fauna as yet not closely studied, but it is evident that there are many genera, including strophomenids, a host of orthoids, *Rafinesquina*, *Rhynchotrema*,[5] and *Zygospira;* Rogers Gap, Kimmswick, and Cynthiana affinities are suggested by a few of the species. Brachiopods are more conspicuous elements in the Second Value formation than in its more northern equivalents.

BRYOZOA: The present collection of these forms is sparse and probably not yet representative. Ramose Trepostomata are present, but not common. Sections made for the corals have yielded some small forms, notably *Stenopora; Rhombotrypa* occurs, a genus that invaded Cincinnati in Arnheim time and has thus long been considered diagnostic of the Richmond.

PELECYPODA: A few large, poorly preserved forms, possibly *Vanuxemia* and *Cyrtodonta.*

GASTROPODA. Large *Maclurites* or *Maclurina*, possibly both. Large *Hormotoma* cf. *winnipegensis; Fusispira* cf. *inflata; Liospira; Lophospira; Bucania,* several planispiral forms.

CEPHALOPODA: *Endoceras,* large species with circular cones; *Cyclendoceras; Actinoceras, Armenoceras, Lambeoceras, Ormoceras* (see Flower, 1957); *Cyrtogomphoceras,* at least two species; *Westonoceras,* probably two species; *Winnipegoceras; Michelinoceras* (aff. *M. clarkesvillense* and *"Cycloceras" selkirkense*); *Gorbyoceras,* large, allied to the Red River *"Spyroceras" fritzi; Wilsonoceras,* large typical species; *Charactoceras; Diestoceras,* moderate-sized species.

TRILOBITES: Fragments of large asaphids, *Bumastus, Illaenus,* fragments of *Hemiarges* or *Acrolichas* or both, ceraurids, *Pterygometopus.*

ECHINODERMATA: Abundant plates and stem fragments, but as yet no identifiable remains.

Red River affinities are obvious in many faunal elements. The Second Value formation contains, however, some forms not evident from lists of more northern occurrences of Red

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[4] Curiously, *P. thomi* is more similar to the much smaller *P. gracile* of the Upham in septal features, but more similar to the relatively large *P. cateniforme* of the Upham in curvature of the tabulae.

[5] The writer shares with the late Dr. W. H. Shideler some scepticism as to the validity of the distinction of *Lepidocyclus* from *Rhynchotrema.* Other brachiopod genera are here treated in broad terms. Current trends seem to favor separating genera on almost any internal differences, whereas species are broadly drawn, allowance necessarily being required for observed variation. Unfortunately, many proposals of new genera (Wang, 1949) are difficult to evaluate, partly from lack of clarity of the discussions, and partly from a failure to include mention of the described species considered as belonging in these groups, thus making evaluation of the faunal and stratigraphic significance of the genera the more difficult.

River beds, and not immediately obvious from casual study of sections or from several collections. In particular, the assortment of brachiopods seems peculiar, and some of these forms, not yet studied in detail, seem to be more similar to species from the Rogers Gap and Cynthiana than to any other previously described forms. The trilobites, on the other hand, seem in general most suggestive of those described from the Kimmswick limestone of Missouri. Clearly, much more collecting must be done, and the systematic groups comprising the faunas require close critical study for proper evaluation of faunal affinities.

ALEMAN

The Aleman sections show striking successions of faunas. In general, zones previously indicated (Flower, 1957) are persistent but not universal. It is evident that absence of zones is in some cases the result of pinching out of the beds, but it seems probable that this explanation is not universal; rather, in other cases there is lateral change in the faunas. Collections have been accumulated over a period of some years, but are still regarded as too small to be truly representative. Faunas are largely represented by silicified brachiopods in dolomites, and the best method of collecting is the accumulation of large pieces, from which the shells are removed by etching. To the previously noted zones (Flower, 1957), there may be added a basal zone, present in southerly sections, but thinning northward and wanting completely in Rhodes Canyon. Where this is dolomite, it appears barren, but can be recognized by the close regular seams of chert nodules. The only fossils so far found are some isotelids and an unidentifiable crinoid. This zone may be as much as 40 feet thick; where present, it underlies the *Dalmanella-Zygospira-Cornulites* horizon (5 to 15 feet thick), although there are sections in which this fauna is not typically developed. The *Rafinesquina* zone, commonly 5 to 10 feet thick, follows.

The corals occur in a zone well developed only in the southern Franklin Mountains and at Lone Mountain. At Lone Mountain the coral zone unquestionably succeeds the *Rafinesquina* beds; there it has a maximum thickness of 1 foot and contains only one coral, *Paleophyllum thomi*. In the southern Franklin Mountains it may be from 8 to 12 feet thick, and contains there the full assemblage listed for the Aleman. Beds below are only sparingly fossiliferous, and the *Zygospira* and *Rafinesquina* zones are not typically developed.

Higher beds show, in general, a variety of brachiopods. The zones previously noted, with *Rhynchotrema capax* and *Platystrophia* below, and with upper layers having megaripples and a sparse fauna largely without brachiopods, prevail in the northern San Andres, Caballo, and Mud Springs Mountains, and continue west into various sections on the eastern side of the Black Range. The Cooks Range section, as well as that of the Florida Mountains, shows thickening of this interval, and significant zonation within it may well be possible. In the Hatchet Mountains, this interval is greatly thickened, but preserved shells are sparse, and similar zonation is not clearly evident. In the Lone Mountain section, faunas just above the coral bed are dominated by *Rhynchotrema argenturbicum* and a *Dalmanella;* higher beds show a more varied association, but these species still continue; still higher beds, transitional into the Cutter lithology, are dominated largely by *Hebertella.*

CUTTER

The Cutter is dominantly a light-gray dolomite, fine grained in general. Vugs with calcite are common but not universal. Chert nodules, other than silicified corals, are small, round, smooth nodules, commonly developed only in the lower beds, but not evident even there in all sections. It is pointless to present comparison here of the various sections. Variations in thickness are largely the result of planation, which produces a relief in the Montoya in Rhodes Canyon in an eighth of a mile from 85 feet of the Cutter to none. There is also indication of onlap relations of the Cutter on the Aleman surface northward in the San Andres Mountains and westward to the Mud Springs Mountains.

Commonly the corals are silicified and form one or more zones, always well above the basal beds with brachiopods. Three such zones occur at Lone Mountain, where the only associated type is a stromatoporid identified by Galloway as *Labechia macrostyla* Parks, a species of the later Richmond in Ontario and at Cincinnati. A single zone of corals occurs in the Mud Springs Mountains. Kelley and Silver (1952) have presented a section showing the corals well above the basal pelecypod zone and the two overlying limestones, which contain mixed faunas. At Tank Canyon a remarkable layer of black dolomite contains corals; there all the known species of the Cutter were found. Associated forms included some silicified *Beatricea* and small ramose Bryozoa. *Beatricea* and *Paleofavosites* occur in a thin layer of similar dark dolomite near the top of the Cutter in Rhodes Canyon. Elsewhere the corals of the Cutter are largely *Paleofavosites mccullochae. Calapoecia coxi* has been obtained in the Mud Springs Mountains, the box of Percha Creek just east of Hillsboro, and the Hueco Mountains section, as well as at Lone Mountain, but nowhere other than at Tank Canyon has the species been found in abundance. *Favistina stellata* is known as yet only from Tank Canyon.

While some sections show indication of a minor break in deposition at the base of the Cutter, other sections present an aspect of gradation. The bed that, from its light color, one would consider the base of the Cutter at Lone Mountain is characterized by *Hebertella* in abundance; the same bed in the Cooks Range is in black lime mud, which one would group with the Aleman instead; in the Florida Mountains the same fauna at the same position occurs in a red lime mud not typical of either division.

Faunal Analysis

THE MONTOYA GROUP

The writer has previously indicated that the Montoya group consists of three major units of deposition widely separated in time. The first contains unnamed remnants believed to be equivalents of the Harding sandstone of Colorado, the unnamed fish-bearing sandstone locally preserved beneath the Bighorn dolomite, and the Winnipeg sandstone of southern Manitoba. This unit has yielded no corals. The second unit, the Second Value formation, contains a fauna of Red River aspect. Its corals are as follows:

Manipora amicarum Sinclair
M. trapezoidalis, n. sp.
M. magna n. sp.
Catenipora workmanae n. sp.
C. sp.
Protrochiscolithus hembrilloensis n. sp.
Coccoseris astomata n. sp.
Nyctopora mutabilis
Saffordophyllum newcombae n. sp.
Trabeculites keithae n. sp.
Calapoecia cf. *anticostiensis*
Crenulites duncanae n. sp.
C. magnus n. sp.
Paleofavosites sparsus n. sp.
Paleophyllum gracile n. sp.
P. margaretae n. sp.
P. cateniforme n. sp.

The colonial corals of the Aleman are confined to the coral zone, which commonly lies 60 to 80 feet above its base and has a maximum thickness of 6 feet. This zone is well developed only in the southern Franklin Mountains, but reappears at Lone Mountain. Its fauna is as follows:

Paleophyllum thomi (Hall)
Cyathophylloides burksae n. sp.
Protrochiscolithus alemanensis n. sp.
Nyctopora nondescripta n. sp.
Paleofavosites kuellmeri n. sp.
P. prayi n. sp.
?*Catenipora* sp.
Pragnellia delicatula n. sp.
Calapoecia cf. *ungava*

The Cutter formation has yielded widespread *Paleofavosites* and, of more restricted occurrence, representatives of three other genera:

Paleofavosites cf. *prayi* n. sp.
P. mccullochae n. sp.
Favistina stellata (Hall)
Calapoecia coxi Bassler
Cyathophylloides, sp.

It may be noted that no species have been found common to the Second Value and Aleman formations, and only one form, *Paleofavosites prayi,* seems to be common to the Aleman and the Cutter formations; even here there are slight differences, although it was felt that they were not conclusive indications of the distinction of two separate species.

There is indication that the present material is not complete, though later collecting has shown diminishing returns in terms of additional species, indicating that it is fairly representative. However, we have had no *Tetradium,* a genus identified by Ulrich in a collection made from the Montoya from near Silver City, New Mexico (Paige, 1916). Two of the forms described and illustrated by Hill (1959) from an outlier of the Montoya, apparently consisting of only a remnant of the Second Value formation, have not been duplicated in our material; these are *Reuschia* sp. and *Nyctopora* sp., the latter a form with small corallites quite different in proportions from our *N. mutabilis.*

The colonial corals of the Second Value formation show a regional concentration. The best material and the largest collections are from the southern end of the Franklin Mountains at El Paso. This region possesses two advantages: first, the limestones are relatively unaltered to dolomite, and the material is well preserved; second, the region is one where extensive collecting is possible because of outcrops readily accessible to roads, no small consideration when collecting involves removal and transportation of coral colonies of considerable size and weight. Much the same coral associations continue east in the Hueco Mountains, and north into the San Andres and Sacramento ranges. However, as the Montoya is traced northward, the colonial corals decrease in abundance, and preservation becomes poorer as dolomitization becomes more advanced. Some sections are close to faults, and in some of these the corals show some distortion, making identification at the specific level more difficult. In the Mud Springs Mountains, *Paleophyllum* and *Catenipora* persist, but westward the Montoya colonial corals decline. *Catenipora* is still present in the Cooks Range, but the phaceloid and cerioid species have not been found there. At Lone Mountain, only *Paleophyllum margaretae* was found, but no colonial forms whatsoever were found in the Big Hatchet Mountains in spite of careful search. However, the outlier of the Second Value at Morenci, Arizona (Hill, 1959), showed marked concentration of colonial forms.

In the Aleman the colonial corals are found only in one restricted zone, rarely over 6 feet thick and varying in position owing to the variable thickness of the underlying members, from 60 to 80 feet above the base of the Aleman. Pray (1958) has published a section showing the position of the coral zone. The best assemblages have come from the southern Franklin Mountains. Curiously, the corals are wanting, and the coral zone is not evident as such in Ash Canyon in the San Andres Mountains, nor in the Sacramento Mountains. The corals are not evident in most New Mexico sections, but at Lone Mountain the coral zone, there only 1.5 feet thick, carries abundant *Paleophyllum thomi,* but has not yielded any of the other species.

It should be noted that only two specimens in the present study are of uncertain origin. One is *Catenipora* sp., based upon a specimen picked up on an outcrop of the Second Value on the nose in front of the crest of the Scenic Drive, El Paso. It differs from Second Value forms in proportions and in lithology, and is believed to have been derived from the coral zone of the Aleman, in which one cateniform coral was observed weathering on a flat surface where collecting was not possible. The holotype of *Protrochiscolithus alemanense* is from the collection of the U.S. Geological Survey; it is recorded as coming from the middle of the Montoya in the Hueco Mountains. Though the stratigraphic indication is most general, the coral zone of the Aleman occupies about this position.

WESTERN AND NORTHERN NORTH AMERICA ORDOVICIAN FAUNAS

The present study of the corals of the Montoya rests upon material which is largely quite well preserved, and on specimens, with very few exceptions, from accurately known horizons. At the present time, however, significant correlation with other coral faunas of approximately or possibly equivalent age is hardly possible, as already noted.

Even were the faunas stratigraphically sorted in the later western North American Ordovician beds, the results would not be very meaningful, for extant published data on the corals involves old and apparently quite approximate identifications, requiring interpretation to varying degrees.

BURNAM LIMESTONE

The Burnam limestone of central Texas (Barnes, Cloud, and Duncan, 1953) consists of a collection of collapse boulders dominantly of massive light calcarenite, containing a Red River fauna. Here, at least, the corals are adequately identified generically, and significant comparison is possible; species have not yet been described, but this work is under way and will be completed by Miss Helen Duncan in the near future. The genera recognized are:

Nyctopora (2 species)
Cyathophylloides (1 species)
Calapoecia cf. *anticostiensis*
Catenipora (2 species)
Coccoseris cf. *astomata*

Of the *Catenipora* one, *C.* cf. *jackovickii,* is a form with tiny enclosed lacunae (Duncan, 1956, pl. 27, fig. 1d-e), unlike any other form encountered thus far in North America. The *Coccoseris,* not originally listed, appears to be conspecific with *C. astomata* of the Second Value; as yet, these are the only two recognized occurrences of this genus in North America. This fact may not be particularly meaningful, for *Coccoseris* is a most nondescript thing, and one readily mistaken for a stromatoporid; I have, in fact, suspected that *Coccoseris* may have been confused with *Protrochiscolithus magnus* in the Red River of southern Manitoba, a conclusion suggested by some of the illustrations of Leith (1952).

MARAVILLAS CHERT

More directly to the south of the Montoya, a small group of corals has been found in the Maravillas cherts of the Presidio region of Texas. Bassler (1950) cites the following:

Calapoecia huronensis Billings
Halysites gracilis (Hall)
Paleofavosites asper (d'Orbigny)
Paleophyllum thomi (Hall)
Streptelasma rusticum Billings

Here one is faced with the necessity of interpreting, encountered in all the older faunal lists of corals. We can reasonably accept the presence of a *Calapoecia,* but must retain reservations at the specific level. *Halysites gracilis* might indicate a *Catenipora* or a *Manipora,* or possibly, both might occur. We can accept as probable the presence of a true *Paleofavosites,* but *P. asper* is a species of the British Silurian Wenlock limestone, not certainly known anywhere in North America, and quite clearly not present in beds of Ordovician age. The *Paleophyllum* reference is possibly correct at the generic level, but the species requires reinvestigation.

ARIZONA

Immediately to the west, an outlier of the Montoya at Morenci, Arizona, yielded some rather poorly preserved corals, which were carefully studied by Hill (1959). This contained material for the most part too poor for specific determination, but from the better preserved material described in the present work, it is evident that there are two species of *Paleophyllum,* which are indistinguishable from *P. cateniforme* and *P. margaretae,* and a *Calapoecia* comparable to our *C.* cf. *anticostiensis.* The *Nyctopora* is not comparable to either *N. mutabilis* of the Second Value nor to *N. nondescripta* of the Aleman, and the *Reuschia* is as yet without a duplicate in the typical Montoya of New Mexico or western Texas; it is, for that matter, the only recorded occurrence of the genus in North America.

COLORADO

To the north, in Colorado, the Fremont limestone contains fused beds with a Red River succession below, not readily distinguishable from a Richmond succession above. Its corals are listed by Sweet (1954), who identified the following from the lower massive beds:

Calapoecia sp.
Halysites sp. cf. *robustus* and *delicatulus* Wilson
Streptelasma sp.

From the upper Priest Canyon member, Sweet identified the following:

Saffordophyllum franklini (Salter)
Streptelasma sp.

There is some confusion as to the identity of *Columnaria franklini,* but the specimens thus identified by Troedsson (1929) and Bassler (1950) from the Cape Calhoun beds of Greenland are true *Saffordophyllum.*

BIGHORN REGION

For the Bighorn group, information is most general, particularly with regard to stratigraphic position, but it has been summarized by Bassler (1950):

Calapoecia borealis Whitfield
C. canadensis ungava Cox
C. huronensis Billings
Favistella alveolata (Goldfuss)
Foerstephyllum halli (Nicholson)
Halysites gracilis Hall
Paleofavosites asper (d'Orbigny)
Paleophyllum stokesi Edwards and Haime
Protarea verneuilli(?) Edwards and Haime
Streptelasma robustum Whiteaves
S. rusticum (Billings)
S. trilobatum Whiteaves

More modern work suggests the following interpretation:

Calapoecia spp.
Favistina, sp.
Foerstephyllum(?) sp.
Catenipora sp. and possibly *Manipora* sp.
Paleophyllum sp.

Closer study is necessary to check the cerioid corals, one attributed to *Foerstephyllum* and another attributed to *Paleofavosites.* The presence of both genera is eminently possible.

BRITISH COLUMBIA

In the Beaverfoot formation of western Canada, there is reason to suspect the presence of both Red River and Richmond sediments. The corals have been described by Wilson

(1926). Some difficulty is encountered in interpreting the species, but the following can be noted:

Catenipora robusta (Wilson)
Catenipora delicatula (Wilson)
Manipora(?) *cylindrica* (Wilson)
Diphyphyllum (?) *halysitoides* Wilson (possibly *Paleophyllum*)
D.(?) *primum* Wilson (possibly *Paleophyllum*)
Plasmodictyon irregulare Wilson
Favistina stellaris (Wilson)
Favosites (*Paleofavosites?* sp.)
Syringopora bulingi Wilson
S. columbina Wilson
Bassler, in addition, cites the following (emended):
Paleophyllum sp. (as *P. stokesi*)
Calapoecia anticostiensis Billings
Favistina calicina (Nicholson)
Astrocerium hisingeri (Edwards and Haime). A species of the British Wenlock originally attributed to *Favosites;* its presence here seems doubtful.

WINNIPEG REGION

In the Lake Winnipeg region of southern Manitoba, stratigraphic information is more accurate, for Red River, Stony Mountain, and Stonewall forms have been differentiated; but coral identifications are old for the Red River formation, and there is some confusion as to correctness of the species.

Sinclair (1959) has found that the "upper mottled limestone" above the Cat Head member is a northern facies of the Stony Mountain, and not the equivalent of the Selkirk limestone, as was formerly supposed. The Selkirk itself is a southern facies of the Dog Head limestone. Some fossils collected from the Stony Mountain mottled limestone have been erroneously listed as from the Selkirk limestone, which contributes to the confusion of the stratigraphic range of the corals. Proper correction is not possible from extant information.

The following identifications have been combined from Bassler (1950), Baillie (1952), and Stearn (1956), with revisions of Sinclair (1955):

Red River formation

Calapoecia sp. (our form is *C. anticostiensis; huronensis* is cited)
Chaetetes perantiquus Whiteaves (inadequately known, possibly a bryozoan)
Favistina sp. (*Favistella alveolata*)
F. calicina (Nicholson)
Catenipora rubra Sinclair
Manipora amicarum Sinclair
Paleophyllum sp. (cited as *stokesi*)
Protrochiscolithus magnus (Whiteaves)
Streptelasma robustum Whiteaves
S. rusticum (Billings)
Tetradium sp. (*fibratum* cited by Baillie)
Paleofavosites(?) (*prolificus* cited by Baillie)

Stony Mountain formation

Calapoecia spp. (*anticostiensis* and *ungava* cited)
Paleofavosites cf. *capax* (Billings)
P. cf. *prolificus* (Billings)
P. okulitchi Stearn
Paleophyllum (*stokesi* cited)
Protarea richmondensis Foerste
Favistina sp. (*Favistella alveolata*)
Catenipora sp. (doubtful)
Tetradium sp. (*ontario* cited)
Streptelasma spp. (*latusculum, rusticum,* and *trilobatum* cited)
Halysites (doubtful; *Catenipora?*)

Stonewall formation

Paleofavosites cf. *capax* (Billings)
P. cf. *prolificus* (Billings)
P. cf. *poulseni* Teichert
P. okulitchi Stearn
Angopora manitobensis Stearn
Calapoecia sp. (*canadensis* cited)
Halysites sp. (cited by Stearn; genus doubtful)
Lyellia sp. (cited by Stearn; again genus seems dubious)
Paleophyllum pasense Stearn
Paleophyllum pasense parvum Stearn
Tryplasma gracilis (Whiteaves)
Neozaphrentis hindei Stearn
Streptelasma (cf. *integriseptatum*)

HUDSON BAY

Our next encounter with similar beds is to the north, on the western side of Hudson Bay, where Savage and Van Tuyl (1919) described the Nelson River limestone and Shamattawa limestone. The former is Red River in affinities; the latter, Richmond. The listing of corals by Savage and Van Tuyl was revised by Bassler (1950) and is here emended slightly further.

Nelson limestone

Calapoecia sp. (*huronensis* cited)
Favistina calicina (Nicholson)
Paleophyllum sp. (*stokesi* cited)
Catenipora(?) (*Halysites gracilis* cited)

Shamattawa limestone

Paleofavosites spp. (*aspera* and sp. cited)
Paleophyllum sp. (*stokesi* cited)
Favistina (*alveolata* and *calicina* cited)
Streptelasma (*latusculum, trilobatum,* and *rusticum* cited)

AKPATOK ISLAND

Akpatok Island lies in the mouth of Ungava Bay, about 200 miles south of the south coast of Baffin Island. It consists of some 800 feet of flat-lying sediments, which apparently range in age from Red River below to very late Richmond above. Some early collections were made, largely by members of the Geological Survey of Canada. In 1931, an Oxford Expedition, to the Arctic Straits made a significant collection from the island, largely through the efforts of Dr. Ian T. Cox, who (1933) described the trilobites and summarized the section. Later, Foerste and Cox (1936) described the cephalopods, and Oakley (1936) described a coral as *Chaetetes akpatokensis,* a form which proves from his illustrations to belong to *Trabeculites.* The collections made are in the Sedgewick Museum of Cambridge University. Inquiry addressed to Dr. O. M. B. Bulman concerning some of the forms resulted in the loan of the unworked part of the collection, with significant specimens of the Calapoecias, which Cox (1936) had studied. Much labor was saved the writer, for sections of the previously unstudied colonies were made at the Sedgewick Museum.

Foerste and Cox (1936) suggested correlation of the interval from sea level to 270 feet with the Nelson River limestone, the interval from possibly 350 feet to 650 feet with the Shamattawa limestone and Red River formation, and the remainder with very late Richmond. Some perplexities are involved here: first, because some intervals for which faunal information was sparse or wanting are left out; second, because there is an anomaly in comparing the views by Foerste and Cox with those previously reached by Foerste and Savage (1927), for the latter had concluded that the Shamattawa limestone was the equivalent of the Stony Mountain formation, the underlying Nelson limestone correlating with the Red River. Foerste and Cox, however, continue correlation of the Shamattawa limestone with the Red River of southern Manitoba. The earlier view of Foerste and Savage seems essentially correct.

The present faunal information is, as indicated by the conclusions of Foerste and Cox, a little inadequate in certain parts of the section. If the reported range of trilobites is correct, *Cerarus tuberosus, Ceranrinus daedalus,* and *Pterygometopus franklini* agree with the coral *Calapoecia anticostiensis* in ranging from 350 feet to 450 feet in the section, whereas *Calapoecia coxi* seems confined to the 350- to 400-foot elevation. The presence of *Huronia septata* at the 650-foot elevation, a species described from the Shamattawa limestone, suggests equivalence of beds at that elevation with the Shamattawa limestone. *Shamattawaceras ascoceroides* occurs at 450 feet; so this interval (450 feet to 650 feet) is logically embraced by the Shamattawa limestone. The trilobites common to the 450-foot elevation and those at 350 feet indicate extension of the Shamattawa equivalent at least down to 350 feet.

The corals here prove most interesting. *Calapoecia ungava* ranges from sea level to 350 feet; *C. anticostiensis* ranges from 350 feet to 450 feet; *C. coxi* ranges from 350 feet to only 400 feet. This is most surprising, for in New Mexico it is only in the Cutter, latest Richmond, that a *Calapoecia* occurs indistinguishable from *C. coxi.*

Crenulites akpatokensis is known from several specimens. Some are of uncertain horizon, records being wanting, but all others were found only at sea level. This species plainly belongs in the Red River interval.

Trabeculites maculatus occurs only at 325 feet; it is uncertain whether this interval, which seems not to have yielded other fossils, should be considered as Red River or Shamattawa-Stony Mountain. On the one hand, *Trabeculites keithae* is a species of the Red River Second Value formation in New Mexico; on the other, the tiny form that Oakley described as *Chaetetes akpatokensis* has also the structure of *Trabeculites* and constitutes a third species of the genus. This form is from the 450-foot elevation.

The only other colonial corals are two species from the 800-foot elevation; the only recorded associated form is *Spyroceras* sp., which is not of much help. These are anomalous forms, the generic reference of which involves some subjective elements. They are here described as *Foerstephyllum porosum* and *F. minutum,* but others might prefer to assign them to *Paleofavosites.* Morphologically, they supply a link between *Foerstephyllum vacuum* of the Richmond of the Cincinnati arch and *Paleofavosites sparsus* of the Second Value. Obviously, true *F. vacuum* and the two Akpatok species are younger than *Paleofavosites sparsus,* but these forms are regarded as representing a lineage transitional from the dominantly older *Foerstephyllum,* the oldest known species of which appears in the Chaumont limestone, and the dominantly younger *Paleofavosites,* of which our *P. sparsus* is the oldest species that is certainly a typical representative of the genus.

The changes in concept that may result from close study of the corals of any of these associations, and the need for interpreting recorded lists with some reservation, are shown by the contrast between the Akpatok corals as interpreted above, from a restudy of the specimens, and the citations that Bassler (1950) collected from published and unpublished lists.

BAFFIN ISLAND

The sections on Baffin Island comprise some 300 feet of sediment containing a fauna that is dominantly Red River in aspect; clear evidence of overlying Richmond beds is wanting. The following list of corals has been compiled, with revisions, from Bassler (1950), Roy (1941), and Miller, Youngquist, and Collinson (1954):

Calapoecia cf. *coxi* Bassler
Calapoecia anticostiensis Billings
Plasmopora lambei Schuchert
Plasmopora pattersoni Roy
Catenipora sp. (*Halysites agglomeratiformis*)
Catenipora sp. (cf. *H. gracilis*)
Lyellia affinis
Favistina sp. (*Favistella alveolata*)

CAPE CALHOUN REGION

The strata at Cape Calhoun present some problems, but the faunas were well studied and illustrated by Troedsson (1926, 1929), whose treatment of the corals is notable as the first work done on North American faunas in which sections were generally employed, and the results remain today clear enough to make generic position certain, and are detailed enough to permit really adequate comparison at the specific level. Some of the species have been transferred generically (Bassler, 1950), and we have in the present work one further modification that applies the more modern distinctions of Sinclair to the cateniform species.

Stratigraphically, the results are less adequate. Troedsson (1929) presented a section, but recognized only two formations, the lower Gonioceras Bay formation, regarded as of approximately Black River age, and the overlying Cape Calhoun formation, which contains a succession of faunas. Certainly the upper beds, with cf. *Leptaena unicostata*[6] are of Richmond age, and below them is a trilobite zone, also showing affinities with the Maquoketa, but still lower are massive beds which yielded some if not all of the species of Red River affinities. It is in the lower part of the section that there are anomalies which led Koch (1929) to separate it as the Troedsson Cliff formation. Flower (1957), noting the presence of true *Vaginoceras,* reported as being confined to the basal beds, a genus not otherwise known in post-Black River strata, and the presence of *Actinoceras* of Black River types, suggested that the Cape Calhoun may include too much, and that there may be here beds of pre-Red River age. It is not, however, evident whether the recognition of the Troedsson Cliff formation as a distinct entity or the inclusion of these

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[6] Wang (1949) has transferred this Maquoketa species to his new genus *Megamyonia.*

beds with the Gonioceras Bay formation would be the better course. Vexingly, much of the Cape Calhoun fauna is not precisely zoned; I understand that much of the material was collected loose at the foot of a cliff, so that it is not definitely known that the *Actinoceras* of Black River aspect came, as did the *Vaginoceras,* from the basal beds. Neither is there precise information as to the associations in the lower part above the *Vaginoceras* beds, where certainly Red River cephalopod types were concentrated, nor as to which forms came from the upper beds. *Protrochiscolithus kiaeri* here has counterparts in the Red River of Manitoba and in the Second Value of New Mexico, suggesting seemingly the general Red River correlation, but an additional species from the Aleman of New Mexico brought to light the astonishing fact that the Aleman species and *P. kiaeri* agree in having a vesicular columella, whereas that of *P. magnus* and *P. hembrilloensis* is, amazingly, bacular instead. One is tempted to suggest that *P. kiaeri* may have come from the upper beds with *Leptaena unicostata* and may be of Richmond age, but this can, at present, be only a surmise.

The following summary of the corals is largely from Troedsson (1929) and Bassler (1950), with a few minor revisions based in part upon slides in the U.S. National Museum collection, and in part upon Troedsson's illustrations, which permit distinction of *Manipora* and *Catenipora* in the cateniform types:

Gonioceras Bay formation

Billingsarea parvituba (Troedsson). Slides in the National Museum confirm the columella and its structure as piles of spheres of poikiloplasm. If *Billingsarea* is to be recognized at all as distinct from *Nyctopora,* this species must be placed in the genus.

Cape Calhoun formation

Manipora sp. (*Halysites gracilis*)
Manipora cf. *fieldeni* Etheridge
Catenipora cf. *agglomeratiformis* (Whitfield)
Calapoecia arctica Troedsson
C. borealis Whitfield
C. huronensis Billings
Foerstephyllum cf. *halli*
Saffordophyllum cf. *franklini*[7] (Salter)
Protrochiscolithus kiaeri Troedsson
Plasmopora lambei Schuchert
Syringopora conspirata Troedsson
Paleophyllum halysitoides Troedsson
Paleophyllum cf. *stokesi* Edwards and Haime
Labyrinthites monticuliporoides Troedsson
Tetradium tubifer Troedsson
Solitary corals are not listed.

SCATTERED ARCTIC OCCURRENCES

Under this heading are brought together notes on corals from other arctic occurrences. Bassler (1950) has collected these citations, and it is pointless to repeat his work. It will suffice to note that there are many occurrences from which corals have been described or cited; references vary from descriptions to citations, and material ranges from really adequate specimens to odds and ends picked up at isolated localities on various arctic expeditions. A few occurrences are worthy of special note. The widely cited *Halysites agglomeratiformis* Whitfield and *Calapoecia borealis* came originally from Cape Harrison, Princess Marie Bay, Ellesmereland. Until the types are studied by sections, identification of these forms must remain somewhat doubtful. *Catenipora aequabilis* Teichert described from Iglulik Island, with which *Halysites fieldeni* Wilson 1931 from Putnam Highland, Baffin Island, is probably identical, is unique among the northern forms in the extremely small lacunae; the only comparable form comes from the other end of the belt of boreal faunas, and is a form with even smaller lacunae, *Catenipora* cf. *jackovickii* (Fischer de Waldheim) reported from the Burnam limestone of central Texas by Duncan (1956). In the discussion of the Cape Calhoun faunas, attention has been called to the dilemma posed by *Columnaria franklini* Salter. The original came from Polaris Bay, Hall Land. It is not very adequately known from the type or original description, but Troedsson found at Cape Calhoun a form with corallites of a similar size and similarly spaced tabulae, which he identified as that species. This form is a good *Saffordophyllum.* Troedsson's conclusion was eminently logical, but our material from Akpatok Island contains a very different form, *Trabeculites maculatus,* which also has very similar proportions of corallites and spacing of tabulae. Though we have retained Troedsson's specific conclusion and given the Akpatok form a different name, inasmuch as *C. franklini* agrees with both and came from a locality about as far from Cape Calhoun as from Akpatok Island, it seems that the dilemma can be resolved only by restudy of the type.

EASTERN NORTH AMERICA

LAKE ST. JOHN, QUEBEC

For eastern North America our information is more precise, but it still contains some vexing gaps. Of particular interest is the section at Lake St. John, Quebec. The lower part of this section has been revised by Sinclair (1953). There can be no question that *Quepora quebecensis* occurs with *Paleophyllum rugosum* in the Simard limestone of Black River age. The former has been refigured by Sinclair (1955), and the latter by Hill (1959). Above the Simard limestone are strata of Trenton age; the top of this sequence is apparently Coburg in age and affinities. However, Snake Island contains a series of strata that are materially younger and have been called Richmond. It is this horizon which is the source of *Crenulites rigidus* (Billings) and *Crenulites? blainvilli* (Billings), as well as of *Saffordophyllum goldfussi* (Billings), a form with 12 septa, which, from its fibrous walls, is here transferred from *Nyctopora.* Bassler also (1950) cites from here *Tetradium shideleri.*

ANTICOSTI ISLAND

Though Twenhofel (1928) has summarized the faunas of the Anticosti section, and Bassler (1950) has listed the corals with generic revisions, there remain vexing gaps in our knowledge of the corals. *Paleofavosites prolificus* (Billings) is supposed to range throughout the entire section; it cannot be

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[7] Salter's type not being available, this determination is accepted tentatively. It should be noted here that the type of *franklini* agrees also in proportions with *Trabeculites maculatus* from Akpatok Island, and the type of the species came from about halfway between Cape Calhoun and Akpatok Island.

identified with certainty, and there can be little doubt that revision will show that there is included under this name more than a single species. The types have not been figured, and different proportions are reported by various authors. *P. capax* is not much better known, but is reported only from the English Head, Vaureal, and Ellis Bay formations, not penetrating the higher strata of Silurian age.

Bassler's lists (1950) summarize the other corals; of particular interest are *Paleophyllum vaurealense* (Twenhofel) from the Vaureal formation and *Saffordophyllum goldfussi* (Billings) from the English Head.

EASTERN QUEBEC

Bassler (1950) lists the corals of the Whitehead formation. It should be noted that the form identified as *Saffordophyllum goldfussi* is typical, agreeing with the Lake St. John and the Anticosti forms. Others are *Calapoecia anticostiensis, Lyellia affinis,* and cateniform types listed as *Halysites gracilis* and *H. catenularia.*

SOUTHERN ONTARIO

Corals of the Liskeard and Haileybury formations of the Lake Timiskaming region are listed by Bassler (1950). Of particular interest is a *Paleophyllum* in both formations, identified as *P. stokesi* Edwards and Haime. *Plasmopora lambei* is also recorded from both formations, as are species of *Favistina* listed as *alveolata, discreta,* and *minima,* and "*Halysites gracilis.*" *Saffordophyllum goldfussi,* the typical form, occurs only in the Liskeard formation.

In southern Ontario, the Meaford member of the Richmond contains a significant coral assemblage, with *Calapoecia huronensis* (type locality included), *C. ungava* (identified by Bassler), *Favistina* sp., *Foerstephyllum* sp. (an undescribed form, but of the *F. halli* group, and not of the *F. vacuum* group), *Favistina calicina* (Nicholson), *Saffordophyllum* cf. *goldfussi* (Billings), and *Protarea richmondensis* Foerste. Species here have been assigned to the unknown species *Paleofavosites prolificus* and *P. capax. Tetradium ontario* is listed by Bassler.

Here are involved the types of *Calapoecia huronensis* and of *Houghtonia huronica,* its supposed synonym. Thinsection examination of type or topotype material is still needed.

The overlying Kagawong limestone contains a smaller fauna, but fewer species and no additional ones; namely, *Calapoecia huronensis, Favistina* sp., and *Saffordophyllum goldfussi.* Some of these corals persist where the Richmond grades eastward into the Queenston facies; Bassler (1950) has listed these forms.

CINCINNATI ARCH

In the Cincinnati arch, colonial corals appear sparingly in the Cynthiana limestone, then disappear from the section and reappear only well up in the Richmond. The Cynthiana forms include *Columnaria alveolata interventa* Foerste, which, from the illustrations of the types, seems to contain a *Saffordophyllum,* possibly a *Crenulites,* and a form with such long septa that it seems to be a *Cyathophylloides* rather than a *Favistina.* This association is confined to the Benson member. The Millersburg member has yielded *Favistina minima* (Foerste). In addition, Bassler (1950) cites *Tetradium fibratum* Safford and *Foerstephyllum halli* (Nicholson).

Bassler (1950) cites a *Favistina* (*Favistella alveolata*) and *Tetradium* cf. *fibratum* from the Maysville of the Ohio Valley. Both are of extremely exceptional occurrence, but southward in southern Kentucky and Tennessee *Tetradium* becomes very abundant in the Leipers formation. Bassler cites *T. fibratum*(?) Safford and *T. unilineatum* Bassler, the latter a form with distinctive cateniform growth.

The Arnheim of the Cincinnati arch has yielded, according to Bassler (1950), *Calapoecia* (*huronensis* listed), *Favistina* (*Favistella alveolata* listed), and *Protarea vetusta.* Bassler described *Favistella magister* from the Arnheim of Tennessee. This species is now known to occur also high in the Richmond, from the Saluda by lithology, at Madison, Indiana.

The Waynesville of the Cincinnati region yields only one colonial coral in abundance, *Protarea richmondensis* Foerste. *Calapoecia huronensis* Billings, *Favistella alveolata* Goldfuss, *Nyctopora foerstei,* and *Saffordophyllum* cf. *goldfussi* Billings are reported.

Bassler (1950) lists essentially the same species for the Liberty. It is in this formation that the familiar "Bardstown coral reef" is developed at Bardstown, Kentucky, in which *Favistina* cf. *stellata* occurs, a form with small corallites and long septa; here also is *Calapoecia huronensis.* Bardstown is the type locality of *Foerstephyllum vacuum* Foerste. *Tetradium* is represented by *Tetradium ontario* Hall.

The Saluda contains significant coral biostromes, and interfingers with the Whitewater lithology. Bassler cites *Protarea richmondensis,* largely a species of the Whitewater facies. The Saluda coral beds contain *Foerstephyllum vacuum, Calapoecia huronensis,* and *Favistina.* Forms with small corallites and long septa, like those of the Bardstown Liberty occurrence, are present, but there are others, with larger corallites and shorter septa; perhaps two species are involved. In addition, *Favistina magister* occurs here, and a new species, *F. crenulata,* is described in the present work from the Whitewater of Weisburg, Indiana. Bassler cites *Foerstephyllum vacuum, Favistella alveolata, Protarea richmondensis,* and *Tetradium ontario* from the Elkhorn.

MAQUOKETA SHALE

The Maquoketa has yielded only a few corals. The zonation of species has not been recorded. The only colonial forms are as follows:

Crenulites ulrichi (Bassler)
Protarea richmondensis Foerste

Beds identified as Maquoketa in Wisconsin are the source of *Halysites gracilis* Hall, a virtually unknown species, the type of which has been lost (Sinclair, 1956). A *Favistina* (*Favistella alveolata*), a *Paleophyllum* (called *stokesi*), and the ubiquitous *Protarea richmondensis* complete the list.

FERNVALE

No colonial corals seem to be listed for the Fernvale of Tennessee; for the Fernvale of Missouri and Oklahoma the only colonial form reported is a *Tetradium, T. occulatum* Bassler.

MICHIGAN RICHMOND

Here are equivalents of the Whitewater (Stonington beds) and Elkhorn (Big Hill beds). Bassler (1950) shows here an interesting mixture of eastern types on the one hand and of boreal types on the other:

Calapoecia cf. *huronensis*
Favistina sp. (*alveolata* cited)
Catenipora (*Halysites* sp.)
Saffordophyllum goldfussi
Paleofavosites (*asper* cited)

Paleophyllum (*stokesi* cited)
Protarea richmondensis Foerste
Tetradium ontario Hall

CONCLUSIONS

The above citations have been given in some detail because of the necessity of interpreting the available published evidence. For example, *Paleofavosites asper* d'Orbigny is a species from British Silurian Wenlock, not properly recognized in the American Ordovician. Citations may mean little more than the presence of a cerioid coral without evident septa, which might be a *Paleofavosites. Paleofavosites capax* and *P. prolificus* are widely cited species; the originals are from Anticosti, but until these species are revised, they cannot be recognized with certainty. Citations vary from indications suspect, even at the generic level, to adequately illustrated and described specimens from the Stonewall formation of Manitoba (Stearn, 1956). Though the application of these specific names to the Manitoba material must still remain uncertain, there are at least forms in Manitoba well enough known for comparison with new material at the specific level. *Paleophyllum stokesi* (Edwards and Haime) is a widely cited species, and certainly such citations indicate the presence of a true *Paleophyllum* in most, possibly in all, instances. However, *Columnaria stokesi* has, from the original illustration of the species, branches connecting the phaceloid corallites, unknown in true *Paleophyllum,* but characteristic of the Silurian genus *Eridophyllum.* Miss Helen Duncan has suggested (*fide litt.*) that perhaps the original came not from the Ordovician but from the Silurian exposed in the vicinity of Lake Winnipeg. Citation of this species largely signifies the presence of true *Paleophyllum* in the typical Red River, north into the arctic, south into the Bighorn group, and east to Timiskaming and Gaspé.

Anomalies to be expected in migrating faunas have already been discussed, and the further limits of correlation are imposed by inadequate knowledge of the corals in many of the western Ordovician faunas. With these limitations, it remains to note what affinities the corals of the several Montoya formations indicate.

The association of *Manipora* and *Catenipora* in the Second Value is a feature of most Red River assemblages. *Manipora* is known as yet only from Red River faunas, extending north to Cape Calhoun. *Catenipora* is unknown in the eastern Richmond and is as yet only sparingly recorded in western Richmond beds. Its presence there is to be expected, for the genus continues up into the Silurian.

Saffordophyllum is a wide-ranging genus, appearing in the Chazyan McLish formation of Oklahoma. The two youngest typical species known are *S. newcombae* of the Second Value and *S. franklini* as identified by Troedsson in the Cape Calhoun of Greenland. Eastern species, which probably include two distinct forms, one of Lake St. John and Gaspé, the other of Cincinnati and southern Ontario, have been included under the specific name *goldfussi.* Both have 12 major septa instead of the usual 8, wherein they agree with many other species of the genus, and their fibrous walls required a transfer from *Nyctopora,* to which these forms had been assigned previously. The matter is discussed more fully in the description of *Saffordophyllum* in the systematic portion of the paper.

Nyctopora is another wide-ranging genus, appearing in the Chazy and continuing into the Richmond. *N. foerstei* of Cincinnati is typical in all essential features, and distinctive mainly in the strong development of poikiloplasm. The Second Value formation has yielded *Nyctopora mutabilis,* a species peculiar in the rhythmic thickening and thinning of the walls. Such *Nyctopora* of the Burnam limestone as have been observed are not closely similar. Hill (1959) figured a species with small corallites from the Montoya outlier in Arizona, which is again distinctive. The coral bed of the Aleman has yielded *Nyctopora nondescripta. Nyctopora* has not been reported from more northern occurrences of Red River strata. Our present observations of *Nyctopora*(?) *parvituba* from the older Gonioceras Bay formation of northern Greenland confirm Bassler's (1950) suggestion that it is properly a *Billingsarea,* which is essentially a *Nyctopora* in which spheres of poikiloplasm form a columella. Elsewhere the genus is recognized in the Chazyan of the Mingan Islands, Montreal, and Lake Champlain, and in beds of Chazyan or possibly slightly later age in the Appalachian Valley.

Trabeculites, first recognized on the basis of *T. keithae* of the Second Value, is represented by *T. maculatus* from an elevation of 335 feet on Akpatok Island, a horizon which is either high Red River or low Shamattawa-Stony Mountain, whereas the much smaller *T. akpatokensis* (Oakley) occurs there at a 450-foot elevation. Possibly *Saffordophyllum tabulatum* of the Lebanon limestone may prove to be a *Trabeculites;* present figures suggest the possibility, but are not conclusive.

Calapoecia is a widespread genus, appearing first in beds of late Black River age, disappearing from the section for a time, but reappearing in Red River and Richmond beds. Previous confusion as to the species limits the value of available records. The Second Value has yielded a fragment of the *C. anticostiensis* type, which is unquestionably identical with a form from the Selkirk limestone of Manitoba. Present figures and descriptions limit possibilities of close comparison with the typical *anticostiensis* form. The Aleman has yielded another scrap of a colony, which appears to be of the general type to which the name *C. ungava* has been applied, whereas the Cutter *Calapoecia* is unquestionably *C. coxi,* agreeing with it in the cross-section of the trabeculae and, in this respect, contrasting rather strongly with *C. huronensis* of the Cincinnati and southern Ontario Richmond. The Cutter form is distinctive in showing disruptive canals, common in *C. huronensis,* but also present, though much more sparingly developed, in typical *C. coxi.* The hoped-for correlation with the occurrence on Akpatok Island was not found; there, *C. ungava* occurs in the basal 350 feet of Red River age, *C. coxi* is known only from the 350- to 400-foot elevation, an interval apparently low in the Shamattawa-Stony Mountain equivalents, whereas *C. anticostiensis* ranges slightly higher, occurring in the interval from 350 feet to 450 feet.

Protrochiscolithus presented interesting problems in correlation. *P. hembrilloensis* of the Second Value is quite close to *P. magnus* of the Red River of Manitoba; further correlation with the Cape Calhoun was at first suggested, where *P. kiaeri* occurs, and such an extension into the Cape Calhoun, where there are elements of undeniable Red River affinities, seemed most logical. Subsequently, however, there came to light *P. alemanensis* from the Aleman formation, extending the range of the genus into beds of definite Richmond age. Sections revealed that *P. magnus* had a bacular columella, which is presumably shared by *P. hembrilloensis,* whereas *P. kiaeri* and *P. alemanensis* had vesicular columellas instead.

This fact raises some interesting questions that cannot be answered now, but should be kept in mind in relation to future studies of the genus. One is tempted to suggest that Red River species had bacular, and Richmond species vesicular, columellas. Such a generalization applies to the Montoya species. The Red River *P. magnus* of Manitoba is consistent with the hypothesis. It is not known, however, from what part of the Cape Calhoun *P. kiaeri* came; if from the upper beds with *Leptaena* cf. *unicostata* (now properly a *Megamyomia;* see Wang, 1949), it is also in all probability of Richmond age, but such a stratigraphic assignment lacks support because the range of this, as of many other species in the Cape Calhoun section, is not precisely known.

Coccoseris astomata is the first published record of the genus *Coccoseris* in North America, but it is not the first find. The genus had been recognized earlier by Miss Helen Duncan in the Burnam limestone of central Texas. We have compared the material, and it seems that the two occurrences represent a single species. The value of negative evidence, the lack of reports of the genus in more northerly Red River faunas, is questionable. This is a nondescript encrusting form. At a glance, one would suspect that it is more probably a bryozoan or a stromatoporid than a coral; so it seems not unlikely that it may be more widely distributed, but has escaped notice. Indeed, some figures of Leith (1952) suggest that possibly some colonies identified with *Protrochiscolithus magnus* (Whiteaves) might be representatives of a *Coccoseris* similar to *C. astomata* in lacking obvious corallite cavities.

Favistina is a genus of wide occurrence in the North American Ordovician. Previous treatments of the genus involve the identification of colonies of generalized aspect with *Favistella alveolata* Goldfuss and the assumption that that species, which cannot be recognized with certainty, is most wide ranging. Without figures and measurements, it is not possible to evaluate many occurrences, and as such information is commonly lacking, it has been necessary to work instead from such comparative material as could be accumulated. Some forms that had before been given trivial names have been restudied and revised, and some new ones have been described, but there remains a need for a more comprehensive study of the genus. It is, however, interesting to note that the one Montoya species, which occurs in the late Richmond Cutter formation, is extremely close to a specimen attributed to *Favistella stellata* Hall from the Saluda beds of Richmond, Indiana, thus supporting the suspected late Richmond age of the Cutter. Future work is needed to determine whether somewhat different forms with slightly smaller corallites and longer septa, which represent the genus *Favistina* exclusively in the Bardstown coral reef in the Liberty of Kentucky, but which also occur in the Saluda at Madison, Indiana, should be separated specifically. It is of interest that the proportions of the Cutter specimens are duplicated by those in the Saluda, but have not been found in specimens from the earlier Liberty beds.

In the systematic portion of this work, the possibilities of intergradation of *Favistina* and *Cyathophylloides* have been noted, though current usage is followed in recognizing the genera as distinct. The Montoya has yielded an abundant and characteristic form, *C. burksae,* in the coral horizon of the Aleman, and the Cutter has yielded a small fragment, specifically undeterminable, with the general aspect of the genus. From one possible viewpoint, the occurrence of *Cyathophylloides* is possibly long ranging in the later Ordovician of western North America. Duncan (1956) has noted the occurrence of the genus in the Burnam limestone of central Texas and the Hanson Creek formation of Nevada. Bassler's (1950) *Cyathophylloides ulrichi* of the Maquoketa shale proves to have amplexoid septa, and is removed to the new genus *Crenulites.*

From another possible viewpoint, dismissing for a moment the distinction between *Cyathophylloides* and *Favistina,* an imperfect but interesting parallel is found between the Montoya and Cincinnati occurrences. In both sections relatively early Richmond beds, the Liberty of Bardstown, Kentucky, and the Aleman coral zone, contain forms with rather small corallites, long septa, and arched tabulae to the exclusion of other types. The higher beds contain forms with larger corallites, shorter septa, and tabulae which, though variable, are less consistently arched upward. Whether there is any significance in this similarity must be left for investigations of wider scope and more material, but significance now seems possible. If so, it is somewhat obscured by the current interpretation in terms of genera and species. Lacking conclusive evidence to the contrary, the present work has followed most recent students (Bassler, 1950; Duncan, 1956; and Hill, 1959) in recognizing a distinction between *Favistina* and *Cyathophylloides.* Again, lacking adequate material to show the two forms to be distinct, those specimens in the Cincinnati section having smaller corallites and longer septa, and those with larger corallites and shorter septa, have been placed together tentatively under *Favistina stellata* (Hall). However, both of these assumptions may prove incorrect. If so, some parallel between the Cincinnati and Montoya successions may be more significant than now appears.

Crenulites, an amplexoid edition of *Favistina* with specialized tabulae, was at first known to me only from the two specimens from the Second Value of the Montoya group, but other species were recognized as the investigation proceeded. *Crenulites ulrichi* (Bassler) is unquestionably a member of the genus; it is from the Maquoketa formation of Iowa; unfortunately, its position there in relation to the several members is not stated. The genus occurs in the "Richmond" of Snake Island, Lake St. John, Quebec, and is certainly represented by what Billings described as *Columnaria rigida;* illustrations of his *C. blainvilli* suggest a similar assignment. These occurrences may not be of Richmond age as has been generally supposed, for some recent work has suggested that the Maquoketa may be in part Covington in age (Maysville and Eden), and the beds at Lake St. John show some affinities with those of the English Head formation of Anticosti, which Sinclair (1956) has suggested may be of Maysville age. Another species, *C. akpatokensis,* occurs at the base of the section on Akpatok Island in beds certainly of Red River affinities. It has been noted too that part of what Foerste described as *Favistella alveolata interventa* from the Benson member of the Cynthiana formation in Kentucky appears, from the original illustrations, to be a *Crenulites* also. The genus remains one in which isolated occurrences involve distinct species, ranging from occurrences of certain Red River age in the Montoya and on Akpatok Island, to possible Richmond in Iowa and at Lake St. John, and possibly invades the east in the Cynthiana limestone of Kentucky.

Paleophyllum makes its first appearance in the Simard limestone of Lake St. John. This is so far its only known occurrence in beds of Black River age. It is widespread in beds of Red River age, ranging from Cape Calhoun on the north to the Second Value formation of the Montoya group. Intervening regions, however, have yielded forms not closely studied at the specific level, and assignment has been to the species *stokesi*, which is possibly not a *Paleophyllum* and possibly not even Ordovician. It may be suggested also that the species which Miss Wilson (1926) assigned tentatively to *Diphyphyllum* from the Beaverfoot formation of British Columbia may be true *Paleophyllum*. In the Montoya, the Second Value formation of Red River age has yielded three species, *P. gracile, P. margaretae,* and *P. cateniforme,* readily distinguishable on the basis of corallite size, but with other more significant differences in septa and tabulae. The species common in the coral zone of the Aleman is true *Paleophyllum thomi,* a species similar in gross aspect to *P. margaretae,* but very different in septal and tabular features. The western Richmond certainly contains some similar forms, but it is hard to evaluate most reports at the specific level. Stearn (1956) has described *P. pasense* and *P. pasense parvum* from the late Richmond Stonewall formation.

Interpretation of citations of *Paleofavosites* from previous reports is highly uncertain. It is quite possible that many such reports rest upon cerioid corals without obvious septa, and may well involve other genera, possibly *Saffordophyllum* and *Foerstephyllum.* The Montoya section has yielded a single rather anomalous species, *P. sparsus,* in the Second Value formation. The Aleman contains two species that lack all septal structures, *P. kuellmeri* and *P. prayi,* readily differentiated by corallite size. The Cutter contains again two forms separable on corallite size. The form with smaller corallites has been represented by rather sparse material, not very well preserved, and is tentatively assigned to *P. prayi.* The form with larger corallites proves to be distinct both from the older *P. kuellmeri* in development of crenulated tabular margins and from *P. okulitchi* in proportions, as well as in having pores confined to the corallite angles.

A perplexing dilemma as to relationships remains in the case of species previously assigned to *Paleofavosites* possessing septal spines and pores. Such species have previously been rather generally assigned to *Paleofavosites,* and such features are found in the inadequately known specimens from Anticosti included in *Paleofavosites prolificus* and *P. capax.* These names have been widely used in identifying material from other regions, but most such citations cannot be evaluated without recourse to the original material. Stearn (1956) however, has supplied adequate descriptions and figures of specimens identified in terms of these species in the Stonewall formation of Manitoba. In the genus, however, the present study has encountered two overlapping but distinct dilemmas. First, there is a group of similar species with distant lax tabulae, and with segments of corallite walls curved, which bear a close resemblance one to another, and which seem to transgress the boundaries between *Foerstephyllum* and *Paleofavosites.* In this group of species are involved topotype material of *Foerstephyllum vacuum,* some other occurrences identified in terms of that species, and two species here described as *Foerstephyllum porosum* and *F. minutum,* from a high horizon on Akpatok Island; these last two forms have spines and much of the aspect of *Foerstephyllum* of the *vacuum* group, but by their pores they would be assigned to *Paleofavosites.* The final member of the series is a species very similar to these in aspect of tabulae and corallite walls, though lacking spines, which is described as *Paleofavosites sparsus* from the Second Value of the Montoya group. I am uncertain as to whether others would agree with these generic assignments, but close relationships are strongly evident, and quite possibly redefinition of genera and redrawing of their boundaries are needed.

A separate but possibly overlapping problem is supplied by possible integradation of spinose species assigned to *Paleofavosites* with species assigned to the genera *Angopora* and *Corrugopora.* Without evidence supplied by wall structure, leaving only gross features on which to base conclusions, there is apparent gradation of both of these genera with spinose species of *Paleofavosites;* on the other hand, fine structures of these genera may, when made known, show that they are not closely related to *Paleofavosites* at all, but allied instead to *Nyctopora* or *Saffordophyllum.*

As can be seen, with the three coral faunas of the Montoya largely represented by new species, close or definite correlations are not clearly indicated. Perhaps this is too much to expect; on theoretical grounds migrating faunas may produce anomalies among the various sections, but many of the anomalies may appear less real when more is known of the corals of equivalent faunas of western Red River and Richmond affinities. Many genera are wide ranging, but occasionally affinities between species may indicate some correlation.

In general, the Second Value shows several imperfect indications of Red River age in its corals at the present time. Only in Red River beds are *Manipora* and *Catenipora* known to appear together, and one species, *M. amicarum,* is previously known from the Selkirk limestone. The same identity is certain for our *Calapoecia anticostiensis,* but the species is more wide ranging in other regions, as at present interpreted. *Protrochiscolithus hembrilloensis* is very close to *P. magnus* of the Selkirk limestone. The *Coccoseris* is identical with one from the Burnam limestone yet unfigured and undescribed, and possibly a *Coccoseris* in the Selkirk is involved in material currently determined as *Protrochiscolithus magnus.* On Akpatok Island congeners of *Trabeculites* and *Crenulites* occur low in the section, the latter certainly and the former possibly in beds of Red River faunal affinities, but both genera range into assumed Richmond strata.

The Aleman has yielded no species in common with other regions, but the *Protrochiscolithus* is close to *kiaeri* of the Cape Calhoun formation of Greenland, and the only other *Pragnellia* known is from the Gunn member of the Stony Mountain formation of Manitoba.

The smaller Cutter association yielded a *Favistina* indistinguishable from one included in *stellata* occurring in the Saluda, but not lower, in the Cincinnati region. The *Calapoecia* is, surprisingly, *C. coxi,* which occurs at a low Richmond horizon on Akpatok Island, and is certainly not *C. huronensis* of the upper Richmond of the Cincinnati region. It was a disappointment that the *Paleofavosites* could not be regarded as conspecific with *P. okulitchi* of the Stonewall formation of Manitoba, but the conclusion was unavoidable.

It will be of interest to see what changes are required in the present conclusions when corals in the later Ordovician of regions to the north and west have been subjected to closer study.

Coral Morphology and Relationships

GENERAL CLASSIFICATION

The corals, which are polyps that secrete skeletons, and the sea anemones, which form no hard parts, together make up the Anthozoa or Actinozoa of the phylum Coelenterata. Classifications vary somewhat, but a suitable basis for discussion is found in the recognition of two major divisions, the Alcyonaria (or Octocoralla) and the Zoantharia. The Alcyonaria possess always eight pinnate tentacles and eight mesentaries; the Zoantharia have numerous tentacles, which are never pinnate, and numerous mesentaries, which are always arranged in pairs.

In the Octocoralla belong polyps that form hard parts by the solidification of spicules which appear first in the mesoglea, the noncellular jellylike layer which precedes the cellular mesoderm in development and is common to all Coelenterata.[8] In addition, in some forms the ectoderm secretes other material, commonly horny, at the base of the polyp. It is such material that comprises the horny axes in a colony of *Gorgonia.* The Octocoralla are not definitely known in the Paleozoic, though from time to time various Paleozoic organisms have been referred to the group more or less tentatively. General similarity of hard parts between the living genus *Heliopora* and the Silurian genus *Heliolites* has given rise to one of the several suggestions that the Alcyonaria were represented in the Paleozoic by part or all of the Tabulata, a view not generally accepted.

The Zoantharia include sea anemones, free living forms that secrete no hard parts. Three orders of sea anemones are known. The living corals of this group, the Scleractinia (or Hexacoralla), form skeletons precipitated upon the surface of the ectoderm, in which radial units, septa, appear concurrently in six radial divisions set off by the first six septa. The group is traceable back only to the early Mesozoic. The Rugosa (or Tetracoralla) in the Paleozoic are superficially similar, differing mainly in that later septa are added regularly in four equal quadrants. From all indications, the rugosan skeletons agree rather closely in fine structure with those of the Scleractinia, and assignment to the Zoantharia, though inferential, is generally accepted. In the Paleozoic there is another group of colonial corals, the Tabulata, in which septa are commonly rudimentary or absent. Tabulae (transverse partitions) are prominent, septa obscure or wanting. All are colonial forms, and in some cases pores connect the various corallites. The scope and treatment of this group is a matter of some divergence of opinion. It has been suggested from time to time that all or part of it might be the ancestors of the younger Alcyonaria, a view now not generally accepted. What has been made known of the fine structure suggests, by similarity of structures with those of the Rugosa and Scleractinia, a skeleton secreted by the ectoderm of the polyp, not a solidification of spicules appearing first in the mesoglea. Some genera with moderately developed septa have been variously assigned to the Tabulata and Rugosa, but most students have agreed that although such ambiguities exist, the groups are, in the main, essentially distinct. A more recent suggestion is the separation of those forms, previously assigned to the Tabulata, that divide by binary fission rather than lateral budding, to a group of their own. Such attention as this matter has received has shown any possible merits of the system obscured by differences of opinion as to the proper scope of such a group; it certainly contains the Tetradiidae and Chaetetidae, but opinions as to what other families should be included have differed.

Most students of fossil corals have come to regard the Tabulata, Rugosa, and Scleractinia as three groups already well differentiated before they independently developed the ability to secrete hard parts. The present work, dealing only with colonial corals of a restricted part of the Ordovician, is concerned with forms that have previously been assigned to the Tabulata and to the Rugosa.

GENERAL MORPHOLOGY

Here are summarized briefly the morphological terms in general use for the corals here described. A later section deals with departures from concepts and anomalies of terminology brought to light in the present study.

Colony Form

The corals involved in the present study exhibit three types of colonies. **Phaceloïd** colonies are those in which the individuals remain free, not commonly in contact one with another. Our one phaceloid genus, *Paleophyllum,* is illustrated in Plates 46-52. **Cerioid** colonies are those in which individuals are commonly in contact one with another. These forms make up the greater number of forms discussed in the present work. Where corallites are thin-walled, they are commonly polygonal in cross section; with thickening of the walls, corallite cavities may become rounded. In extreme cases, corallites may appear as scattered round cavities in a broad generalized skeletal meshwork, the **coenenchyme,** best shown in *Calapoecia* (pl. 31).

Cateniform colonies are those in which corallites grow in chains, the chains anastomosing and forming a meshwork. Linear groups, curved or straight, are termed **ranks.** Areas that are enclosed are **lacunae;** the size and shape of lacunae are diagnostic of certain species, particularly where they are small. *Catenipora* cf. *jackovickii* (see Duncan, 1956, pl. 27) has tiny lacunae, each bounded by 4 or 5 corallites; in *C. aequabilis* (Teichert, 1937, pl. 9, fig. 4), the lacunae are bounded commonly by 5-8 corallites. In general, where lacunae are predominantly larger, their size and shape become more variable. Some corals are dominantly cateniform, but where ranks join there may be agglomerative patches, 2-3 corallites in width, shown variously in our several species of *Manipora* (pl. 1-4). There may be gradations between true cateniform and true cerioid colonies. Such forms as *Manipora* cf. *fieldeni* (see Troedsson, 1929, pl. 41) could be considered either as cerioid colonies in which cavities exist between many of the corallites, or as a cateniform coral in which lacunae are small and irregular, and the colony is a meshwork of

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[8] One should note in passing the concept that the Coelenterata might be evolved by degeneration of the mesoderm of turbellarian Platyhelminthes to the coelenterate mesoglea, discussed by Hand (1959).

closely joined ranks. Again, some dominantly phaceloid corals have individuals joined in short linear series, and are thus imperfectly cateniform. Such forms are *Paleophyllum cateniforme* of the present work (pl. 49-50) and *P. halysitoides* (see Troedsson, 1929, pl. 28).

Colonies are formed by the budding of one primary polyp; this polyp is developed from a free-swimming planula. Possibly the early stages of such individuals may show significant ontogenetic development, but beyond the first 0.5-1.0 mm of the length, the parent individuals cannot be differentiated from other members of the colonies. Most individuals are, in the corals encountered in the present study, developed by lateral budding; budding by binary fission is wanting or very rare in the present forms, though it is the dominant condition in the Tetradiidae, an Ordovician family not included in the present study, and the younger Chaetetidae. Chaetetids have, from time to time, been reported in the Ordovician. Bassler (1915) has noted that such reports are based in part upon bryozoans, in part upon dubious material of uncertain nature. Oakley (1936) described a species, *Chaetetes akpatokensis,* from Akpatok Island, but from his illustrations, this is a species of the genus *Trabeculites* and is not properly a member of the Chaetetidae.

CORALLITE

The hard parts secreted by an individual polyp constitute the **corallite.** Diagrammatic relationships of corallite and polyp are presented in Figure 1. Here is depicted a simple coral, such as *Lichenaria.* The wall, here shown as consisting of parallel oblique fibers, is secreted by the addition of material to an oblique surface at its anterior end; this surface is approximately at right angles to the slope of the fibers. As the wall grows, the corallite moves forward, secreting at intervals **tabulae,** primitively flat partitions at its base. Tabulae shut off parts of the skeleton in which there is normally no living tissue; the polyp remains in an anterior region, which is tubular, as shown in the present figure, conical or cup shaped, and anterior to the last tabula, termed the **calyx.** For simplicity, a coral was selected for Figure 1 lacking septa; when septa are developed, they attain their full length in the basal part of the calyx, thinning anteriorly, and wanting or vestigial at the extreme anterior edge. The secretion of septa involves, necessarily, corresponding infolding of the body wall of the polyp.

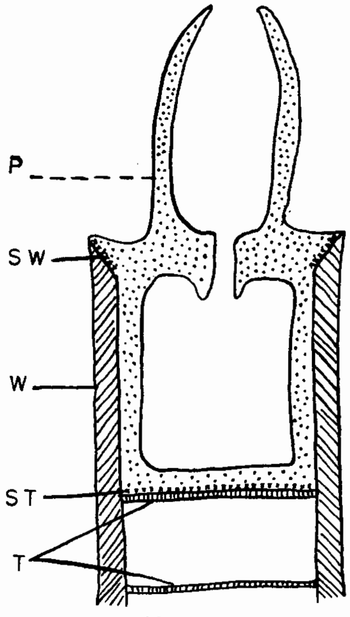

Figure 1

DIAGRAMMATIC VERTICAL SECTION OF CORALLITE, SHOWING RELATIONSHIP OF SKELETON WITH THE POLYP

Polyp (P) shown in a most generalized way with no attempt to differentiate tissues. The wall (W) is secreted by a special portion of the polyp (SW) and grows by addition to its anterior end, which presents an oblique surface; fibers are produced that form a sharp angle, usually close to a right angle, with the growing surface. At the base of the polyp tabulae (T) are secreted periodically by specialized secreting surface (ST). For simplicity, a simple coral without septa is selected for the illustration. Septa, lateral extensions of the wall toward the corallite center, commonly with their anterior surfaces descending from the wall toward the corallite center, require folding of the polyp surface; such folding is primarily lateral in the older corals, but may become confined largely to the basal region.

GROSS CORALLITE MORPHOLOGY

Corallite morphology generally involves a distinction between vertical and horizontal structures. Vertical structures constitute the corallite walls and the septa, which are platelike extensions from the wall toward the corallite center. Horizontal structures are, in their simplest form, simple transverse plates, tabulae. In addition, axial structures are collectively grouped under the term **columella;** they may be formed in various ways. All such structures are not by any means homologous. Outside of the wall individual corallites may be enclosed by an **epitheca,** or a similar covering may enclose an entire colony, which is termed a **holotheca.**

Septa

Their fine structure momentarily being ignored, septa are commonly radial plates extending from the corallite wall toward the center. For reasons explained later, the concept is rejected here that septa are primary longitudinal structures, and that walls, when developed as such, are formed by widened edges of septa either fused directly or joined by supplementary calcareous material. Such conditions, readily apparent in younger corals, are believed to be derived rather than primitive, and the present study has shown the wall to be primitive, and the septa derived from the wall. Septa are commonly each vertical plates extending the length of the corallite, though shortening in the anterior end of the calyx (fig. 2A). The edges may be straight, undulate, or finely serrate. The forms dealt with in the present work show septa without perforations, but some younger corals may have septa with abundant openings within them. In a number of the Ordovician corals, septa are extremely short extensions of the corallite wall, and are properly **septal ridges** (fig. 2B). Their edges may be smooth, undulate, or serrated. When such ridges are short and excavations between the serrations become deep enough to reach the corallite wall, the septa are reduced to vertical rows of discrete **septal spines** (fig. 2C). Such spines may be elongated or may be essentially circular in section; they may be blunt and short or long and slender; they may be pointed up or down, curved or straight. The figure shows such variations, which would not be found in a single column of spines in a single corallite. Caution is to be urged in distinguishing between septal ridges and septal spines; the former are longitudinally continuous, the latter are not. Cross sections of ridges and spines alone may present much the same aspect, except that the full number of ridges

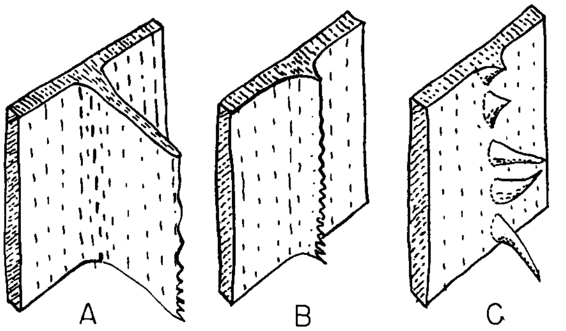

Figure 2

VARIATIONS IN FORM OF SEPTA

Septa shown as extensions from inner surfaces of segments of corallite walls.

A. A typical long, continuous septum, showing variation of the edge from smooth to undulate and to serrate.

B. A septal ridge, differing from A only in brevity; edges may vary from smooth to serrate.

C. Septal spines, showing in one column variations in shape found in different species and genera. Logically, spines may develop from extreme development of serrated ridges, as is apparently true in *Foerstephyllum,* but in the Halysitidae and Syringoporidae septal structures appear as spines and are not preceded by continuous ridges.

is commonly shown in every cross section, whereas cross sections will pass as often as not in regions between the spines, and may show only a few spines, or may miss them altogether.

As will appear later, septal ridges seem to characterize the main lineages of Ordovician corals, but are absent in the supposedly ancestral genus *Lichenaria.* Examples of serrated septal ridges being reduced to spines are known, and are shown most strikingly in the contrast between the dominantly old group of *Foerstephyllum halli,* and the younger *Foerstephyllum vacuum.* There is reason, however, to believe that in the Halysitidae septal spines develop as new structures, not preceded phyletically by ridges; this change marks the boundary of the genera *Quepora* and *Catenipora.* In another lineage, the Syringoporidae, neither ridges nor spines develop in the simpler Ordovician forms, but spines are developed in some younger genera.

Studies of the ontogeny of corals have shown significant features in the relative appearance of septa, ordinarily first the appearance of cardinal and counter septa, then two alar and two counterlateral septa. These together are **primary** or **protosepta;** those added later are **secondary** or **metasepta.** Although a number of the genera here treated have long been considered as belonging to the Rugosa, in which such differentiation may be expected, they show only the faintest suggestion of any such differentiation. The orderly arrangement of septa in ontogeny is a feature confined to those corals that developed from a planula. Such individuals, at the extreme bases of colonies, have been recognizable only in a very few colonies, and where shown, were seen in fragile, etched material. It is evident, however, that essentially mature features are developed in the first 1 or 2 mm of the corallite length. Budding individuals, which commonly contain at their inception one or more of the septa of the parent, show no orderly or regular increase. Although *Streptelasma* and allied genera of solitary corals commonly show a cardinal fossila, owing to suppression of the cardinal septum, and a long counter septum, the colonial forms here considered have shown scarcely any trace of such development, an interesting fact in view of Wang's (1950) treatment of *Paleophyllum* as a subgenus of *Streptelasma.* Some *Favistina* have shown general but not universal development of one rather long septum flanked by two conspicuously shorter pairs. The long septum might be considered a counter septum, but the reality of this interpretation seems not susceptible of proof. Adult corallites with 16 or more septa commonly show alteration of long **major septa** and short **minor septa.** Specific differences are shown in the minor septa. In *Paleophyllum margaretae* they are always developed and are relatively long; in *P. cateniforme* they are generally developed but much shorter; in *P. gracile* and *P. thomi* they are vestigial, a cross section showing only one or two, and even these are mere stubs. The prevalence and length of minor septa vary among colonies of *Favistina,* and it is suspected that there may be real specific differences in the *Favistina* of the Richmond of Cincinnati, though at present both are included under the single species *F. stellata.* In *Nyctopora* and *Foerstephyllum* there is variation, some species showing minor septa markedly smaller than major septa, others showing the two nearly indistinguishable.

A special type of septum exemplified by the genus *Crenulites* described in the present work is the **amplexoid septum,** a name derived from the coral genus *Amplexus.* Such septa appear as ridges on the anterior faces of tabulae, but as they are traced forward they shorten and disappear before the next tabula is reached.

Tabulae

The horizontal structures in the Ordovician corals are simple plates, **tabulae.** They may be simple transverse partitions or may be mainly transverse with edges up- or downturned, and in some cases such edges may be scalloped, as are those of *Crenulites,* which are downturned between the amplexoid septa, or those of some *Paleofavosites,* where there are no septa (pl. 37, fig. 11). They may be arched, up or down. In *Paleophyllum* the conformation of the tabulae is quite diagnostic for the species, being sinuate, the centers uparched, in *P. gracile;* rectilinear, transverse peripherally, then vertical, and nearly horizontal centrally in *P. margaretae;* sinuate with edges faintly upturned, but with submarginal and central depressed regions in *P. cateniforme.* (See pl. 49-52.)

Where tabulae are crowded and irregular, they tend to anastomose, and in extreme cases the corallite is traversed by a series of short irregular intersecting plates. Such plates, which are nothing more than incomplete tabulae, are termed **dissepiments.** In younger corals there is sometimes a peripheral region with dissepiments, the **dissepimentarium,** and a central region with tabulae, the **tabularium,** but no forms showing these features are encountered in the present study.

The form and spacing of tabulae tends in general to be more variable in the Ordovician corals than the septal features. Commonly, early stages show tabulae more widely spaced than do adult stages. A number of these corals show alternative zones of widely spaced and of crowded septa; crowded zones commonly occur at the same level throughout a colony. It has been suggested (Ma, 1954) that alternate zones of widely spaced and of crowded tabulae indicate growth in a temperate climate, the crowded zones representing retarded growth in the cool season. It was at first thought that this might apply to the corals of the Montoya, but it became apparent that alternation of crowded zones was developed in some, but not all, of the species, and it is hard to visualize seasonal changes of temperature that would show a reaction of this sort in some species but not in others. It seems, then, that the zonal spacing of the tabulae is more probably an inherent feature of certain of the species.

Thecae

The **epitheca** is a covering of an individual corallite. A similar covering for an entire colony is termed a **holotheca.** Both are encountered in the corals included in the present work. Both the epitheca and the holotheca are thin, and are most clearly evident in thinsections. They are darker than the other structures of the corallite and appear homogeneous, and the distinction between them is purely that of their position, whether surrounding a colony or individuals in the colony. They are not possessed by all corals, and the homology of the holotheca and epitheca seems, from our present evidence, somewhat dubious. Problems of relationship involve questions of fine structure and phylogeny, and are discussed more fully after consideration of these matters.

FINE STRUCTURE

Different types of fine structures occur in (a) walls and septa, (b) tabulae, (c) epithecae and holothecae, and (d) poikiloplasm, the last being a structure previously overlooked.

Much attention has been given to the fine structures of walls and septa, which not only form the most conspicuous parts of the corals, but also show wide textural variation among different types. As already noted, it has been necessary in the present work to reject the hypothesis that septa are primary and walls are formed by a secondary fusion of septal edges. It is necessary to go farther, and to regard walls as primitively composed of parallel fibers, the grouping of fibers into radiating bundles (sclerodermites), and the arrangement of these into columns of varying complexity (trabeculae), being secondary also. For the moment, however, attention is confined to the several types of walls relevant to the present study.

FIBROUS WALL

The simplest wall encountered in the older corals is fibrous. In such walls, as indicated in Figure 1, fibers are formed normal to the secreting surface, which slopes obliquely up and outward at the anterior end of the calyx, and is continuous around the corallite. Fibers formed on such a continuous secreting surface slope obliquely down and outward. This type of fibrous structure is well shown in longitudinal sections through the calices of *Catenipora* (fig. 3B; pl. 7, fig. 1). Where, as in Figure 3B, the section cuts across the rank, the wall of only a single corallite is involved. There are three complicating factors, however: (1) The outside of the corallite wall here is bounded by a thin, dark, homogeneous, aphanitic layer, the holotheca, which forms a common surface of the entire cateniform colony, (2) the inner surface is projected as a series of columns of septal spines, (3) near the base of the calyx is added a new structure, a layer of light calcitic material filled with tiny dark granules, the poikiloplasm. In *Catenipora workmanae* this material forms spheres which center upon the septal spines. There is reason to believe that as the spheres grow, the spines are resorbed. The spheres are seen, however, in many cases to be connected by a thin lining of this same material.

In tight-growing (cerioid) colonies where corallite walls are in juxtaposition (fig. 3A), the fibers of individual corallites may form a fused wall, without any homologue of the holotheca separating them. In such walls, the only indication of the boundary between walls of individual corallites is seen in the change in slope of the fibers, which now form a V-shaped, troughlike pattern in each common wall. The condition is analogous to that found in the division Amalgamata of the Trepostomata of the Bryozoa, but the effect is quite different, because the bryozoan walls commonly show growth lines, and these corals show only fibers that are essentially normal to the growth lines. In cerioid forms of this type, the boundaries between individual corallite walls may be most obscure in cross-section, but where they show at all, in thinsections, they appear as faint, light lines. These are here termed **axial planes,** being essentially planes with no real structure and no real thickness. In longitudinal section the change in direction of the fibers marks the plane, but under various conditions of alteration the plane may be obscured and perhaps even obliterated. A possible variation of the structure is produced where the slope of the fibers is so decreased that they are essentially horizontal in longitudinal section. Such an effect has been observed in our material of *Lichenaria heroensis*, but it is not certain that the observed condition is real; it may be a result of alteration.

TRABECULAR WALL

In contrast, a very different type of wall is found in *Nyctopora* (fig. 3D). Here the walls are formed by monacanthine trabeculae, fibers arranged in inverted cones about linear axes. The pillarlike bodies which result are ideally more or less rounded in cross-section, but in *Nyctopora*, as shown in the figure, the pillars are extended on one side or the other into the corallites, forming low septal ridges. A much simpler condition, in which the trabecular pillars are essentially round in cross-section and scarcely flattened where they touch one another, is found in *Trabeculites keithae* (pl. 26-27). Here longitudinal sections parallel to a segment of the wall will show the individual trabecular pillars within which fibers form V-shaped patterns, or, if the section is off center, U-shaped patterns may be apparent (pl. 26, fig. 5).

A seeming anomaly was found in another species, *Trabeculites maculatus*. Here cross-sections showed walls with alternating thick and thin areas, and it was easy to believe that the thick areas represent the centers of the trabecular columns and the thin areas are points of contact between trabeculae. However, close inspection showed that the fibers were not arranged, as in *Nyctopora* and in *Trabeculites keithae*, upon axes which were vertical lines, but rather there was wide variation, some parts showing axial planes continuous over much of a segment of a wall, others showing instead the continuous axial plane disrupted and broken up into a series of short, discrete planes. Others showed the planes so limited in lateral extent as to approach linear axes. Fibers ascend obliquely upward from the planes not only to the two surfaces of the common wall, but also slope up between the short discrete planes (see pl. 28; pl. 45, fig. 11, 12). Recrystallization was something of a complication, but the disruption of a continuous plane such as is possessed by *Saffordophyllum* into short discrete vertical units was retained, both in portions of

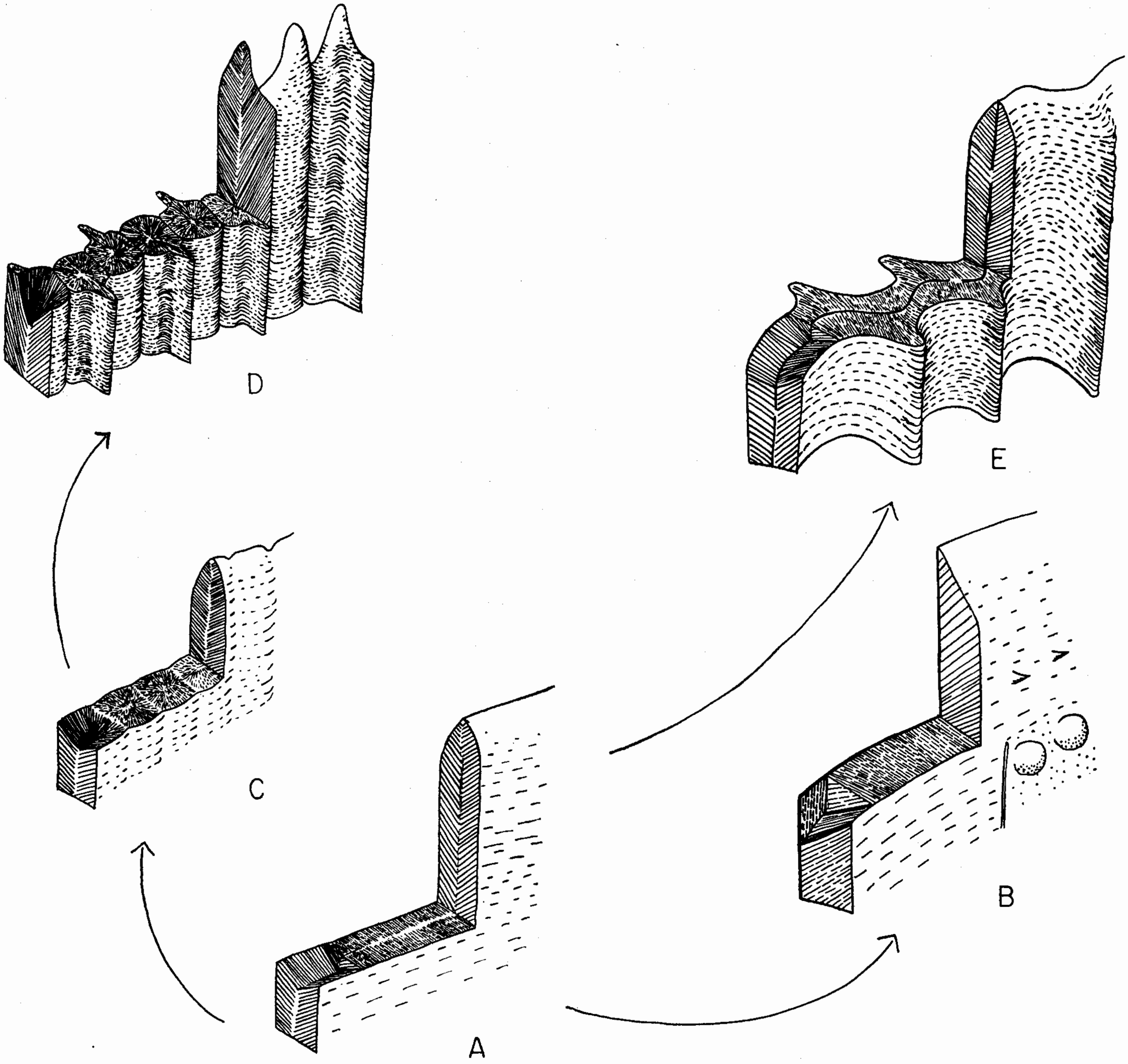

Figure 3

TYPES OF WALL STRUCTURE IN SIMPLER ORDOVICIAN CORALS, WITH INFERRED RELATIONSHIPS

A. Simple fibrous walls in cerioid colonies; fibers slope obliquely downward and outward in relation to individual corallites, resulting in a V-shaped pattern in vertical section. The *axial plane* marking only change in direction of the fibers is the one feature distinguishing parts pertaining to individual corallites.

B. Section through outer wall of a corallite of *Catenipora,* showing fibers sloping obliquely downward and outward. The exterior is covered by a holotheca; the interior by a thin band of poikiloplasm inflated into spherical bodies covering and replacing the septal spines, shown only in the lower right.

C. *Trabeculites maculatus.* Here the axial plane of A is broken into discrete planes, around which fibers slope obliquely upward and outward.

D. Typical *Nyctopora.* Here short axial planes of *Trabeculites* are reduced to vertical linear axes, around which fibers form inverted cones, thus forming monacanthine trabeculae; trabeculae are further specialized in being extended on alternate sides of the common wall as septal ridges.

E. Simple linear fibers are very much as in A, but a dark axial plate separates the fibers of individual corallites. Though single for all observational purposes, the plate is probably of two layers, one pertaining to each corallite, the two layers separating in younger and more specialized forms.

the colony altered by calcitic recrystallization with possibly some dolomitization, and in portions finely replaced by silica (pl. 28, fig. 7, 8). It was necessary, then, to consider it as an original condition rather than as a phenomenon of alteration. The species shows, as indicated in Figure 3C, a condition intermediate between the true fibrous wall and the true trabecular wall. If, as has been assumed in all previous classifications, there is an actual close relationship between the forms with fibrous walls, *Lichenaria* and *Saffordophyllum,* and those with trabecular walls, some transition between the two conditions should be expected. Here it is. It should be noted that although in the fibrous walls so far encountered, it is still possible to distinguish, by the axial plane, the discrete portions pertaining to each corallite, by the time the axial plane is broken up, the walls of individual corallites have lost their identities and a true common wall is developed.

Nyctopora is the point of origin of further specializations, which will be dealt with later. It will suffice here to note two general types of specialization involving widening of the wall into a coenenchyme, seemingly a generalized mass of calcareous material within which corallites show as cavities. In one line, typified by *Calapoecia,* abundant pores connect the corallites and form a meshwork in a porous coenenchyme. In the other, the walls seem to be composed of solid trabeculae, which are closely packed and polygonal. Lindström (1899) called these rods baculi. They are essentially monacanthine trabeculae, but although the fibers in the columns may be obscured or lost under various conditions of alteration, their surfaces commonly remain clear. The term baculi is found convenient and is here employed for these structures.

RUGOSAN WALL

The term **rugosan wall** is here introduced for a type of wall similar to the fibrous wall discussed earlier, but in which the fibers pertaining to the individual corallites are separated by a very different sort of material, an **axial plate.** Where the fibers are relatively light and show a characteristic texture, the axial plate is dark and homogeneous. This is the type of wall that is found in *Favistina, Cyathophylloides,* and *Crenulites,* and is modified in *Paleophyllum.* These are the genera customarily assigned to the Rugosa; hence the name. The structure is seen in younger but not the oldest species of *Foerstephyllum,* and it is believed that the axial plate underwent development within this genus. In one respect the term is a misnomer, for although it is certainly retained in the Rugosa, and it is no great strain to add *Foerstephyllum* to this assemblage (the genus was placed by Hill and Stumm, 1956, tentatively in the Tabulata), the same general type of structure persists throughout *Paleofavosites,* and other studies indicate that it dominates the Favositidae, curiously perhaps the most widely known family of the Tabulata.

The term **axial plate** is new; the dark band forming the division between the corallites is, for all purposes of inspection in the cerioid colonies, a single structure. There is reason to believe that it is actually composed of two parts, one belonging to each corallite, but under ordinary observational conditions the two parts cannot be distinguished. The new term for it is introduced for this reason; actually, where this structure has been observed before, it has received various terms. In the cerioid Ordovician genera, this layer has been termed the "wall," and the fibrous material on either side of it is called "sclerenchyme," with the strong implication that the wall is primary and the sclerenchyme is some sort of supplementary deposit. But the so-called sclerenchyme is obviously the homologue of the wall of the simple fibrous cerioid genera *Lichenaria* and *Saffordophyllum,* whereas the new "wall" is a structure not heretofore encountered in these simpler and older corals.

The development of the axial plate seems to take place within *Foerstephyllum.* In examining comparative material of that genus, it was found that among forms of Black River age customarily assigned to *Foerstephyllum halli* d'Orbigny, there are at least three different forms, quite possibly specifically distinct, differing in corallite size, in spacing of tabulae, and in the number and spacing of the septal ridges. The oldest such form is a colony (NMBM No. 737) from the Chaumont beds exposed at Crown Point, New York. This form (pl. 45, fig. 1-3) shows some variation in thickness and aspect of the walls; doubtless there has been some alteration, for the walls vary from those in which crystalline structure is irregular but conforms in general to the spacing of the septal ridges (pl. 45, fig. 3), through those in which the material is obscurely fibrous but largely homogeneous (pl. 45, fig. 2), to others in which the fibrous layers of individual corallites are divided by an obscure, light line. This is discontinuous, and occasionally irregular, and, by itself, would have been dismissed as a phenomenon connected with alteration of the corallite wall. It does, however, agree closely with the axial plane of the simpler fibrous genera.

Two other species differ in showing instead of a light, vague axial plane, a definite axial plate, uniform in preservation, always darker rather than lighter than the fibrous sclerenchyme, and definite and uniform in thickness. Three sections from such a colony (NMBM No. 738) from the Amsterdam limestone near Schenectady, New York, show a thin axial plate, uniform in thickness, the sclerenchyme extending into rather widely spaced septal ridges, which are short in Plate 45, figures 4 and 5, but greatly extended in figure 6. A third colony, from beds regarded as of Rockland age at Newport, New York (NMBM No. 739), is a form with materially larger corallites, with the axial plate distinct, and with the sclerenchyme thin and extended as uniformly relatively short and quite widely spaced septal ridges (pl. 45, fig. 7-8).

In cerioid *Favistina* and *Cyathophylloides* the wall structure is much as in these more advanced species of *Foerstephyllum.* However, in *Favistina paleophylloides* and in *F. calicina* corallites in distal parts of the colonies become free. When this occurs, the axial plate is divided into two component parts, each enclosing its own corallite, and the structure is obviously what one would call an epitheca. The same development occurs, though less clearly shown because of silicification of the material, in distal parts of the colony of *Cyathophylloides burksae.* The homology with the epitheca in *Paleophyllum,* in which there is no early cerioid stage, is plainly evident.

If this were all, it would perhaps be simplest to retain the term epitheca for the axial plate of the Ordovician cerioid forms, but another and a more startling homology was found.

The dominant *Foerstephyllum* of the Richmond of the Cincinnati arch is *F. vacuum.* Probably, as has been found true for many species, too much has been included in this one, but at least the topotype material shows good uniformity. Here septal ridges, slightly serrated in the older species, are reduced to columns of discrete septal spines; further, they are sparse enough that it is difficult to find, in a series of sections, enough of them around a corallite circumference to establish the number of columns present in the species. No pores have been observed in *F. vacuum*, but it shows two trends shared by other species with pores: (1) In cross-section segments of the walls are commonly curved rather than straight; (2) the tabulae tend to be lax and irregular in form and spacing. Two species from Akpatok Island share these features, but have very prominent septal spines in the young, more widely spaced spines in the adult. They also have pores, sparse in young stages, but more frequent in adult stages. Though the resemblance to *Foerstephyllum* is strong, and I have assigned them to the genus, others may well insist that they belong in *Paleofavosites*. They are here described as *F. porosum* and *F. minutum*. A third species, again agreeing in lax, irregular, and distant tabulae, showing wall segments curved in cross-section, lacks spines and is, in all essential features, a *Paleofavosites*. This is described as *Paleofavosites sparsus*. All these forms show walls of the rugosan type. More advanced and more typical *Paleofavosites*, with more regular tabulae and walls not commonly curved as seen in cross-section, are represented by somewhat replaced material, but all indications are that their fine structure was originally identical with these types. This posed something of a dilemma, for it was previously recognized that since *Saffordophyllum* possessed pores, it might well be assigned to the Favositidae, and as such, might be the ancestral radical of that family. However, such studies of fine structure of young Favositidae as have shown enough detail, notably those of Swann (1947) and Ross (1953), indicate a structure compatible with the rugosan type of wall shared by the species which show such a remarkable transition from *Foerstephyllum* into *Paleofavosites*. However, in the Devonian forms Swann found that the axial plate is commonly divided, and a completely different terminology is employed. The two outer layers are termed "peripheral stereozones"; the two dark bands, obviously the two parts of a split axial plate, are the two "primary walls" separated by a layer of light calcitic material, the "intramural coenenchyma."

Ross (1953) noted the bipartite nature of the axial plates of the present work, the primary walls of Swann's paper, and their tendency to separate occasionally, but questioned the organic nature of the "intramural coenenchyma," noting that it could be formed by inorganic calcite in a closed space. She interpreted the axial plate, the primary walls, as an epitheca. With the minor difference that the common wall is actually the fusion of two fused epithecae, her conclusion is most fully supported by the present work. The term axial plane is retained here as objectively useful, but there is little reason to doubt its homologies with epithecae in rugosan genera, as well as with the structure that Ross has recognized as epithecal in the Favositidae.

One other bit of evidence indicates the axial plate to be a double structure in the Ordovician genera. In *Crenulites*, in which the septa are amplexoid and fail to give the same support to the colony as do the continuous septa of related genera, crushing is a relatively common phenomenon. Among the sections of crushed corallites some can be seen which are only slightly displaced from their neighbors, and such corallites show individual thin, dark outer surfaces, each obviously the homologue of half of the axial plate.

Because of the surprising nature of this homology, the structures are shown in some detail on the accompanying plates. *Foerstephyllum* is illustrated in Plate 45. The structures are shown in *Crenulites* in Plate 19, figures 4-6, and Plate 45, figure 13; unfortunately the best examples of splitting of the axial plate were not included. Simple plates in *Favistina magister* (pl. 39), *F. calicina* (pl. 40, fig. 3), *F. magister* (pl. 41, fig. 4), and *F. paleophylloides* (pl. 42, fig. 5-8) are shown, and *Cyathophylloides* is illustrated in Plate 44, figures 1-5. The structure becoming an epitheca in free corallites is shown for *Favistina paleophylloides* in Plate 42, figures 7-8, and for *C. burksae* in Plate 43, figure 5. Similar epithecae are shown for *Paleophyllum*, but sections prepared primarily for other structures show the epitheca poorly differentiated, for the most part, from the dark matrix. However, the epitheca is shown between the main part of the corallite and attached organisms in Plate 9, figures 1-5, and can be seen in *P. margaretae* in Plate 48, figures 5 and 7, and in *P. cateniforme* in Plate 50, figures 1, 2, and 4.

The possible homology of the holotheca with the axial plane and epithecae is a question involving indirect evidence and phyletic considerations, and is left therefore to follow the discussion of phyletic relationships.

TABULAE

It is generally accepted that the tabulae are composed of very fine fibers vertical to their surfaces. Material examined in the present study has, for the most part, failed to show clear fine structure in the tabulae, but the observations give no cause to object to the above interpretation. Parallel vertical fibers have, however, been observed in a number of genera, supporting the concept that such structures are quite general. Under varying conditions of alteration, tabulae show a behavior rather distinct from that of the walls and septa. Curiously, under silicification many specimens that show walls and septa perfectly silicified will fail to show tabulae when etched. This has been most strikingly shown by the finely silicified corals from the Cutter formation of Tank Canyon. In order to ascertain the character of the tabulae of the *Favistina* in that assemblage, sections were required through colonies the centers of which remained unaffected by the acid. Such sections showed perfectly adequate tabulae, though etched surfaces showed them only as such poor traces that neither their form nor their spacing could be estimated.

Variations in the form of the tabulae have been noted in the discussion of the gross morphology and need not be repeated here.

POIKILOPLASM

Poikiloplasm is the name here given to 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 faces of tabulae. In *Catenipora* it forms spheres centering around the septal spines, and in most cases, though it occupies the position of such spines, no true spines can be seen within the material, suggesting that spines are resorbed as the poikiloplasm is formed. Its distribution suggests that it is a supplementary layer, quite apart from the fibrous walls or their extensions as septa, and that it developed only at the base of the corallite. The granular texture distinguishes it sharply from the fibrous walls, septa and tabulae; it may be lost under slight alteration where the fibrous structures are preserved and little altered. Its peculiar behavior under various conditions of alteration shows that it is a substance very different from those discussed previously.

The deposit was first encountered in *Catenipora workmanae*. Most sections, which were made through tabulate parts of the colonies, failed to show the normal septal spines that were expected; instead, in the position of these spines, in

12 vertical columns in each corallite, there were spheres, obviously and consistently different in composition from the fibrous walls. In the vertical rows the spheres were moderately spaced, and showed exactly the distribution that would be expected of normal septal spines.

Spheres of poikiloplasm encountered in cross-sections are apparently free in the corallites. Longitudinal sections indicate, however, that such apparently free spheres are those encountered in cross-sections that are formed on the anterior faces of the tabulae.

In appearance these bodies vary widely, particularly when seen in cross-sections. In Plate 5, figure 4, are seen a series of these bodies which vary from some that are rounded and narrowed at the bases, to others which are subquadrate, some nearly square and others slightly elongated. Further, elongation of the bodies is seen in Plate 5, figure 7. In Plate 6, figure 4, the bodies vary from round to subquadrate to pointed, and extremely long pointed bodies, quite suggestive of true spines, are found in Plate 6, figure 6. Just to the right of the center of Plate 6, figure 8, are seen essentially round bodies which are connected by a thin layer of similar material; the same effect can be seen, though not so clearly, in several of the other illustrated sections. Bodies apparently free in the corallites as seen in cross-section are shown. One large body is seen just to the right of the center in Plate 5, figure 4; small scattered bodies are seen in Plate 5, figure 7, and Plate 6, figure 7.

In longitudinal section, the bodies are seen forming regular columns against the corallite walls (pl. 6, fig. 1, 3). A central section will show them at the corallite sides, but in most sections of any appreciable extent a region is found in which the plane of the section is close enough to the outer walls of the rank to cut numerous columns tangentially. In centrally located sections the spheres appear ranged along the sides of the corallites (pl. 7, fig. 3); here they may appear round and slightly elongated, and may point very slightly upward when any elongation is evident, though elongation is exceptional.

The occasional development of spheres on anterior faces of tabulae is shown in the upper right of Plate 7, figure 3, and at several points in Plate 6, figure 1.

True septal spines, which are simple extensions of the fibrous wall and agree with the wall in texture, occur. Such spines are shown faintly in the calyx shown in Plate 7, figure 1, and one is more clearly shown, as the section apparently shows its full length, in Plate 7, figure 5. In cross-section similar spines are shown in Plate 6, figure 2, where they are, for the most part, only faintly indicated, probably because the plane of the section does not coincide with the point at which their greatest lengths are developed, but extremely long pointed spines are seen in the lower right of that figure. Plate 8, figure 13, shows some cross-sections through calyces where fibrous spines are developed, but adjacent corallites show bodies of poikiloplasm in calcite-filled sections that apparently cut the tabulate part of the corallite. Such a condition is general, though not universal. Occasionally true fibrous spines are seen in the tabulate region. One such is shown in Plate 11, figure 12. Several spines, simple extensions of the fibrous wall, are shown in Plate 6, figure 5; most clearly in the lower half of the center.

The spheres of poikiloplasm formed along the walls plainly occupy the position of the septal spines. In most cases, however, the septal spines appear to be completely lost and replaced by these structures. One section, however, which is essentially tangential to a large portion of the outer wall of a rank and cuts the spheres, showing them in cross-section (pl. 10, fig. 5), shows dark peripheral regions of granular material, but the centers are light and, apparently, fibrous. Here, evidently, the poikiloplasm has developed around spines that are simple extensions of the fibrous wall. Apparently, this condition is exceptional, for it is not shown in other sections, and enough sections were made so that the condition could hardly have escaped more general observation if it had been common. Numerous sections are shown in Plates 9-12 in connection with organisms attached to the outside of the colonies.

Such spheres are not confined to *Catenipora*. In an undescribed species of *Nyctopora* from the Burnam limestone of central Texas (pl. 21, fig. 5-6), abundant bodies of this sort are seen attached to walls and the rather long septal ridges, where the plane of the section is just enough off center to intersect them. In cross-section the bodies are abundantly represented, although photographs fail to bring out the textural contrast between the trabeculae of walls and septa and the granular spherical bodies. *Billingsarea* is differentiated from *Nyctopora* only in that it possesses an obvious columella. Typical material of *Billingsarea parva* from the Chazyan of the Champlain Valley shows considerable recrystallization, and the nature of the columella is not clear. However, the collections of the U.S. National Museum contained sections of well-preserved *Billingsarea* from the Ottosee limestone of Tennessee which showed the columella to be formed by piles of such spheres confined to the centers of anterior faces of the tabulae. An identical condition was found in *Billingsarea parvituba* (Troedsson) of the Gonioceras Bay limestone of northwestern Greenland. Bassler (1950) noted the apparent columella and referred to this form as *Nyctopora (Billingsarea) parvituba*. Quite possibly the recognition of *Billingsarea* as a subgenus of *Nyctopora* is appropriate.

Spheres of a similar nature occur, though apparently sparsely, in *Manipora*. Some are shown in the lower center of Plate 1, figure 10, in a longitudinal section which is well off center at this point and cuts a number of spheres in cross-sections. Prior to the recognition of these bodies as poikiloplasm, they presented a serious dilemma, for they were interpreted as sections of septal spines built on the common walls, though other sections showed that both common and outer walls exhibited short but longitudinally continuous septal ridges.

Occasional spherical bodies were observed attached to the tips of the septa in *Favistina* and *Paleophyllum*. Several small bodies of this sort are shown in Plate 48, figure 3, and one large one in the center of the corallite is shown in the lower part of Plate 48, figure 7.

In sections made from the holotype of *Saffordophyllum deckeri* similar material was found, but here it forms a thin, continuous lining as seen in cross-sections. Such a lining is, from its very uniformity, suspect as far as organic origin is concerned, simply because inorganic calcite may form concentric bands which formed in a closed space. However, in sections of *Saffordophyllum crenulatum* the poikiloplasm was seen in some places forming a lining continuous and uniform in thickness and texture (pl. 31, fig. 7-9), but in other parts of the same section, the poikiloplasm was slightly thicker and very much darker where it curved around the short septal ridges (pl. 31, fig. 10-12). Indeed, under low magnification and in a strong light such sections offered the astonishing appearance of septal ridges each crowned by a cloudy top-shaped or mushroom-shaped mass. This form is of particular significance, for it connects a continuous lining, uniform in thickness and homogeneous in texture, with the large spheres noted in *Catenipora*, where there is only the thinnest connection, if any, between the spheres.

Similar bodies have been noted in other corals. They are abundantly developed in *Nyctopora foerstei*, where they form the structures observed by Bassler (1950, pl. 264, pl. 14, fig. 8-9) on the anterior faces of the tabulae.

Under good conditions of preservation the poikiloplasm remains strikingly distinct from the fibrous walls and tabulae. Under extensive recrystallization fine structures of both walls and poikiloplasm may be lost, and indeed, it is because typical material of *Billingsarea parva* is thus recrystallized that the distinction was not evident there. Under extensive replacement the poikiloplasm may be obscured. It has not been observed in any extensively silicified material, but silicified material of species known to possess the structure has not been available. It is, however, worthy of note that under advanced silicification originally fibrous parts may be reduced to material similar to the poikiloplasm, as shown in *Paleofavosites kuellmeri* (pl. 36, particularly fig. 8). Similar alteration of the fibrous walls is developed also in *Paleofavosites mccullochae* and *P. prayi*, as well as in silicified material of *Favistina* from the Cutter, but the accompanying illustrations are not shown at a sufficient enlargement to exhibit this condition clearly.

The recognition of poikiloplasm as a distinct structure quite apart from walls, septa, or tabulae, but secreted upon them, poses some problems that are not answered; namely, what the function of this material could have been, why it should differ from the other parts, how the ectoderm at the base of the corallite could secrete fibrous tabulae at one moment and granular bodies upon it at the next. However, numerous sections have shown the reality of the structure, and original differences shown in the most clearly preserved materials are supplemented by others, showing the poikiloplasm to be subject to destruction or alteration even when fibrous walls and tabulae remain intact. Obviously it had differences in texture, composition, or both, making it particularly susceptible to alteration.

Recognition of the poikiloplasm as a distinct entity does produce an explanation for several features that had before seemed puzzling. If walls and septa are secreted first, and later tabulae are formed, how could it be that septal spines, which are integral parts of the wall, could appear on the anterior faces of tabulae? Our present observations indicate that the "spines" on the anterior faces of tabulae are poikiloplasm, and the same species that show such bodies will show others attached to the inside of the corallite wall, where they may replace septal spines or simulate them in position.

A columella in the broad sense is an axial structure that may be formed in various ways. However, the commonest method of formation in the Rugosa is the forward extension of the tip of the counter septum.[9] How such a columella could be formed in *Billingsarea*, a genus in which major septa are too short to reach the corallite center, has always been something of a puzzle. Recognition of the columella in this genus as piles of spheres that may extend from one tabula to the next, supplies a completely different explanation, not involving septa, and removing the above-mentioned dilemma.

One of the perplexities encountered early in the present study was our complete failure to see in sections of our *Catenipora* the three layers recognized by Hamada (1957, 1959), or septal spines with bases broadly embedded in the innermost of the three reported layers. Unfortunately, most of the photographs that Hamada has published are a little too small, a little too dark, or both, for certain comparison, but it seems possible that the septal spines that he represents are bodies of dark poikiloplasm embedded in lighter material of the same nature, and that both are distinct from the true fibrous wall. Certainly the best correlation of his material with the sections of *C. workmanae* shown here is made in this way. Also, it is clear that the axial structures in *Catenipora* are the effect produced by cross-sections cutting such spheres which are developed on the anterior surfaces of tabulae. Quite possibly, reported columellas in Silurian Halysitidae are based on homologous structures.

The development of poikiloplasm seems to characterize certain species. It is not in general characteristic of all species within a genus. The material has been observed in *Saffordophyllum, Manipora, Catenipora, Nyctopora, Favistina*, and *Paleophyllum*. Possibly, with further studies, the structure will prove to be even more widely distributed. It seems analogous in this respect to the actinosiphonate deposits, which occur throughout the Oncoceratida, but show an erratic and seemingly puzzling distribution. In the oncoceroids the solution is really quite simple; such deposits develop in conformation with structures of the siphonal strand wherever connecting rings are excessively thickened. An equally simple solution for the poikiloplasm can hardly be postulated, at least in the present state of our knowledge, but the presence of the structure in species scattered through several genera disparate in other structures and not closely related does suggest that there is a general similarity and relationship among these corals, and that the potential qualities necessary for the secretion of such material are quite general, though realized only in certain species, largely not closely related one to another. Its abundant development in individual species is governed by conditions not as yet understood.

EVOLUTION AND RELATIONSHIPS

As already indicated in the discussion of morphology, the present study has encountered evidence requiring a review of some previous concepts of morphology and relationship, and showing some current terminology as rather anomalous. Perhaps this is to be expected. It is in the Ordovician that the first great expansion and differentiation of the corals is found. It is not too much to hope that one may find there truly primitive forms. Yet current concepts of morphology have stemmed very largely from close studies of younger forms, in which it is not impossible that secondary specializations have obscured primitive features. Many concepts stem from a study of living species belonging to the Scleractinia, a group that appears first in the Mesozoic. Except in regard to septal insertion, many of the same concepts and much the same terminology have been applied to the Rugosa (Hill, 1935, 1936, 1956), but close morphological studies have been based in large part upon relatively young members of the group; indeed, except for Dorothy Hill's (1936) study on Silurian forms with acanthine septa, most such material has come from the later

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[9] Some students have considered it proper to confine the term columella to this type of axial structure.

Paleozoic. Much the same terminology and many of the same concepts have been applied to the Tabulata (Hill and Stumm, 1956).

Some departures from these concepts have been required by the present investigation. These points, already touched upon, involve the following matters: (1) It is held that the primitive corals possessed a fibrous wall, and that septa first develop as processes on the inside of the wall. It is believed that as septa develop in length and prominence, fibers are rearranged so that in larger *Paleophyllum* the rearrangement is such as to suggest the concept that septa are primary, and walls are only edges of septa thickened and joined. (2) The simplest walls and septa are composed of parallel fibers formed normal to the secreting surface. Development of fibers into radiating bundles or columns, which are trabeculae, is a derived condition. (3) Close similarities both of species in some cases and of structures in others, suggest relationships among the genera in such a way that it is not possible to group these forms into two distinct divisions, the Rugosa and Tabulata, in accordance with current usage.

If the study of these Ordovician corals has given rise to some seemingly novel concepts, these are surprises for which we must not be totally unprepared. This is not the first time that study of the most ancient members of a group has required radical revision of theoretical concepts based on the study of younger forms. The cephalopods supply a telling example. Orthocones were long believed to represent the primitive cephalopods; many believed that the circular section and central tubular siphuncles were primitive, although the alternate idea that ventral holochoanitic siphuncles might be primitive was proposed. Today it is evident that the primitive cephalopods were endogastric cyrtocones, compressed in cross-section, and that the ventral siphuncle was composed of short necks and expanded rings, forming the structures known as siphuncular bulbs, a matter not at first generally accepted, largely because a study of younger forms had supplied no indication that any such condition should have prevailed in the oldest and, from all indications, the most primitive cephalopods.

The general concepts of relationship have already been indicated in the discussion of the wall structures, and shown in general in Figure 3. The present section deals with the relationships in more detail, shown diagrammatically in Figure 4. Before proceeding to details, some reservations should be noted. First, only the genera indicated here have been studied in detail. Some significant Ordovician forms have not been included, notably *Lyopora* and *Plasmopora*. Extension of the study into Silurian forms, notably the Heliolitidae, which remain of uncertain origin in this scheme, was not possible. Even the present discussion is actually somewhat of an extension of an investigation originally limited in stratigraphic and regional scope. It is included here because it offers a suggested solution to problems of structure and relationship which could hardly be ignored. It is, however, the feeling of the writer that the study could and should be extended greatly, and there are matters here indicated as meriting further critical investigation.

Reports of corals in the Cambrian are rare, and for the most part the reported forms are small and not very well known; the best known of the group, *Cambrophyllum* Fritz (1955) and *Cambrotrypa* Fritz and Howell (1959), have not yielded enough information on their wall structure to permit one to place them in relation to their younger forms.

The oldest true coral that is at all adequately known is *Lichenaria*, a genus which ranges from the Lower Canadian into the Middle Ordovician. Unfortunately, not much is known of the structure of Canadian species. *Lichenaria cloudi* Bassler (1950), is known only from silicified specimens in the Tanyard formation of central Texas and from similar material in the Chepultapec dolomite of Maryland (Sando, 1957). Additional material, probably a distinct species, a form in which small irregular colonies of 5-15 individuals are common, was found by the writer in the Fort Ann limestone of eastern New York, but this association shows in general gross recrystallization of calcitic material, and the hope of obtaining adequate structural details from it is remote.[10]

Our knowledge of detailed structures of *Lichenaria* rests largely upon sections made from unsilicified material from beds of Chazy or younger age. The colony is formed of cerioid tubes, without any traces of septa, but with regular tabulae. Bassler (1950) has shown that reported pores in *Lichenaria heroensis* (Raymond) of the Chazyan of the Champlain Valley are actually large calcite crystals intersecting the corallite walls. Additional material has confirmed this interpretation. Our material of this species has shown corallite walls in cross-section as fibrous, but there is no clear axial plane indicating change in fiber direction at the fused corallite margins. In cross-section narrow light bands are seen between broader areas of darker fibers traversing the walls, and longitudinal sections show these bands to be of indefinite vertical extent. Bassler (1950) regarded these lines as adventitious, and as connected with calyces filled with matrix. Our present observations show them to be universally developed in calcite-filled parts of corallites; they do not seem to be confined to this species, and somewhat analogous structures are developed in *Trabeculites* and *Nyctopora;* so an organic origin is suspected. If they represent communications between the corallites, which seems the most logical explanation, they must have been openings only in the anterior ends of calices, later filled in, for the corallites are evidently of solid construction. Were these bands true separations between parts of the walls, one would expect the corallites to separate along them after death unless they were cemented by supplementary material.

The absence of V-shaped fibers in *Lichenaria heroensis* requires fuller investigation. At present, the negative evidence seems inconclusive. Material in the Chazy limestones of the Champlain Valley is commonly subject to extensive recrystallization, probably due to tectonic events.[11]

Some species of *Lichenaria* show only the faintest beginnings of septa, as in *L. major* (Bassler, 1950, pl. 11).

Saffordophyllum is the next more advanced genus than *Lichenaria* among the cerioid corals. It was first differentiated by the crenulations of the walls, in which convexities are variously thickened into septal ridges. The species here described,

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[10] This material, discovered and collected by the writer, is in the New York State Museum. Colonies are small and inconspicuous, and even the presence of the coral was detected only in sections made to reveal other fossils.

[11] The limestones of the Champlain Valley were subject to compression at the period of Taconic thrusting and later block faulting. Some recent work has denied any major thrusting at the close of the Ordovician, but seems to have been built upon the simple premise that extensive lateral movements did not exist; unjustified stratigraphic assignments, notably the interpretation of a large mass of Lower Cambrian shale as Upper Cambrian, are only one of several anomalies involved. Recent work has also shown that Silurian and Devonian strata are metamorphosed in New England, and doubtless the Acadian and Appalachian disturbances contributed.

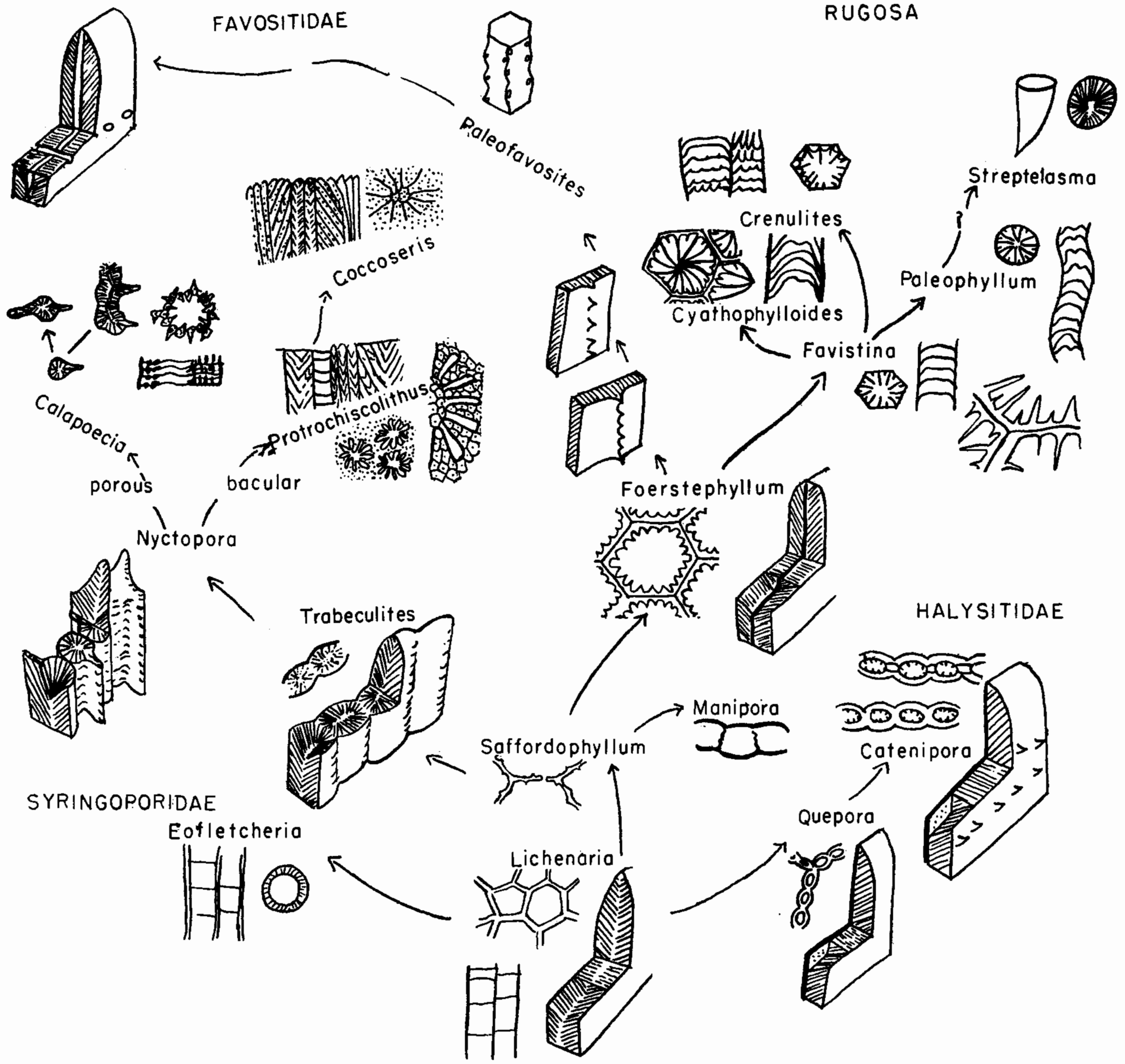

Figure 4

Inferred relationships of some Ordovician coral genera, showing crucial structures

Lichenaria, with fibrous common walls fused along an axial plane, is regarded as the ancestor of the phaceloid *Eofletcheria,* the first of the syringophyllids, and of *Quepora,* the first of the Halysitidae. Addition of spines, and later the addition of balken, occur in *Catenipora.* More specialized genera of the Halysitidate are not included.

Saffordophyllum is advanced beyond *Lichenaria* in crenulations of walls, the beginning of septal ridges, and the development of pores. Both are inherited by the cateniform *Manipora,* further specialized in the insertion of common walls into the outer walls. Pores are admittedly an anomaly shared by these two genera. *Trabeculites* shows breaking up of the axial plane into short discrete planes, which are later reduced to linear axes; thus monacanthine trabeculae are formed, which in *Nyctopora* are extended into septal ridges. Further specialization involves (1) widening of a porous coenenchyme in *Calapoecia,* where trabeculae may become secondarily elongated either parallel with or normal to the corallite margin, and (2) development of solid bacular coenenchyme in *Protrochiscolithus* and *Coccoseris,* in which all other structures are finally suppressed.

In *Foerstephyllum* the axial plate develops, separating fibrous walls of individual corallites and initiating the "rugosan" type of wall. This continues in *Favistina* and its allies, where, as corallites become free, the plate splits, forming epithecae about individual corallites. It is suggested that reduction of budding may have developed the first solitary Rugosa from *Paleophyllum.*

From typical *Foerstephyllum,* reduction of septal ridges to discrete spines (group of *F. vacuum*), subsequent development of pores, and later reduction of septal spines supply a transition into *Paleofavosites;* in higher Favositidae, the axial plate may split into two "primary walls" separated by "intramural coenenchyme."

S. newcombae, shows V-shaped fibers in the walls in vertical section, and horizontal sections show the walls traversed by fibers, with the axial plane varying widely in clarity, but often most obscure. Similar structures have been found in other species. Were this all, it would be possible to look upon *Saffordophyllum* as only a *Lichenaria* beginning to develop septal ridges, which are more fully developed in such more advanced genera as *Nyctopora* and *Foerstephyllum.* However, a surprising discovery, the phyletic significance of which is not yet clear, is the appearance of pores, usually but not always at the corallite angles in *Saffordophyllum.* Such pores are quite general, having been observed in material of *S. deckeri* of the McLish formation. *S. crenulatum, S. newcombae, S. franklini, S. undulatum,* and *S. kiaeri* show such pores. They are not common, but when one is found in a section, others are commonly present in nearby corallites, suggesting that the pores may be widely spaced but aligned. Nothing similar to the light vertical lines in *Lichenaria* has been found. The presence of pores, which are general if not universal in the genus, and the absence of the light lines are obstacles in the inferred position of *Saffordophyllum* as expressed in Figure 4, and suggest that the genus is specialized in these respects, lying just outside of the general lineage. Indeed, on the basis of pores, it was considered that *Saffordophyllum* might be assigned to the Favositidae, and, as the only genus known to extend into Black River or Chazy strata, might be the ancestral radical of the family. This interpretation had, however, to be rejected when it was found that the Favositidae possess rugosan and not simple fibrous walls, and that *Paleofavosites* was so closely connected with *Foerstephyllum* of the *vacuum* group that it is difficult to say where the boundary of the genera should be drawn.

Trabeculites is a *Saffordophyllum* in which the axial plane breaks up first into short, discrete planar units which are centers of fibers sloping obliquely upward and outward, and finally the short, discrete planes are reduced to linear axes, and thus true monacanthine trabeculae are achieved. In *Trabeculites* there are no pores. Septal ridges are vestigial, represented by little more than thickenings of the wall at the centers of the trabeculae, the walls thinning where edges of trabeculae are in contact. In this genus also there are light vertical lines, possibly analogous to those seen in *Lichenaria,* though fainter and more widely spaced, lying between the trabeculae.

Nyctopora, like *Trabeculites,* has the wall composed of vertical pillars of fibers arranged around vertical linear axes in each of the pillars, and forming an inverted series of cones. It is advanced mainly in that the trabeculae are extended into prominent septal ridges generally 8 or 16 in number. Commonly the walls are only one trabecula in width (see pl. 44, fig. 6-7), but a thick-walled species from the Burnam limestone, as yet undescribed, suggests that walls more than one trabecula in width may develop (pl. 21, fig. 5-6). Probably such a form should be separated generically. In wall and septal structure it approaches *Protrochiscolithus.*

Nyctopora is the logical origin of a number of other corals with trabecular walls. There has not been material for investigating all these types, but there is a general broadening of the wall in two descendant stocks, one of which develops abundant pores connecting corallites, whereas the other tends to develop a coenenchyme of solid trabeculae.

Calapoecia typifies the porous forms. Here the simplest species, *C. coxi* and apparently *C. canadensis* (which agrees largely with *C. coxi,* but is more poorly known, all available material so far studied showing advanced silicification), have thin walls one trabecula wide and trabeculae extended into septal spines, the spines in any one common wall alternating from one side to the other. The changes from *Nyctopora* involve (1) reduction of septal ridges, already serrate in some species, to discrete spines, and (2) the development of abundant pores. In *Calapoecia anticostiensis* the trabeculae come to be extended into the coenenchyme in processes which, in relation to the septal spines, are not only longer as seen in cross-sections, but are much less widely separated in the vertical plane. A surprising feature was found in *Calapoecia huronensis.* Here walls are relatively thin, not much thicker than those of *C. coxi.* Two features distinguish this stock: (1) The "disruptive canals," the nature of which still seems somewhat doubtful, but the possibility remains that they may be, all or in part, tubes of commensal organisms, which, as we know nothing about them, it is tempting to dismiss as "worms." (2) A more significant feature is the elongation of trabeculae parallel to the length of the wall segments. Axes are widened from vertical lines to planes, and the numerous planes join and even overlap. An extreme development along this line would produce something very much like *Lypora,* but it is not certain that *Lypora* is a derivative of *Calapoecia.*

The corals in which the skeleton tends to develop into closely packed rods, baculi, are not well enough known to permit anything approaching a thorough analysis of their evolution and relationships, but clearly, corals of this type are logically derived from *Nyctopora.* In the present work two genera have been encountered. *Protrochiscolithus* shows corallite walls trabecular, the trabeculae forming solid bacular rods of conical fibers to varying degrees of perfection. Here such rods not only form the walls, but constitute the septa, sloping forward in the septa from the wall to the tips of the septa. In *P. magnus* and *P. hembrilloensis* there is a columella of vertical baculi, and some sections show clearly that the baculae of the columella are derived from some of those of the septa; they bend, assuming a vertical instead of an oblique position. Necessarily, only a few baculi of the septa are continued in this way; there is not room for all of them to do so. Astonishingly, *P. kiaeri* and *P. alemanensis* have columellas of very different structure; they are vesicular, forming such a meshwork that it is uncertain whether they are derived from septa or tabulae, or from both. The meshes are fine and fail to show detailed structure; possibly some alteration of original materials is also involved.

Protrochiscolithus retains tabulae, but they appear confined to interseptal spaces. *Coccoseris,* however, as represented by Lindström (1899), not only has a broader coenenchyme, but shows septa so broad that, when fully developed, their margins touch one another. They are composed, as in *Protrochiscolithus,* of oblique baculi, and in the corallite centers are vertical baculi. Our species, *C. astomata,* shows a skeleton of vertical baculi in which it is impossible to differentiate corallites. Original surfaces, which might be helpful, have not been observed; there is evidence that the observed surfaces were abraded prior to burial. Probably corallites are not really absent, but cannot be recognized in sections because the baculi of coenenchyme, septa, and columella are all essentially vertical. This perplexing situation is developed by a quite simple process; baculi of the septa, oblique in primitive forms, have been steepened, until they are parallel with those of walls and columellas.

Saffordophyllum and the simpler *Lichenaria* are the logical origin of another great lineage. *Foerstephyllum* has fibrous walls, and neither pores nor light vertical lines, in which it differs from both genera, but the numerous short septal ridges are logically a development from the fewer and smaller ridges of *Saffordophyllum.* As already noted, the oldest observed *Foerstephyllum,* in beds of Chaumont age, seems to have only an axial plane marking the division between adjacent corallite elements in the walls, but younger specimens, probably properly distinct species, have developed a dark, solid axial plate. The differences shown are not convincingly interpreted in terms of alteration of walls; rather it is believed that the axial plate, which must have made its appearance somewhere, is developed within *Foerstephyllum.*

Genera long regarded as colonial members of the Rugosa differ from the advanced *Foerstephyllum* of the *halli*[12] group primarily in longer and more numerous septa, differentiation of major and minor septa, and specializations of the tabulae, which here depart from the primitive, simple transverse condition. The essential features of the genera are indicated in Figure 4. *Favistina* has 10 or more major septa, which commonly do not meet in the corallite center, and tabulae which are downturned at their edges and show a variable tendency to arch upward. *Cyathophylloides* has longer major septa, which commonly meet, twisting slightly, and tabulae more consistently and more prominently arched upward. *Crenulites* is a specialized genus in which the septa have become amplexoid, appearing as ridges on the anterior faces of tabulae, very short at their tips and lengthening anteriorly as they are traced toward the corallite walls. In some species they are definitely discrete, but in others they are continuous vertically, though only as the shortest septal ridges. Between the septa, the edges of the tabulae are downcurved and scalloped.

Some *Favistina,* notably *F. paleophylloides* and *F. calcina,* and also *Cyathophylloides burksae* have colonies that are cerioid throughout most of their extent, but distally corallites become free, rounded, and essentially phaceloid, though only for the last few millimeters of their length. In such corallites, the axial plate splits, becoming an epitheca around each corallite, and the end result is very much like *Paleophyllum.* True *Paleophyllum,* however, is phaceloid through its life. *Favistina paleophylloides* of the Lowville is the logical origin of *Paleophyllum.* It could be considered on the one hand a *Paleophyllum* with early cerioid stages, and on the other a *Favistina* with a late phaceloid stage. Ironically, it is the oldest certainly known species that could be placed in either genus. The interpretation that the cerioid *Favistina* is the ancestral stock is, thus, subjective in one sense, but demonstrated in another, inasmuch as cerioid corals are known to extend farther back stratigraphically, but the only older phaceloid genus known is *Eofletcheria,* which shows a simplicity of structure indicating that it has nothing to do with the lineage under discussion.

As far as colony form is concerned, it is in early Black River time that the first phaceloid tendencies are observed in corals with axial plates, fibrous walls, and appreciable development of septa. There is, as noted under discussion of the genus, only a faint indication in *Favistina* of any differentiation of septa even remotely approaching the biradial pattern of most streptelasmid corals. The hypothesis that *Paleophyllum,* by decrease in budding and development of conical rather than tubular corallites, may even have been the origin of the streptelasmids, seems worthy of closer investigation.

In the lineage involving *Foerstephyllum* and *Favistina* and its descendants, yet another specialization of interest (fig. 5) is apparent. The first septal ridges show fibers that are simple continuations of those of the walls, but when, in *Favistina,* the septa elongate, fibers tend to assume a V-shaped pattern in the septa, with the change of direction commonly apparent as a light band in cross-sections, just as is the change in direction of the fibers in the walls of *Saffordophyllum.* Longitudinal sections of septa in *Favistina* show, however, only faint transverse lineation. In *Cyathophylloides burksae* there is indication (possibly inconclusive in view of replacement by silica, but still most suggestive) of the lineation's becoming oblique and passing obliquely up from the wall to the tips of the septa.

Cross-sections of these genera show fibers of the septa aligned along their axes, curving gently at the bases of the septa, and joining the fibers of the corallite wall without a break (fig. 5B). However, in *Paleophyllum,* as shown by the three species present in the Second Value formation, there is a progressive specialization of the fibers as species grow larger and as septa become larger and stronger. Our material of *Paleophyllum gracile,* the smallest species, shows the fibers to be relatively simple and quite like those of *Favistina* (fig. 5B). In *P. margaretae,* however, and more fully developed in *P. cateniforme,* the axes of the septal fibers no longer extend to the outer surface of the corallite wall, but terminate within it, with the result that in cross-section fibers are aligned about the tip of their own axial planes (fig. 5C). The end result, quite analogous to the transition in the walls from *Saffordophyllum* to *Trabeculites,* is that the coral now has the appearance of being made up of septa, with the wall formed only by widened edges of the septa connected by supplementary fibrous material; it is, indeed, this interpretation that has been generally accepted, but there is evidence here not only that the condition is a derived one, but of actual progressions in its development.

In *Foerstephyllum* of the group of *F. halli,* the septa are ridges; their edges may be serrated, but it is only in a group of Richmond forms included broadly under *F. vacuum* that the ridges are reduced to columns of discrete spines. In some examples of this form (topotype material and presumably typical), the spines are small and quite widely spaced, sparse enough that they are not always evident in every cross-section.

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[12] Wells (1958) has pointed out that quite possibly *Tubipora striatula* Rafinesque, based on a specimen from Glens Falls, is identical with *Columnaria alveolata* Hall 1847, based upon material from several localities, including material of Chaumont and Rockland ages. *Columnaria halli* Nicholson was only a new name proposed for Hall's species, which was a junior hononym of *Columnaria alveolata* Goldfuss, 1826. If all these Black River forms are one species, Rafinesque's name would certainly have priority, but the problem is not that simple. Our present observations indicate profound differences, not the least of which are the absence of the axial plane in a specimen, quite probably a valid species, of Chaumont age, and two forms of Rockland age so different in proportions that they should probably be two separate species, both with good axial plates developed. Revision is not attempted here. Available material was inadequate to prove that marked differences in corallite proportions were constant, though general experience indicates that if they are not, the situation will prove to be exceptional. However, proper solution of the problem will involve a restudy of Hall's types (it is doubtful whether Rafinesque's is extant, and its study by sections, or similar study of a lectotype, would be necessary for the certain establishment of the morphological characters of the species), as well as of much comparative material of Black River age. This is one more needed study that could not be included in the present work.

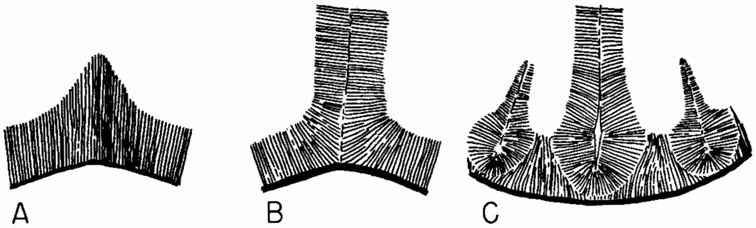

Figure 5

CROSS-SECTIONS, SHOWING PROGRESSIVE MODIFICATION OF FIBERS IN THE FAVISTINIDS IN ACCORDANCE WITH THE FORM OF THE SEPTA

A. In *Foerstephyllum,* where septa are still short and are essentially septal ridges, fibers are unmodified, and septa are little more than extensions of the margin of the wall.

B. In *Favistina* and *Cyathophylloides* septa have become longer, and fibers become aligned on axial plates within the septa; longitudinal sections show the fibers here to be V-shaped, and the condition in the septum is like that found in the common walls of *Saffordophyllum.*

C. With further specialization, the bases of axial planes no longer extend to the axial plate or epitheca; fibers are arranged around ends of axial planes, very similar to the fibers around the discrete axial planes in the common walls of *Trabeculites,* and are markedly discordant in pattern with the simple fibers of the wall found between septal bases. Such specialization, progressive in *Paleophyllum,* produces the effect of septa as primary structures, widened basally and joined by supplementary material, forming a wall of secondary and composite origin.

With this change come two others, seemingly superficial, but giving the corallites characteristic aspects. In cross-section wall segments, straight in the ancestral group of *F. halli,* commonly have become curved. Tabulae, transverse in the older forms, tend here to become irregular in form and variable in spacing, but with frequent zones where tabulae are rather widely spaced. Walls remain unchanged.

Three species are next to be considered that agree with *F. vacuum* in curved wall segments as seen in cross-section; their tabulae are even more irregular in spacing, tending to be even more widely spaced and downcurved in early growth stages. Two of these species have good septal spines. One, *F. porosum,* shows spines abundantly developed in early growth stages, where pores are sparse, but reduced, apparently both smaller and less closely spaced, in late stages, where pores are more commonly observed and probably more frequent. A second species, *F. minutum,* shows much the same growth relationships as to pores and spines, but has tiny corallites. The anomaly is that by the development of pores ordinary usage would dictate assigning these species to *Paleofavosites.* A third species, *Paleofavosites sparsus,* similar in aspect of the walls and tabulae, and having abundant pores but no spines, is referred to that genus. Yet all three show a marked similarity of aspect that can hardly be dismissed as accidental. Their walls are of the rugosan type previously discussed. Our material of more advanced and more typical *Paleofavosites* shows more regular walls and more regular tabulae, and the tendency for wall segments to show curvature in cross-section is vestigial or absent. Having found in *Saffordophyllum* a possible source of the Favositidae, the evident relationships between *Foerstephyllum* and *Paleofavosites* raise the question as to whether the Favositidae might be a polyphyletic family. This is not by any means impossible, but such information as is available on younger Favositidae shows homologies with the rugosan type of wall developed in *Foerstephyllum,* but not with the simple fibrous wall of *Saffordophyllum.* Swann (1947) has figured excellent sections of favositid walls, and though he has applied a quite different terminology, homologies are quite evident. The axial plate has split, becoming the two "primary walls"; the original fibrous material is the "sclerenchyme," and the only new feature is light calcitic material separating the primary walls, the "intramural coenenchyma." Although it is still possible that *Saffordophyllum* may have given rise to younger forms with simple fibrous walls, forms which would be included in the Favositidae on all general features, evidence of such forms is not apparent in the present literature.

Of the cateniform genera, *Manipora* stands quite by itself as a cateniform derivative of *Saffordophyllum,* as Sinclair suggested. The difference in texture of outer walls and common walls, and the evident insertion of edges of common walls in excavations of the outer walls provide a specialized feature connected obviously with the cateniform habit, but it is one that does not prevent the development of frequent agglutinative patches of corallites.

Sinclair, in describing *Quepora,* regarded it as a cateniform *Lichenaria,* differing primarily in the thicker corallite walls, cateniform growth, and the appearance of a holotheca surrounding the ranks. The only species certainly assigned to the genus are from the Simard limestone of Black River age, from Lake St. John, Quebec. From this genus it is not a great step to the simpler *Catenipora,* which develop septal spines, but lack balken. The balken, mesocorallites filled in solid basally instead of having their cavities traversed by diaphragms, are a further specialization, and from the Ordovician types the derivation of the Silurian forms seems a relatively simple matter. It may be noted that in the specialized *Catenipora* with balken there is a further specialization. Fibers of the walls slope obliquely down and out from the corallite cavity to the holotheca, normal to the rank, but junctions of adjacent corallites do not show fibers of individual corallites sloping obliquely out and down so that they form a V-shaped pattern where they meet. Rather, it is as though such common walls were removed, and the outer walls shirred together between the corallites, for sections normal to the rank show fibers sloping obliquely downward and outward in the regions of the balken. Material was not available for the present study to determine how early in the lineage of the Halysitidae this development occurs, and present available descriptions and illustrations of the simpler *Catenipora* and of *Quepora* are inadequate to show these details. Plainly, however, the advanced *Catenipora* show a specialization of the walls that is connected with the cateniform habit of growth, and once such walls have developed, a return of descendants of such forms to a cerioid growth would be greatly complicated.

Quite probably another lineage, indicated in Figure 4 as the Syringoporidae, began with *Eofletcheria*, a phaceloid genus with thick fibrous walls, no septal structures, and simple tabulae. The genus may well be a phaceloid modification of *Lichenaria*. The separate corallites have an outer covering, commonly called an epitheca, which may be homologous with the suspected holotheca of *Lichenaria* and the observed holothecae of the Halysitidae. *Eofletcheria* is particularly characteristic of beds of approximately Chazyan age in western North America (Duncan, 1956). *Reuschia* is the only other Ordovician genus recognized as belonging to this lineage; it has thicker walls, a beginning of septal spines. Hill (1959) has recognized this genus in an outlier of the Montoya in Arizona, thus far the only recorded occurrence of the genus in North America. Specializations of the younger Syringoporidae are not of immediate concern to the present work.[13]

Although it must be emphasized that further critical investigation is needed on the proposed relationships of these genera, the present evidence seems particularly strong where the phylogeny appears most novel. If this relationship is real, and the writer has come to these conclusions often reluctantly and without preconceived ideas on what evolution or progression of morphological specialization ought to be, it is evident that there is no natural division of these corals into Tabulata and Rugosa. Rather it seems that the following groups are natural: (1) Cerioid types with simple fibrous walls, *Lichenaria, Saffordophyllum,* and *Manipora;* (2) the Syringoporidae, an early offshoot of phaceloid forms with simple fibrous walls, only complicated in much younger genera; (3) the Halysitidae, cateniform types with a holotheca, first with simple fibrous walls, later developing spines, mesacorallites, and other specializations; (4) a group of forms with trabecular walls, these forms giving rise on the one hand to (5) forms with thick porous coenenchyme, and on the other hand to (6) forms with solid bacular coenenchyme. There are admittedly forms, notably most of the heliolitids, that remain for the present of uncertain affinities, but are probably derived in general from *Nyctopora* or *Saffordophyllum*. However, *Foerstephyllum* is a derivative of *Saffordophyllum* in which the axial plate develops; from it develop (1) the favistinids with increase in septal development, and trending toward phaceloid, a trend that possibly may lead to the older and simpler solitary corals, (2) the Favositidae, with development of pores and suppression of septa.

A word should be said about the relation of known ranges of the genera to the phyletic scheme represented in Figure 4. As noted above, *Lichenaria* is the oldest of the genera, beginning in the Lower Canadian. Other members of the genus range from the type Chazyan into the Hermitage of the East and the Kimmswick of the Mississippi Valley. The absence of known Middle and Upper Canadian types suggests that the stock might not be a unified one, but absence of the genus in that interval may be more apparent than real.

In eastern North America *Billingsarea, Nyctopora, Eofletcheria,* and *Lichenaria* occur together in the Chazyan of the Champlain Valley. They continue in equivalents north into Quebec and south into the Appalachians. In western North America *Eofletcheria* occurs in beds broadly regarded as Chazyan (Duncan, 1956). It is not certain whether this horizon is properly placed in the Whiterock or Chazy (Marmour) stages, but the genus occurs in zone O of Hintze (1952), and it is in underlying beds, zones M and N, that the typical Whiterock faunas are developed, a fact that suggests Chazy rather than Whiterock equivalence. *Saffordophyllum* makes its first appearance in the McLish limestone, equivalent to the middle and upper Chazyan, in Oklahoma. Admittedly, the presence in the Chazyan of the fibrous-walled *Saffordophyllum* and of the apparently more advanced trabecular *Nyctopora* and *Billingsarea* is an anomaly, particularly since *Trabeculites,* which is in most respects intermediate between the two, is as yet not known definitely prior to the appearance of *T. keithae* and *T. maculatus*, the first certainly and the second probably in beds of Red River age. Possibly *Saffordophyllum tabulatum* might be a representative of the genus, but if so the species brings the range of the genus down only to the Lebanon limestone, of Black River age. The later Canadian and Whiterock are intervals in which nothing is known of the corals and their evolution; so it is not surprising to find the disparate genera *Saffordophyllum* and *Nyctopora* appearing together in the Chazyan. That early Canadian *Lichenaria* has simple fibrous walls is of course an inference, but it is one there is no good reason to question. It could be argued that since fibrous walls of *Saffordophyllum* and *Lichenaria* are known first from Chazyan species, the evidence would support equally well the primitive nature of the trabecular wall. The fibrous wall is theoretically simpler; surely general secretion around the circumference of a corallite is more generalized than the developing of pockets in the ectoderm within which the trabeculae are secreted. Although the Chazyan contains the trabecular genera *Nyctopora* and *Billingsarea* (so allied that possibly the generic distinction should not be recognized), it shows greater diversity among the genera with fibrous walls, suggestive of a longer history of that stock, for we find there not only the cerioid *Lichenaria* and *Saffordophyllum,* but also the phaceloid *Eofletcheria.*

Again the Chazy-Black River hiatus marks a gap in our knowledge of the corals. In Black River time new genera appear together that, morphologically, we should expect to find in succession, notably *Foerstephyllum,* which is simpler than the associated *Favistina.* Bassler (1950) cites *Favistina* (as *Favistella*), *Foerstephyllum, Lambeophyllum,* and *Streptelasma* as occurring in the Lowville, a matter on which confirmation is desirable. Certainly the Simard limestone of Quebec is not earliest Black River; it is the source of the oldest *Paleophyllum,* and of *Quepora,* the first of the Halysitidae. *Calapoecia* seems to make its first appearance in the beds of the Paquette Rapids, probably Rockland and late Black River in age. Some uncertainties of precise equivalence are involved in widespread correlations throughout the Mohawkian. It is, however, apparently slightly later that *Protarea* and *Lyellia* appear, in beds certainly as old as the Sherman Fall, middle Trenton.

Little is known of the late Trenton corals, but it is here in the East that the probable equivalents of the Red River occur. In Tennessee and Kentucky some corals are known. Most of them belong to genera that have appeared earlier. The only marked advance is the possible inclusion of species of *Cyathophylloides* and *Crenulites* in part of *Favistella alveolata interventa* Foerste.

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[13] The Syringoporidae is here used with essentially the scope of the Syringoporinae of Hill and Stumm, 1956. Those authors place it as one of two subfamilies of the Auloporidae. If the implications of this classification are correct, the Syringoporinae represent the ancestral radical of this lineage, and the Auloporinae developed from them. Such a relationship seems eminently probable, but investigation of the matter has not been possible in the present work.

Anomalously our knowledge of the corals of many of the occurrences of Red River faunas involves in most cases old determinations that are somewhat suspect and require revision, or assemblages in which there is reason to suspect there has not been sufficiently precise stratigraphic control (the Bighorn and Fremont involve insufficient differentiation of Red River and Richmond elements; the same is probably true of the Cape Calhoun, where there is an additional complication, the serious possibility of the inclusion of pre-Red River elements in addition). However, Barnes, Cloud, and Duncan (1953) indicate the proper genera of the Burnam limestone corals. Some Red River types are reasonably well known through the work of Leith and Sinclair, and Troedsson's (1929) descriptions of the Cape Calhoun faunas leave at least no doubt as to the proper generic position of the species of that formation. Together with the present study of the Second Value corals of the Montoya, it is possible to establish the presence of some new types in the Red River faunas: *Crenulites* of the favistinids, with somewhat advanced types of *Favistina* and *Paleophyllum;* also *Protrochiscolithus* and *Coccoseris,* specialized types with trabecular walls. *Manipora* is known with certainty only from the Red River beds; *Catenipora* makes its first appearance here, but continues upward. To judge from faunal lists, *Calapoecia* is represented by both thin-walled types (reported as *huronensis* from the Red River of Manitoba), intermediate types (*ungava,* which occurs at sea level on Akpatok Island), and thick-walled types (cf. *anticostiensis,* definitely known in the Second Value of New Mexico and in the Selkirk limestone of Manitoba). Genera continuing up from lower beds involve *Saffordophyllum, Nyctopora, Favistina, Foerstephyllum, Protarea,* and *Paleophyllum. Trabeculites,* probably of earlier origin, makes its first certain appearance here, occurring in the Second Value of New Mexico and at 325′ in the section on Akpatok Island. A remarkable first occurrence is that of the rather anomalous species of *Paleofavosites, P. sparsus,* in the Second Value Reports of *P. capax* and other species in the typical Red River require confirmation.

Occurrences in the western Richmond involve few new types; more specialized types of *Paleofavosites* probably represent the most conspicuous advance. *Pragnellia* is as yet known from two occurrences, the Stony Mountain of Manitoba and the Aleman of New Mexico.[14] The western Richmond contains the first species that can be assigned to *Cyathophylloides* with certainty, though a possible earlier occurrence in the Benson member of the Cynthiana limestone of Kentucky has been noted.

The late Richmond faunas as known from the Cutter of New Mexico bring in no new generic types. In Manitoba, Stearn (1956) has described the genus *Angopora;* from published evidence it is not certain whether *Angopora* is related to *Paleofavosites* or to *Saffordophyllum* of the group of *S. goldfussi,* or possibly to *Nyctopora.* It is certainly in the later Richmond of the west that *Paleofavosites* first becomes really prolific.

As can be seen, there is a general correlation between the proposed succession of genera as shown in Figure 4 and their order of appearance, but there are anomalies, the incursion in Chazy and again in Black River time of forms regarded as derived one from the other, although the only occurrence of a genus appearing appreciably later than one of its supposed descendants is the newly recognized genus *Trabeculites.* The obvious lack of information on coral faunas in later Canadian and Whiterock, again in the Chazy–Black River hiatus, and yet again in much of the Trenton, will explain some of the anomalies, and it is doubtful whether the one serious anomaly, the late appearance of *Trabeculites* is particularly meaningful, as the genus has not been recognized previously.

No formal revision of the classification of these corals is attempted here. The present study has dealt exclusively with Ordovician forms, and from such forms alone proper perspective for a valid taxonomic scheme is probably lacking. There are, after all, subjective factors in classifications, and genera that, from the viewpoint of Ordovician types alone, seem so closely related that their separation into different major taxonomic categories seems most unwise, may prove in a wider view to be the beginnings of different major lineages, the recognition of which as major taxonomic categories becomes not only desirable, but, in many cases, a real necessity. If evolution was not thoughtful enough to progress by marked morphological saltations at the initiation of each family or higher group, and nature is rarely as convenient as this, primitive members of distinct major lineages must be expected to show close relationships, perhaps even to the point of intergradation, with their ancestors that may be placed in other major categories.

It does, however, seem an inescapable conclusion from the present investigation that separation of the genera here dealt with into Tabulata and Rugosa is completely untenable. *Foerstephyllum,* within which the rugosan type of wall first appears, is plainly allied with the forms that may be referred to broadly as the favistinids, which are quite probably also the beginning of the Rugosa; yet the same genus is clearly the origin of the Favositidae, which are thus not directly related to the other genera with which they have long been grouped in the Tabulata.

The conclusions here reached oppose most strong recognition of the Tabulata and Rugosa as distinct lineages or distinct taxonomic categories. There remains another proposal, not dealt with here, which deserves mention; namely, the proposed separation of those corals that divide by binary fission as the Schizocoralla. Discussion of this question seems to have been confused by differences of opinion as to the proper scope of the Schizocoralla, if it is to be recognized at all. Two major families involved, the Tetradiidae and Chaetetidae, have not been treated in the present study. True representatives of the Chaetetidae are not represented in the Ordovician coral faunas of North America. The Montoya faunas have not yielded any Tetradiidae, but this is doubtless due to limitation of materials. Such Tetradiidae as have been examined suggest such a very different behavior than that shown by the other corals under varying conditions of alteration and replacement as to suggest not only rather different composition of the walls, but also the possibility that they are not at all closely related to the main coral lineage of the Ordovician. This observation would thus tend to support the recognition of the Schizocoralla. The propriety of including the Heliolitidae in that group seems, however, somewhat more dubious;

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[14] Actually the Franklin Mountains of Texas; the writer subscribes to the view that the present State boundary is the result of political chicanery and unworthy of serious notice.

inconclusive indications suggest that the Heliolitidae might possibly have developed from *Saffordophyllum*.[15]

ENVELOPES

Two types of coverings of the outer walls of corals have been recognized that are distinguished largely by their distribution; namely, the epitheca, which surrounds individual corallites, and the holotheca, which is the common outer covering of whole colonies. Full discussion of these structures has been delayed until after general considerations of phylogeny and relationship have been considered, because distribution of the envelopes and the relationships of genera in which they have been observed are of paramount importance. Both epithecae and holothecae are so extremely thin in the Ordovician forms in which they have been observed, that thinsections are necessary to show their presence. In color and texture the two structures are indistinguishable; they appear as dark, amorphous layers, quite homogeneous throughout and without fibers or apparent growth lamellae. The critical question is whether the two structures are homologous, differing only in distribution, or whether they are two distinct structures, the one not derived from the other. If they are distinct, one must postulate that they are formed similarly on the outer walls of the corallites. It has been found in the cephalopods that actinosiphonate deposits, similar in composition and showing a general agreement in form, are developed in several independent stocks in the Oncoceratida, but there the origins are less distinct, for apparently all such deposits are merely thickenings of the connecting rings, which are shared by the common ancestors in which the rings remain thin; further, the actinosiphonate deposits are clearly thickenings of the rings which develop in conformation with the pattern of the tissues of the siphonal strand, and this general pattern prevails throughout the Oncoceratida and even its descendants, including the Nautilida. In the corals, however, there is no common, generalized structure analogous to the connecting ring, and if holothecae and epithecae are distinct, they have in common only the same specialized secreting region of the corallite and the same general composition.

The available factual evidence suggests the holothecae and epithecae to be two completely independent structures, but such evidence is fallible. The epithecae are found in the phaceloid genus *Paleophyllum* and in the distal phaceloid portions of certain species of *Favistina*, and the axial plates of cerioid favistinids are clearly the homologues of the epithecae of free corallites. The axial plate may be traced back farther into the younger and more advanced species of *Foerstephyllum*, which in general features, as well as wall structure, are the logical ancestors of this group of genera with, in general, fairly well-developed septa. However, the axial plate is wanting in some *Foerstephyllum*, and the belief that such species, which are among the older ones, represent a primitive group within the genus is at least reasonable. The axial plate is also retained with minor variations in the Favositidae, and both similarity of walls and close similarity, approaching intergradation, in gross structures indicate a close relationship between *Foerstephyllum* of the *vacuum* group and *Paleofavosites*.

Do the genera *Lichenaria* and *Saffordophyllum* possess holothecae? None have been observed in those genera, but conditions of preservation make this fact of perhaps little consequence. Cerioid colonies commonly show evidence of breakage and abrasion prior to burial; under such conditions the holothecae would be the first parts destroyed. It is, in fact, practically impossible to be certain that the observed lateral margins of such colonies are original and undamaged. It is not impossible that such coverings of the colonies developed independently in *Manipora*, the Halysitidae, and the Syringoporidae, but it is at least logical to believe that such envelopes may well have been shared by the cerioid genera through which these three stocks are connected phyletically. It then seems possible that the axial plate as developed within *Foerstephyllum* might have developed from a holothecal covering that suddenly developed the property of surrounding individual corallites rather than the whole of the colony, but it is by no means certain that this is actually what happened; present evidence leaves the question without any certain solution. It is, however, apparent that the appearance of thecal coverings around individual corallites was a new feature, one developed within the genus *Foerstephyllum* and inherited by derived stocks, and as such it supplies a valuable and badly needed clue to coral relationships.

SPECIFIC CRITERIA

Early works on Paleozoic corals tended to rely rather heavily on the form of the corals or the form of the colonies, but when subsequent work revealed that these features could vary within species of living corals, there resulted much uncertainty as to how species could be recognized and defined.

In the present work, happily, a substantial number of colonies were available, particularly from the Second Value formation, and it was possible to estimate from considerable material the amount of variation in a colony and the variation between individual colonies. Happily, also, each colony contained numerous individuals, and with some 400 thinsections a good idea of the extent of variation in the colonies could be reached. Presence or absence of gradation influence concepts of morphological limits of variation in the species.

Corallite size has been found to be a valuable criterion in the colonial forms studied in the present work. In employing it, the maximum size of the corallites is the matter to be considered primarily, and this has been found to be amazingly

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[15] After completion of the present work, Miss Helen Duncan, to whom I am already indebted for so much help, has continued investigations which will require some modification of the above scheme, but which will certainly remove some perplexities noted above. It seems proper to let such revision await the publication of her results, but one matter is of sufficient importance to deserve mention now. Attention has been called to the anomalies found in comparing the walls of *Saffordophyllum* and *Lichenaria*. Miss Duncan has found that *Lichenaria*, as employed here, is possibly two distinct genera. One, true *Lichenaria*, as it includes the genotype, does have simple fibers in the walls and pores at the corallite angles, and is thus a logical ancestor of *Saffordophyllum*, being simpler in that crenulations of the wall and septal ridges are wanting. However, pores are wanting and longitudinal light lines traverse the walls in other species which, including *Lamottia heroensis*, may be separated as the genus *Lamottia*, which Bassler (1950) and the writer have regarded as a synonym of *Lichenaria*. Thus *Lamottia* may well be a simple aseptate coral which is trending toward the trabecular walls more fully developed in *Trabeculites* and *Nyctopora*. Several anomalies encountered in attempting to derive *Trabeculites* from *Saffordophyllum* are thus removed, and instead of this relationship, the development of *Lamottia* from *Lichenaria* is suggested, this relationship being indicated by the logical premise that the simple fibrous walls are primitive. An interesting question is whether such an ancestral "*Lichenaria*" would have pores.

Presence or absence of pores presents anomalies in almost any projected scheme of relationship of these Ordovician colonial corals.

uniform in individuals of a colony and in colonies of an association in one formation. This has been found true in general for cerioid, phaceloid, and cateniform colonies. The frequency of small immature individuals is, in cerioid colonies, largely correlated with form; many young individuals occur in radiating colonies, relatively few in those in which the corallites are subparallel; quite generally also, colonies are dominantly radiating in the young, but corallites assume a more parallel attitude in later growth stages. One might expect frequently budding individuals to produce a confusing disparity of size in cross-sections, but this is not nearly as general as might be expected; it has been found generally true that young, budding individuals enlarge in size rapidly, particularly in the basal 1-3 mm of their length, and will either attain or approach closely to the size of the large, mature corallites. The same has been found true of phaceloid colonies. In later stages of a colony where corallites are dominantly subparallel, one might expect that budding individuals would enlarge more gradually, but this has not been found to be true in any of the Montoya species with which this study is primarily concerned. One described species does show such features, *Columnaria goldfussi* (Billings), a species referred by Bassler (1950) to *Nyctopora*, but our present investigation shows it to have a wall of simple fibers rather than of trabeculae, and it is transferred to *Saffordophyllum* and discussed briefly under the genus. Gradual enlargement of budding individuals in mature parts of colonies is in general a restricted feature found in relatively few Ordovician colonial corals.

It has been suggested many times that a close relationship may exist between phaceloid and cerioid species. Although this is true in the broader sense, the colony form does seem to be eminently characteristic of the species. In *Favistina paleophylloides* the colonies remain cerioid for a definite and quite uniform distance; though the colonies tend to be depressed slightly, so that the length of vertical corallites is less than that of those which are strongly oblique, there remains a surprising uniformity in the size of mature cerioid parts of the colonies, beyond which the corallites may become free and phaceloid, though only for a short distance, commonly not exceeding 5 mm. There is indication that in the younger forms of Chaumont and possibly of Rockland age, in the later Black River, the phaceloid portion of the corallites is somewhat more extensive, but here material has been scant, and the literature is sadly inadequate in illustrations or detailed descriptions. In *Favistina calicina* our material agrees with previous descriptions indicating larger, more massive cerioid portions of colonies and similar short, distal phaceloid regions. In the Montoya it is significant that the three species of *Paleophyllum* of the Second Value formation are consistently phaceloid, with a tendency for the corallites to remain in contact in short, irregular cateniform ranks in *P. cateniforme*, but nowhere is there a significant departure from the habit of growth, and neither here nor elsewhere are there known cerioid forms that agree in corallite size, or in number and spacing of septa and tabulae, which could be considered as cerioid editions of the same species. Likewise, there are no phaceloid variants in the Aleman of the *Cyathophylloides burksae*, or in the Cutter of the *Favistina stellata*, and no phaceloid equivalents are known for any of the species of *Crenulites*.

Number and length of the septa are reliable and useful characters, if only one recognizes that the typical features of the species are not developed in small, and necessarily young, budding individuals. There must be, of course, the reservation that there will be some variation, and the extent of variation increases in general with the average number of major septa. It has been found also that the prevalence and general length of the minor septa are significant, and the general variation in colonies assigned to *Favistina stellata* of the Richmond of the Cincinnati arch, which is exceptional in this respect, is possibly a reflection of the inclusion under this name of two really distinct species.

Tabulae, though they tend more to vary than do the septa, supply valuable criteria. Ma (1954) has suggested that alternate zones of widely spaced and crowded tabulae may represent seasonal growth in a temperate climate, the crowded tabulae being produced in the cooler seasons. In our Montoya corals, however, it has been necessary to conclude that this explanation is not convincing. It is hard to visualize conditions under which some species would show this reaction to temperature changes whereas other forms in the same association would not. Rather, it seems that the rhythmic alternation of crowded and widely spaced zones of tabulae is a feature peculiar to some species but not possessed by others. Bassler (1950) has employed as a convention a count of tabulae in a length equal to the width of the corallites. This method has been found useful to some extent, but its value is somewhat limited, for longitudinal sections may not pass through the corallites at their centers, and thus the maximum width may not be shown. Further, we have found that in the same region of the coral colony, tabular spacing is relatively uniform between mature individuals of maximum diameter and smaller, immature individuals; we have, therefore, measured the spacing of the tabulae largely in terms of the number in an arbitrary length (usually 5 mm), which proves convenient, though upon occasion difference between species is emphasized more strongly by showing the relation of tabular spacing to the width of mature corallites. In form, tabulae are also highly variable, but examination of any series of sections from a colony will show that a general characteristic pattern emerges, and there is also to be found some significance in the extent of variation shown in the individuals of a colony and of a species.

It has been found also that there is a definite ontogenetic or astogenetic trend in the colonies, a matter that has not been altogether understood. Extremely early stages of a colony may show features not found in later stages. This is not surprising, for both the colony and the individuals are young. The perplexity encountered in distinguishing colonies that have grown only 5-10 mm from a common center at the specific level is not astonishing; we would find the same perplexities in distinguishing comparably small species of almost any other fossil organism, from Foraminifera to Cephalopoda. We have found that although Cutter *Paleofavosites* are readily differentiated into two species from mature colonies, colonies with corallites only 5 mm long are almost impossible to distinguish. However, once the colony has grown to develop mature individuals of normal size, budding individuals approach this size so rapidly that there are never enough to cause confusion. Cox (1936) concluded that all species of *Calapoecia* were one, because of the similarity of early stages of colonies; the perplexity was increased by budding individuals in later stages. It seems, however, that in doing so he overlooked the significance of ontogenetic progression, and of the variation to be expected in the initial phases of colonies on the one hand and that of budding individuals in later growth stages on the other. Rather, in the present work, it is concluded that although early stages of colonies of *Calapoecia* may be indistinguishable, and budding individuals in later stages may result in perplexing variations in corallite width and width of the separating coenenchyme, the mean size of mature corallites, the character of their walls, and the maximum width of the coenenchyme present significant and useful characters. The opposing view and the assumption that specific criteria not shown by every individual and every part of the colony are invalid, reflect an empiricism and an arbitrary approach to the problem completely inconsistent with what should be generally understood principles of ontogeny and astogeny. Although it is, of course, true that fossils are not organisms, they were organisms or parts of organisms, and any attempt to treat them in any other manner will result in the absurdity that Romer (1959) has dismissed so nicely as "classifying assortments of nuts and bolts."

The present study suggests also that recognition of variation in colony form, and the possibilities of ecological control, have resulted, particularly in these colonial corals, in what is almost certainly an excess of conservatism in regard to the recognition of species. The extremely conservative treatment of *Calapoecia* by Cox (1936) has already been noted. There are many similar examples, such as the previous broad inclusion of most Ordovician favistinas as *Favistella alveolata,* the loose, broad definition of *Favistella discreta* Foerste, and the general recognition in North America of only one species of *Protarea* and of *Protrochiscolithus;* our material suggests, moreover, that the current recognition of still other species, notably in *Foerstephyllum,* may still be far too broad. Associations are a guide, but not an infallible one. Of course, the old idea that only one species of a genus should be found in an association is absurd. Go to any pond in August, and a sweep of the net may bring to light four species of *Lestes;* the same pond may yield three species of *Sympetrum,* three or four of *Aeschna,* and as many of *Libellula,* all in the Odonata. The same pond will commonly yield three or four species of *Helephorus, Hydrochus,* and *Enochrus* (Coleoptera: Hydrophyllidae), to cite only a few examples from my own experience. Happily, this once popular concept now seems to have few adherents, and its fallacy is shown nicely by the consistently distinct presence of three species of *Manipora* and three species of *Paleophyllum* in the Second Value formation in the present work.

Description of Genera and Species

Presented here are the systematic descriptions of genera and species of the Montoya group, supplemented by species from outlying regions added where need arose. Discussions of genera are designed to show ranges, stratigraphic, geographic, and morphological.

The present concept of relationships, set forth in an earlier section of this work, was developed only after the study was well advanced. The systematic descriptions and the assembly of plates necessarily were developed together, for descriptions depend heavily upon illustrated features. No attempt is made to place the genera in systematic groups; it is felt that any revision along these lines would be too incomplete, and would probably not be very stable. Cateniform genera are considered first, as a group readily recognizable, followed by cerioid forms; considered last is the one phaceloid genus. Descriptions, but not the plates, have been rearranged slightly; first the encrusting bacular corals are treated, then the simpler cerioid forms with fibrous and trabecular walls, bringing together at the end *Foerstephyllum* and its derivatives, the favositids and the favistinids (the stocks with the axial plate), and at the end *Paleophyllum*, the phaceloid relative of the favistinids.

Proper analysis of species for comparison with those of other regions is necessarily detailed and presents more information than one would need simply for the identification of the corals of the Montoya group; the lack of such information in older descriptions is a source of confusion, particularly in the study of comparable forms from regions remote from the type localities of the species, and raises problems that can be settled only by restudy of the type material. Descriptions and illustrations should as far as possible be designed to prevent this contingency.

THE CATENIFORM CORALS

Corals that form cateniform colonies are not by any means all related, but for convenience are discussed together. Until quite recently most species were placed in the genus *Halysites*, though with rather general, but variable, recognition that most, possibly all, Ordovician species, with a few Silurian ones, constituted a different genus, *Catenipora*, characterized by the absence of mesocorallites. Bassler (1950) noted some *Tetradium* that developed cateniform colonies, but *Tetradium* is readily recognizable, usually without recourse to thinsections, and no attempt was made to separate such forms generically. Sinclair (1955) added two other genera. One, *Quepora*, based upon *Halysites quebecensis* Lambe, a species first described actually as a "variety" of *Halysites catenularia*, has thick-walled corallites quite like those of *Catenipora*, but shows a complete absence of septal structures. Sinclair suggested that this genus was a cateniform development of *Lichenaria*. He also described the genus *Manipora*, based upon the new species *M. amicarum*, a species having thin, common walls which are crenulate, and suggested that it was a cateniform development of the typically cerioid coral *Saffordophyllum*. Duncan (1956) summarized succinctly the genera *Catenipora*, which has thick walls and septal spines but no mesocorallites; *Halysites*, which is similar but has mesocorallites traversed by simple tabulae; and *Cystihalysites*, in which tabulae, particularly in the mesocorallites, are irregular and anastomose. Miss Duncan's paper was in process of publication when the descriptions of *Manipora* and *Quepora* appeared.

Hamada (1957) added several more genera, most of which are known only from the Silurian and are as a consequence not particularly relevant to the present study, but he added some genera occurring in the Ordovician; namely, *Labyrinthites* Lambe, a massive coral with lacunae in the colony and thus imperfectly cateniform, and a new genus *Eocatenipora* based upon *Halysites cylindricus* Wilson. This genus he regarded as lacking mesocorallites and septal spines, thus agreeing with *Quepora* and *Labyrinthites*, but with rounded corallites forming imperfect chains, occasional free individuals being found. Hamada presented a list of described species with assignment to the genera there recognized. Unfortunately, his conclusions do not seem to be supported by the available descriptions and illustrations of the species, and it is necessary to take some exception to his views. The genus *Eocatenipora* is not recognized here; the present description and illustration of its genotype are inadequate to show whether this form is perhaps related to *Quepora*, or whether it is properly assigned to *Manipora*.

With the elimination of *Manipora*, which, as Sinclair indicated, is closely related to *Saffordophyllum*, it seems possible to recognize the main group of Halysitidae as constituting a definite lineage. The oldest genus is *Quepora*, with elongate, rounded corallites in chains, thick walls, tabulae, and no septal structures. As yet, the only species that can be assigned to the genus with certainty are the two Sinclair (1955) assigned to it, *Q. quebecensis* (Lambe) and *Q.*(?) *lacustris* Sinclair. It is extremely doubtful whether any younger species are properly placed in the genus, though Hamada (1957) has added nine others.

The next step is the genus *Catenipora*, which is the first of the halysitids to show septal spines. Structures in this genus are quite diverse. True septal spines apparently are generally present, but in our material they are supplemented, and commonly completely obscured, by spheres of poikiloplasm; similar spheres may develop on anterior faces of the tabulae and are apparently the origin of the reported columella. Balken are a reality, but are not present in all species. They represent small depressions in the growing surface of the colony, but the depressions are later filled with solid material instead of being traversed by tabulae. Quite possibly, it may eventually become desirable to subdivide *Catenipora*, recognizing one genus without balken and another with these structures, but at present such a step does not seem altogether desirable, and there is not enough detailed information on the morphology of the described species to permit their assignment to such genera.

Halysites is a logical next step, in which mesocorallites are occupied by tabulae instead of a solid filling. Hamada's genus *Schedohalysites* is interesting, supplying a theoretically desirable link between *Catenipora* and *Halysites*; it shows obvious mesocorallites in some parts of the colony, but not in others. Unfortunately, good photographs of sections are wanting, and one wonders whether indifferent preservation might not be the cause of this apparent condition. *Cystihalysites* is one degree more complex, having tabulae that anastomose in the mesocorallites and also, though to a lesser extent, in the corallites. As the genotype of *Halysites* is not known to possess septal spines, Hamada (1957) has differentiated species with such spines as *Acanthohalysites,* and has erected *Densoporites* for massive, largely cerioid colonies with mesocorallites and, reputedly, small polygonal spaces between the corallites; the two are hard to differentiate in published figures, and either only mesocorallites or only lacunae may be involved.

DESCRIBED NORTH AMERICAN SPECIES

The cateniform corals described from the Ordovician of North America include a large number of species that vary from difficult to impossible to recognize from present descriptions and illustrations, and reexamination of the types, which in many cases have never been sectioned, will be required before the characters of the species can be determined. *Catenipora gracilis* (Hall, 1852) is a specific name that has been used most widely in the identification of Ordovician cateniform corals, but Sinclair and Bolton (1956) have pointed out that no type material can be found and that the present description and illustration are inadequate for recognition of the species. The type material is from the Ordovician of Green Bay, Wisconsin. It is in any case a junior homonym of *C. gracilis* Milne-Edwards, 1849.

Whitfield (1900) described *Halysites agglomeratiformis* from Cape Harrison, Cape d'Urville in the Arctic, which was originally considered to be Silurian in age, but its association with *Calapoecia* and *Receptaculites* indicates that it belongs to the group of arctic faunules that are certainly Ordovician and quite probably Red River rather than Richmond in age. *Halysites fieldeni* Etheridge is involved in the same stratigraphic perplexity, but Troedsson (1929) has pointed out that both the locality and the associated fauna indicate Ordovician age. Sections of the types of both these species are needed for establishment of the specific characters. It is even uncertain whether *H. agglomeratiformis* is a *Catenipora* or whether it belongs to *Manipora.*

Wilson (1926) described a number of species from the Beaverfoot formation of British Columbia, all as species of *Halysites. H. robustus* appears to be a good *Catenipora,* with long elliptical corallites forming the chains, and tabulae 1 mm apart. Corallite dimensions are not given. *H. delicatulus* has 3 corallites in 5 mm and 6 to 7 tabulae in 3 mm. The corallites have straight, narrow, common walls, suggesting that this species is probably a *Manipora. H. cylindricus* has corallites round in cross-section and occasional free individuals; those forming chains are in flattened contact with one another, the common walls thin and straight; corallites 1 mm in diameter; 6 to 7 tabulae in 3 mm. The aspect of this species again suggests *Manipora.* Hamada (1957) has made this the type of his genus *Eocatenipora* already mentioned. *H. pulchellus* has 3 corallites in 5 mm, attaining a maximum width of 1 mm, and 4 to 5 tabulae in 3 mm. It appears to ge a good *Catenipora.*

Troedsson (1928) figured several corals from the Cape Calhoun beds of northern Greenland. He figured as *Halysites gracilis* (pl. 40, fig. 3, 3a, and probably 2) a form that is certainly a *Manipora,* showing narrow, slightly crenulate common walls. In longitudinal section (pl. 40, fig. 3a) the common walls show an unusual thickness. Corallites are 1.5 to 2.0 mm wide and 1.75 to 2.0 mm long, 3 occurring in a length of 5 mm; 12 tabulae occur in 8 mm.

Troedsson's *Halysites fieldeni* appears to contain two different things. His Plate 41, figure 3a-b, and Plate 42, figure 1a-b, is a massive coral, mainly cerioid with small lacunae rather than properly cateniform. Slides of the original of his Plate 41, figure 3a-b, in the U.S. National Museum show that the species is a true *Manipora.* Corallites have a very narrow contact; the outer walls are commonly convex. Crenulations are developed on the common walls. One other specimen appears to be different; namely, Troedsson's No. 456, shown on Plate 41, figure 2, and in section on Plate 43, figure 1a-b. It is a good *Manipora* with distinct ranks, each one corallite wide. The corallites have common walls normal to the course of the rank; the outer walls are convex and well rounded. Three corallites occur in 5 mm; 7 tabulae occur in 5 mm. Size is somewhat different, but the illustrations show an aspect very close to our *Manipora magna.* The original description of *Halysites fieldeni* seems to apply to the first of these species rather than to the second, but restudy of the Etheridge type is needed before new names should be proposed.

H. agglomeratiformis Whitfield, as figured by Troedsson, is a true *Catenipora,* with 3 corallites in a length of 5 mm; the corallites having a maximum width, normal to the rank, of 1 mm, and with 15 tabulae in 8 mm. From the illustrations, the corallites of this form are considerably more elongated than those of Whitfield's type.

Wilson (1931) described *Halysites gracilis* var. *borealis* from Putnam Highland. Unfortunately, only a longitudinal section is illustrated, and such sections in *Manipora* and *Catenipora* look much alike. The form has corallites rectangular in cross-section, with the longer axis parallel to the rank. Rectangular corallites are characteristic of *Manipora,* but some *Catenipora* show rather straight common walls also. Miss Wilson also figured and described *H.* cf. *fieldeni,* a species in which the elongate, oval corallites suggest *Catenipora,* and in which the ranks tend to form small intersecting circles, each composed of only 5 to 6 corallites.

Teichert (1937, p. 55, pl. 7, fig. 3, 6) has figured as *Halysites gracilis* a cateniform coral that shows in cross-section corallites which are unusually broad, the outer walls quite strongly convex, so that corallites may be nearly as broad as long. The common walls are unusually straight, and under less favorable conditions of preservation this species might be mistaken for a *Manipora,* but the walls are anomalous in thickness for that genus, and it shows good, even extremely long and prominent, septal spines. It is a good *Catenipora,* but a distinctive one in the narrow, straight common wall, the prominent septal spines, and the breadth of the corallites. Teichert gives the following dimensions: length of corallites, 1.5 to 2.5 mm; width of corallites, 1.5 to 1.7 mm; walls thin, 0.2 mm; tabulae, 6 to 9 in 5 mm. The specimen is from the Ordovician of Kûk, west coast of Duke of York Bay, Southampton Island.

Teichert (1937, p. 57, pl. 8, fig. 2; pl. 9, fig. 4) described *Halysites aequabilis* from the Ordovician of Iglulik Island. This is a *Catenipora* with ranks forming small intersecting circles, like the *Halysites* cf. *fieldeni* of Wilson (1931). Quite possibly the two are the same species. Corallites are 1.1 to 1.3 mm long, 0.4 to 0.7 mm wide; walls thin, rarely over 0.1 mm; tabulae straight, 8 in 5 mm. Common walls are quite thin, widening at their ends owing to the rounding of the oval corallites. Septal spines are not shown. If they are really absent, this species could be a *Quepora,* but spines may be sparse and short in *Catenipora* if not commonly encountered in cross-sections; when this form was described, their importance was not fully appreciated. The illustrations leave some doubt as to whether small, short spines are really absent, and are insufficient to show whether balken are present or wanting.

Roy (1941) figured as *Halysites agglomeratiformis* Whitfield a form from Baffin Island that is clearly a *Manipora,* with corallites about 2 mm long and 1 mm across, and with tabulae straight or concave and averaging 18 in a space of 10 mm.

Roy also figured as *Halysites* cf. *H. gracilis* a form that is a true *Catenipora,* with corallites 2.8 mm long and 2.0 mm wide, and with 9 tabulae in 8 mm. Septal spines are observed only in a few corallites, and are short. Common walls are rather thick, long, and nearly parallel sided, and show some transverse markings in cross-sections, which may be replacement phenomena rather than true balken. Here again the long, straight common walls suggest a *Manipora,* but the spines and the thickness of the wall indicate that the species is a *Catenipora.*

Buehler (1955) recognized only two genera of cateniform corals, *Halysites* and *Catenipora.* He discussed most of the above species, and assigned to *Catenipora H. robustus, H. delicatulus, H. pulchellus, H. gracilis* var. *borealis* (all of Miss Wilson, 1926), *H. aequabilis* Teichert, and *H. quebecensis* Lambe, here recognized for the first time as a species. He attempted to reestablish *Catenipora gracilis* (Hall) on the basis of a neotype from the Selkirk limestone, a procedure that can hardly be valid inasmuch as the original type came from Green Bay, Wisconsin, but he did give dimensions of his specimens. Corallites are 2 mm long, 1.5 mm wide; tabulae about 1 mm apart. He retained *H. fieldeni* Etheridge in *Halysites.* Apparently much of this revision was done without access to specimens of many of the species. *Halysites agglomeratiformis* Whitfield is assigned to *Catenipora,* but comments on the species deal primarily with the specimen figured under that name by Roy (1941), and apparently the holotype was not studied. Leith (1944) had presented a study of "*Halysites gracilis*" as developed in the Ordovician of Manitoba. He presented some significant illustrations, but included under that name two species, one a true *Catenipora,* the other a *Manipora.*

Sinclair and Bolton (1956) presented a review of some cateniform corals, and a second paper, apparently intended to follow this one, but which by chance was published first (Sinclair, 1955), carried the discussion farther. Sinclair and Bolton pointed out that Milne Edwards (1849) used the name *Catenipora gracilis* for a coral from Drummond Island. This was then a new species, and is valid; that difficulty attends its recognition is quite beside the point. Hall's description of *Catenipora gracilis* in the Foster and Whitney report of 1851, which apparently was actually published in 1852 (see Flower and Teichert, 1957, p. 100-101), is a junior homonym. The species is nameless, but was based upon material from Green Bay, Wisconsin. The type is lost. The general assumption that it is this same form which occurs in the Red River beds, is based in turn upon the assumption that the two occurrences are of the same age; neither assumption is warranted. Sinclair and Bolton (1956) therefore propose the name *Catenipora rubra* for the true *Catenipora* in the Selkirk limestone of Manitoba, indicating that another species, previously confused with this one, would have to be separated. This is evidently *Manipora amicarum* Sinclair (1955). Sinclair's further contribution, which was published first, involved the recognition of three genera, *Quepora* (new), *Manipora* (new), and *Catenipora. Quepora* was based upon *Halysites quebecensis* Lambe, and a new species *Q.*(?) *lacustris* was doubtfully assigned to the genus. Both species occur in the Simard beds of Lake St. John, of Black River age, and this locality and horizon represent the oldest known occurrence of cateniform corals in North America. As previously noted, *Quepora* differs from *Catenipora* in the absence of septal spines and in having oval corallites with rather thick fibrous walls. Sinclair considered it as a cateniform development of the dominantly cerioid genus *Lichenaria.* His new genus *Manipora,* which he considered as a cateniform development of the cerioid genus *Saffordophyllum,* was based upon the new species *Manipora amicarum* of the Selkirk limestone, which had not been differentiated previously from the associated *Catenipora.* Here also are additional figures of *Catenipora rubra* Sinclair and Bolton, but details of corallite dimensions and spacings of tabulae, useful characters in specific recognition, are not given.

Hamada (1957, 1959) has presented some observations on the morphology of *Catenipora,* discussed more fully under that genus. His revision of the halysitids (1957a) involves the recognition of the subfamily Cateniporininae, including the genera *Labyrinthites,* Eocatenipora (new), *Quepora,* and *Catenipora;* the subfamily Schedohalysitinae, involving only the genus *Schedohalysites;* and the Halysitinae, including the genera *Halysites, Cystihalysites, Acanthohalysites,* and *Densoporites.* Those genera occurring in the Ordovician have been noted in an earlier section of this work. Of particular interest is a list of the described halysitid corals with references to these genera. The conclusions are apparently based largely upon extant descriptions and illustrations, which are in some instances far from adequate, and the writer's conclusions differ materially from those of Hamada. In some cases, difference of interpretation results from the ambiguity of the extant descriptions and illustrations, but there remain two important differences of viewpoint that should be noted. First, Hamada has assigned a number of species to *Quepora,* because extant information does not indicate the presence of septal spines. However, septal spines may be obscure and scarce in some *Catenipora,* and have doubtless been overlooked in particularly the older descriptions. Further, examination of a considerable amount of Ordovician material has failed to yield any true *Quepora* among the halysitids of the later Ordovician. Second, Hamada has recognized only a single species of *Manipora, M. amicarum* Sinclair. It is quite clear that Troedsson's *Halysites fieldeni* belongs in that genus; it can be recognized in specimens assigned, rightly or wrongly, to older species figured by Troedsson (1929) and Roy (1941), and although one cannot say with certainty exactly how many of the species described from the Beaverfoot formation belong there, a number of them suggest the genus quite strongly, and Duncan (oral communication) has found the genus not uncommon in the later Ordovician coral faunas of Western North America.

It is because of uncertainty of the generic assignment of some of the less adequately described and illustrated species, that it has been most convenient to summarize the Ordovician cateniform corals under one heading. Proper examination of the types and a general revision of the North American species were not possible in the present work.

Although the origin of the Halysitidae in *Lichenaria* and of *Manipora* in *Saffordophyllum* is amply supported by the present study, it should be noted that both genera show some specializations that set them apart from their cerioid relatives. *Manipora* shows outer walls of the ranks continuous and homogeneous, but common walls are slightly different in color and show distinct boundaries, and their edges are buttresslike and commonly inserted into reentrant grooves in the outer walls.

Catenipora shows a different but equally significant specialization. One would expect the fibers of outer walls, which slope obliquely down and out from inner to outer surfaces, to continue around the corallite and form V-shaped patterns where corallites join. This is not found in *C. workmanae;* the slope of the fibers at intercorallite regions is unchanged in direction, the slope directed obliquely down from the balken to the outer surface. It is, indeed, as though common walls were dissected out, leaving the outer walls continuous throughout the rank, but shirred together between corallites, interrupted here only by the small depressions of the balken, which are shallow and filled in below with solid calcitic material, instead of being shut off by discrete tabulae. Such specialization makes a transition back to the condition of cerioid colonies impossible. Material is not available to show whether this specialization is shared by simpler *Catenipora* lacking balken, or by the still simpler forms lacking septal spines, now included in the genus *Quepora.* It is significant that both *Catenipora* and *Manipora* show specializations other than cateniform growth, but specializations in accord with this specialized form of colony.

MANIPORA Sinclair

Genotype: *Manipora amicarum* Sinclair

Manipora Sinclair, 1955, Royal Soc. Canada, Trans., 3d ser., v. 49, sec. 4, p. 97.

Cateniform colonies of corallites with rather thin fibrous walls. Corallites in single ranks are quadrangular in cross-section, those in agglutinative patches or double ranks, both of common occurrence, are polygonal. Common walls are commonly undulate, convexities forming short septal ridges; similar ridges are usually poorly developed on the interior of the outer walls, which are covered by a thin holotheca. Pores are developed commonly at the corallite angles, but may be sparse enough to escape notice. Tabulae are simple, generally transverse.

Discussion. This genus is, as Sinclair suggested when he described it, essentially a cateniform edition of *Saffordophyllum.* Though both outer and common walls are fibrous, the common walls appear considerably darker than the outer walls, and are seen at the edges inserted in excavations of the outer wall. Spheres of poikiloplasm are rare and apparently erratic in development.

As at present recognized, *Manipora* is a fairly common genus in Red River faunas. Three species are described below from the Second Value formation; one is *M. amicarum*, first described from the Selkirk limestone of Manitoba, the two others are new. Material from the Fish Haven dolomite of Utah has revealed the presence of the genus, but dolomitization and distortion of the material result in specimens that cannot be identified specifically with certainty. As noted in the discussion of the cateniform corals, *Manipora* is represented in the Cape Calhoun beds of northern Greenland by specimens that Troedsson (1929) figured as *Halysites fieldeni* and *H. gracilis,* and in the Mt. Silliman beds of Baffin Island by a form that Roy figured as *Halysites agglomeratiformis.* Quite possibly, *H. cylindricus* Wilson and *H. delicatulus* Wilson of the Beaverfoot formation of British Columbia are species of *Manipora,* though present figures and descriptions leave some room for doubt. Miss Helen Duncan states that the genus is not uncommon in Western North American faunas of Red River affinities.

The genus has been recognized only recently, and probably its range is not yet fully known. It has not been found as yet, however, in any faunas known definitely to be older or younger than the Red River faunas in North America.

Sokolov (1949) has proposed a generic name that may possibly preoccupy *Manipora.* This is *Tollina,* based upon *Halysites kayserlingi* von Toll (1889) from the Ordovician of the New Siberian Islands. Some species figured under that genus suggest *Manipora.* However, the original illustrations of Von Toll's species do not suggest *Manipora* at all closely. Sokolov's description is not available in America. I am indebted to Miss Helen Duncan for the suggestion that the two genera might be identical. For the present it seems better to use *Manipora,* being based upon an adequately known and readily recognized species, than to attempt a change of generic name based upon supposition; if the genera prove to be identical, the transfer will be a relatively simple matter.

Manipora magna Flower, n. sp.

Pl. 1 (entire); pl. 2, fig. 6, 7

Cateniform colonies commonly large; corallites moderately small, 3 to 3½ in a length of 5 mm; in single ranks common walls are vertical, normal to course of rank; both outer walls are convex, the corallite being somewhat moniliform in cross-section.

The type colony (pl. 1, fig. 1), incomplete, was in excess of 160 × 70 mm, and corallites up to 35 mm in length have been observed. Ranks are meandering and irregular, lacunae elongate, length variable, but the width between ranks rarely more than 5 mm. Ranks are more commonly only one corallite in width than double, but frequent agglutinative patches occur where ranks divide or are bent sharply.

In single ranks the corallites show both outer walls convex (pl. 1, fig. 8, 9), with the corallite length variable, but the width always appreciably greater across the center of the corallite than at the region of the common wall. A corallite 1.0 mm in width at the common wall increases to 1.8 mm across the center of the corallite; one 1.5 mm across the common wall increases to 2.0 mm at the center. Corallites somewhat variable in length, from 3 to 3½ in 5 mm; rarely 3 in 6 mm. Plate 1, figures 8 and 9, shows the extremes of variation in length and shape in cross-section. A thick, fibrous outer wall is covered by a thin dark holotheca, but the fibrous part is light in thinsection, far lighter than the common walls. Common walls are fibrous, somewhat darker than the fibrous outer walls. Ends of the common walls are buttresslike, somewhat thickened, and set into excavations of the outer wall (pl. 1, fig. 9). In some sections the contact of common and outer walls may be mistaken for a pore. True pores occur, but although commonly near corallite angles, they are actually within the common walls rather than at the contact of common and outer wall, and the common wall shows extensions in cross-section on one or on both sides of the pore. The lower left of Plate 1, figure 6, shows a pore close to the corallite angle in the lower part of the common wall at the left. Only one example of a pore in the center of a common wall has been observed; it is shown in Plate 1, figure 7.

Crenulations in the common wall are variable, but the convexities rarely are markedly thickened. A common wall will never show more than three septal ridges on one side. Sections cutting the common walls at steep angles show the septal ridges as linear extensions without evidence of serrations or separation into spines (pl. 1, fig. 3, 5). Crenulation of the inner surface of the outer walls cannot ordinarily be seen, but the upper right of Plate 1, figure 9 shows spinous extensions that are such septal ridges. The lower center of Plate 1, figure 10, shows some dark round bodies, at first believed to be septal spines seen in section, developed from the outer wall, but closer examination showed that they represent spheres of poikiloplasm instead. Such bodies are not common in the species, and have been observed only in a few sections; their fine structure is granular and quite unlike the fibrous corallite walls. Extreme thickening of septal ridges is shown in the upper part of Plate 2, figure 7. Apparently, new corallites may appear by budding between two individuals in a rank. The beginning of such an individual is seen in the lower left of Plate 1, figure 8, and apparently another is represented by the enclosed space against the second common wall from the base of Plate 1, figure 9. In double ranks and agglutinative patches, all common walls are crenulate, and it is in these regions that the crenulations and septal ridges are most strongly developed.

Longitudinal sections show some variation in the spacing of the tabulae. Where the tabulae are most sparse (pl. 1, fig. 5), only 5 occur in a length of 5 mm, but 7 to 8 are commoner in normal regions. There are, however, poorly defined regions, never very long, in which the tabulae are crowded, and in these regions, rarely more than 7 mm long, there may be from 9 to 11 tabulae in 5 mm. Tabulae are commonly transverse, but irregularities occur, the edges being turned slightly down or up; in crowded zones one incomplete tabula may fuse with an adjacent one. The undulate tabulae near the bottom center of Plate 1, figure 10, are uncommon; apparently, where edges are slightly modified they tend to show a slight crenulation, for this part of the section is markedly eccentric. It is here also that poikiloplasm spheres, which must have been attached to the corallite wall, are shown.

Discussion. Part, but not all, of the apparent variation in corallite proportions is due to the fact that in these sections some are not normal to the corallite axes; this is because various individuals and various ranks grow at different angles, and are definitely not all vertical and parallel. Crowded zones are observed in a number of longitudinal sections; although possibly they are rhythmically repeated, our specimens are not long enough to show the frequency of repetition of such zones.

Corallite size in this species is rather close to that of *M. amicarum,* but that form has thicker walls and better developed septal ridges, and in single ranks common walls are as often oblique as straight and normal to the rank, and the corallites fail to show a similar moniliform cross-section.

Holotype. NMBM No. 664; slides indicated a through *l.*

Occurrence. From the Second Value formation, Upham limestone member. The holotype is from the nose in front of the Scenic Drive, El Paso, Texas. Another specimen indicates the species in Hembrillo Canyon in the San Andres Mountains, and fragments have been obtained in the Sacramento Mountains near Alamogordo, New Mexico.

Manipora amicarum Sinclair

Pl. 2, fig. 1-5, 8, 9; pl. 3 (entire)

Manipora amicarum Sinclair, 1955, Royal Soc. Canada Trans., 3d ser., v. 49, sec. 4, p. 97, pl. 1, fig. 1, 4, 10.

Colonies with meandering ranks as commonly double as single, with common agglutinative patches. Corallites occur 3 to 4 in a length of 5 mm; common walls irregular, normal or oblique; outer walls not strongly convex. Common walls thick, crenulate, with convexities thickened into septal ridges.

Colonies may be large, 15 cm across, with corallites 40 mm or more in length. Double ranks are common, as are agglutinative patches at bends or points of bifurcation of the ranks. Lacunae are highly irregular and commonly not perfectly closed as in *M. magna.* Plate 2, figures 1-4, shows in four sections variations in the aspect of the ranks. Of these, figure 2 is a section adjacent to figure 1, and coinciding with the left side of that figure. Owing to mounting, figure 3 is a mirror image, with the bifurcation at center and to the upper right coinciding with that at the extreme right of figure 1. Figure 4 is too far separated from the others to match obviously, but is included to show unusually extensive development of single ranks, which widen where the rank bends, and the dominance of oblique common walls.

Cross-sections show corallites exhibiting a wide range of sizes and shapes. In general, single ranks tend to show corallites with the narrow, relatively straight common walls oblique, as in *M. trapezoidalis,* but here corallites are much smaller than in that species, 3 occurring in a length of 5 to 6 mm. One small portion of a corallite, shown just to the left of the center of Plate 2, figure 1, has corallites with transverse common walls, as in *M. magna,* but here the corallites are much smaller than in that species, 3 occurring in a length of 4 mm. Corallite width is again variable, but in single ranks the difference in width is rarely more than 0.2 mm, for the curvature of the outer walls is generally slight. Particularly in the agglutinative patches, large irregular corallites are seen; the largest observed is 4 mm in one direction, 2 mm in the other. It is apparently these larger individuals which, when traced upward, bud. Small budding individuals attached to the parent corallite are seen in the lower right of Plate 2, figure 9, around the large, spiny corallite at the right of Plate 3, figure 3, and a small individual showing no connection with the parent is seen above the center in Plate 3, figure 3.

As is usual in the genus, common walls are darker than the fibrous outer walls in which they are inserted; in this species the crenulations of the common walls are strongly developed, the convexities being not uncommonly extended as definite septal ridges, clearly seen in Plate 3, figures 3-5. An exceptionally thin section, in Plate 2, figure 9, shows, rather exceptionally, thin common walls on the left side of the figure; here also the textural contrast between common and outer walls is less marked than is usual. Just to the right of the break in the outer wall, a pore is seen where the common wall is traced toward the top of the figure. Similar pores at the angles of corallites are shown in the upper center of Plate 3, figure 4, in the upper left of Plate 3, figure 5, and in the upper right of the latter figure. A pore in the middle of the wall is shown at the left of Plate 3, figure 3; at the middle right in the same figure a large, spiny corallite is open on either side, but the openings are probably not pores, but rather connections with budding individuals. An oblique longitudinal section (pl. 2, fig. 5) shows the rather prominent linear extensions where walls are cut at steep angles, indicative of the strong development of the septal ridges.

Tabulae are lighter, in general, than the walls, transverse, though irregular, and spaced 6 to 7 in a length of 5 mm. No crowded zones have been observed, but possibly observations have been insufficient. The medium-gray granular material bounding and traversing some of the corallites in Plate 2, figure 9, is in large part the edges of slightly bent tabulae; similar material traversing some of the corallites represents tabulae cut obliquely.

Discussion. This form has the proportions of *M. amicarum,* as described by Sinclair from the Selkirk limestone of Manitoba, and the growth habit of the colony agrees with that figured by Leith (1944, pl. 42, pl. 43, fig. 4), but the serial sections that Sinclair (1955, text fig. 1) shows seem to be rather more like *M. magna* in the predominance of single ranks with transverse common walls and both outer walls markedly biconvex. Our form, however, is again very similar in aspect in cross-section to Sinclair's Plate 1, figure 10, in the strong development of septal ridges on the common walls and in the size and aspect of the corallites, particularly in the agglutinative patches.

Figured specimen. NMBM No. 622.

Occurrence. From the Second Value formation, from near the crest of the Scenic Drive, El Paso, Texas; also in Hembrillo Canyon in the San Andres Mountains, New Mexico.

Manipora trapezoidalis Flower, n. sp.

Pl. 4 (entire)

This form has slightly larger corallites than the other two species. Double ranks are extremely common, but wide, irregularly rounded agglutinative patches are exceptional, and larger groups of corallites are confined to intersections of ranks. In single ranks this form is characterized by oblique common walls sloping strongly and alternating in direction, resulting in corallites with trapezoidal cross-sections, the longer base slightly convex, the shorter one straight.

Colony size uncertain; the type is evidently incomplete, but shows ranks 45 mm high and is 55 mm across. Ranks are commonly double; lacunae rather large, elongate, and rather smoothly rounded in outline.

Corallites in cross-section show a characteristic trapezoidal form in single ranks, the slope of the common walls alternating in direction. Corallites occur commonly 2½ in 5 mm, parallel to the rank; occasionally 3 in that length, but more commonly 3 in a length of 6 mm. In width, corallites measure 1.8 mm across at the common wall; owing to the slight convexity of the one outer wall and the straightness of the other, expansion to the middle of the corallite is slight, ordinarily from 1.8 to 2.0 mm. Common walls are thin, and though the undulations or crenulations are slight, cross-sections commonly show septal ridges as short but distinct spinous projections. A section cutting corallites at a steep angle shows the septal ridges as linear projections, without serrations at their edges, but the lack of uniformity of such ridges in cross-sections suggests irregular or possibly rhythmic variation in their prominence. Walls are fibrous and usually thin (pl. 4, fig. 8), but occasionally attaining considerable thickness; the extreme observed in this respect is shown in Plate 4, figure 7, which overlaps in part the upper left of figure 8.

Tabulae transverse; slightly irregular, but fairly uniform in observed spacing; 4 to 5 in a length of 5 mm. Our present material does not show enough corallite length to demonstrate that zones of crowded tabulae do not exist, but they have not been observed.

Discussion. The rather larger corallite diameter and the characteristic trapezoidal section of corallites in single ranks characterize this form, but the septal ridges, which are more actual thickenings of the common wall rather than crenulations, are likewise distinctive.

Holotype. NMBM No. 663.

Occurrence. From the Second Value formation, south Franklin Mountains. The type is from near the crest of the Scenic Drive, El Paso, Texas.

CATENIPORA Lamarck

Genotype: *Catenipora escharoides* Lamarck

Catenipora Lamarck, 1816, Histoire naturelle des animaux sans vertèbres, Paris, p. 207.

Paleohalysites Chernyshev, 1941, Vse soyuznny arkticheskiy ibst. Trudy, t. 158, p. 36.

Catenipora Thomas and Smith, 1954, Annals and Magazine Nat. Hist., ser. 12, v. 7, p. 767.

——— Buehler, 1955, Yale Peabody Mus. Nat. Hist. Bull. 8, p. 25.

———Sinclair, 1955, Royal Soc. Canada, Trans., 3d ser., v. 49, sec. 4, p. 99.

——— Duncan, 1956, U. S. Geol. Surv., Bull. 1021-F, p. 222.

The above synonomy is far from complete, and calls attention only to significant changes in the concept of the genus. For years *Catenipora* was regarded as doubtfully distinguished from *Halysites,* and it was not until Chernyshev in 1941 proposed a new genus, *Paleohalysites,* that it was recognized that these forms, without mesocorallites, could be distinguished from true *Halysites,* which has mesocorallites. The genus was further restricted when Sinclair removed as *Manipora* forms that generally had been included in *Catenipora gracilis.*

As now defined, *Catenipora* contains cateniform corals having corallites with rather thick fibrous walls from which spines, commonly in 12 vertical rows, extend into the corallite cavity. Common walls of corallites may lack mesocorallites, but small mesocorallite cavities developed in more advanced species are filled in with solid calcitic material with further growth, the resultant effect being that of parenthetical marks or round bodies in the common wall, to which the name BALKEN has been given. They are subject to quirks of preservation, are variable in clarity, and are found in many species, but almost certainly not throughout the entire genus. Spheres of poikiloplasm may surround or replace spines, and may appear on anterior faces of tabulae, but are not uniformly distributed among the known species. Tabulae are generally transverse, simple, are somewhat irregular, and may arch slightly either upward or downward.

Thomas and Smith (1954) have refigured and redescribed the genotype, which apparently lacks balken. Possibly it may prove desirable eventually to distinguish generically between species with and without balken, but at present such a procedure would serve no good purpose and would, because of the inadequacy of our present knowledge of many of the species, cause much confusion.

For many years most of the Ordovician cateniform corals of North America were assigned to *Halysites gracilis,* and the belief that this is a very widespread form has at least inhibited descriptions to such an extent that there are not many potential members of *Catenipora* described but imperfectly known. When *Catenipora* was first generally recognized, it was considered as containing all of the known Ordovician halysitids, except, of course, some obviously cateniform *Tetradium,* which though cateniform has perfectly obvious affinities. Sinclair (1955) separated two genera, *Manipora,* which is a cateniform edition of *Saffordophyllum,* and *Quepora,* based upon *Halysites quebecensis* Lambe, which was, indeed, first described as a subspecies of the Silurian *Halysites catenularia. Quepora* contains only two known species, *Q. quebecensis* and *Q.* (?) *lacustris* Sinclair, both from the Simard limestone, and the only halysitids known in the early Middle Ordovician in beds of essentially Black River age, in North America. Hamada (1957) has assigned some other and younger species to *Quepora,* but his conclusions, evidently based completely on published figures and descriptions, deal entirely with inadequately known and poorly illustrated species; so much so that the implied assumption that spines are wanting is scarcely justified.

Catenipora, as it is now known, appears in Red River faunas in western and northern North America, and continues, though apparently only sparsely, into beds of true Richmond age. A few Silurian species are also assigned to the genus.

For years most American cateniform corals of North America were referred to *Halysites gracilis* Hall. Sinclair and Bolton (1956) have shown that this specific name was preoccupied. The type specimen, from Green Bay, Wisconsin, is apparently from beds of undisputable Richmond age, but this specimen has been lost, and the characters of Hall's species are known only in such general terms that precise identification is impossible. Sinclair (1955) based a species *Catenipora rubra* upon what has been commonly called *Halysites gracilis* Hall in the Selkirk limestone of southern Manitoba.

Previous citations of Ordovician forms that are either certain or possible species of *Catenipora* have been largely discussed under the cateniform corals. *Halysites agglomeratiformis* Whitfield (1900), from the Ordovician (not Silurian) of Cape Harrison, must be restudied before its generic position as *Catenipora* can be certain; until this is done, we cannot be certain of the characters of the species, except that it has rather small corallites. Of the forms described by Wilson (1926) from the Beaverfoot formation of British Columbia, *H. robustus* and *H. pulchellus* are quite probably good species of *Catenipora,* but again description and illustration fail to supply some criteria needed for a careful comparison of the species, and even the generic assignment involves assumptions. Forms that are certainly *Catenipora* were described and figured from the Cape Calhoun beds by Troedsson (1929) as *H. agglomeratiformis* Whitfield. We are uncertain as to the genus of *Halysites gracilis* var. *borealis* Wilson (1931), but the same work illustrates as *Halysites* cf. *fieldeni* a *Catenipora* with small round ranks, bounded by 6-10 corallites. Until the type of *H. fieldeni* Etheridge is restudied, we shall not know what it is, but certainly Troedsson (1929) figured a *Manipora* under that name, and Miss Wilson's form is quite certainly the same that Teichert (1937) figured and described as *Halysites aequabilis* from the Ordovician of Iglulik Island. Interestingly, such restricted ranks are rare and apparently characterize only a few distinctive species. A form with even more restricted ranks was described by Fischer de Waldheim from Europe as *Halysites jackovickii;* with ranks of usually 4-6 corallites forming their circumferences, this is a highly distinctive form. Amazingly, a form very similar to this was noted by Duncan (1956, pl. 27 and its explanation) as occurring in the Burnam limestone of central Texas. *Catenipora* is certainly present, and apparently widely present, in the Red River equivalents included in the Bighorn, Fremont, and Fish Haven formations, but proper specific evaluation of these forms remains to be made.

Curiously, we have passed from an era in which every Ordovician halysitid in North America was believed to be *H. gracilis,* to one in which it is recognized that species are more numerous and perhaps not widely distributed stratigraphically or geographically. Nevertheless, of the additional species that have been named, a large number remain with the features so generally known that we cannot be certain of their recognition until their types have been restudied; indeed, the generic positions of some of them remain uncertain. Anomalously, only one Ordovician species that is certainly *Catenipora, C. rubra* Sinclair, is at all accurately described; perhaps *H. aequabilis* Teichert is a distant second, for we do not yet know the spines or balken of this form.

Catenipora is absent in eastern Richmond beds. The most easterly occurrence is that at Green Bay, Wisconsin, and material from this locality supplied the basis of Hall's *Halysites gracilis.* In the west, where Richmond beds succeed Red River equivalents, *Catenipora* is largely unreported. The present work includes one case. A silicified cateniform coral was observed by the writer in the coral zone of the Aleman in the southern Franklin Mountains near El Paso. The specimen defied extraction, and a second one in this horizon has not yet been collected. It is suggested that it may be the same as *Catenipora* sp., here described from a fragment picked up loose on the surface of an outcrop of the Second Value formation; it is a form that fails to agree either with Second Value *Catenipora* found in place, or with the lithology of the formation.

Our present material brings out two facts of interest at the generic level, the nature of the balken and the astonishing replacement of septal spines by poikiloplasm. Though balken were first noted and so named long ago (von Fischer-Benzon, 1871), there seems to have been no suggestion as to their nature; indeed, Buehler (1955) dismissed them as effects of recrystallization, an interpretation completely opposed by our present material and one that Hamada (1957) has also rejected. The present work shows that the balken represent solid calcitic filling in small shallow mesocorallite cavities at the growing end of the skeleton. Balken are, however, obscured and may be lost under various conditions of replacement, and are in general not shown by material in which dolomitization has been extensive.

It should be noted that it has been impossible to correlate the structures seen in the walls of *Catenipora workmanae* with those reported by Hamada (1959) for *C. rubra.* In part at least, there are real differences involved, for *C. workmanae* has failed to offer any suggestion of true septal spines showing swollen bases that are clearly differentiated from surrounding material, such as are shown by Hamada in his Figure 7 on

p. 281, and his photograph shown on Plate 12, figure 3. Resolution of further differences involves some uncertainties of interpretation.

What Hamada has called an epitheca is here termed the holotheca, the holotheca being properly a common covering of the surface of the colony. In relation to the Halysitidae and to *Manipora*, only a change in terminology is involved; inasmuch, however, as the epitheca in *Paleophyllum* is derived from the axial plate in *Foerstephyllum*, and homology of that structure with the holotheca is not evident, the distinction may prove to be significant.

The holotheca of *C. workmanae* shows as a thin dark band, usually very thin; the term holotheca is applied, as this is obviously a common external covering of the colony. It is not clear in many of our illustrations of sections in which darkness and contrast were designed primarily to show other features; when these are emphasized, the distinction between the dark holotheca and the dark matrix is commonly obscured. The holotheca, however, is commonly well displayed in sections showing organic bodies attached to the outside of the corallites, and can be seen as a dark band beneath those bodies in Plates 9-12. In Plate 12, figure 1, the dark holotheca, faintly granular in texture, is particularly well displayed, and it can be recognized in most of the other figures in the same plate. A curious variation is shown in Plate 12, figure 11; on the left, the holotheca shows as the usual very thin dark band, sharply set off from the *Tholella* above it, but its distinction from the fibrous wall within is obscure. Below the *Tholella* on the right there appears beneath the holotheca a narrow band of lighter calcite and then a second dark band; this seems, however, to be one of the anomalies presented by recrystallization. A thin dark holotheca, again slightly granular in texture, is shown in Plate 11, figure 2. In Plate 11, figure 5, the holotheca is slightly broader and darker; a similar condition is shown in Plate 11, figure 12, and, though less clearly, in figures 7-10 of the same plate. Variation in darkness of the holotheca in the various illustrations results in part from variations in thickness of the sections, but in some cases differences are exaggerated by varying degrees of contrast and darkness in prints primarily selected for the clarity with which other features are shown.

Within the holotheca, *C. workmanae* shows a homogeneous fibrous wall. In only a very few sections is there even the faintest suggestion of differentiation into layers comparable with the middle wall and inner stereozone of Hamada's figure (1959, p. 281, fig. 7). Such sections show a suggestion of a possible middle wall in which fibers appear thicker and slightly darker, and an inner zone in which fibers are fine and lighter in texture, but no clear boundary can be found between the two zones; without Hamada's interpretation, the slight differentiation would certainly have been dismissed as adventitious and unworthy of notice. Unfortunately, the differentiation shown in Hamada's text figure is not clearly displayed in his photograph (pl. 12, fig. 3), though the septa are shown as darker entities than the fibrous wall in which their swollen bases are enclosed.

Clearly, in *C. workmanae*, true septal spines are simple extensions of a fibrous wall (pl. 6, fig. 2; pl. 7, fig. 5; pl. 8, fig. 13), from which they are not differentiated in any way in texture, and this condition is quite unlike that of *C. rubra*. The question was raised as to whether the inner stereozone and the embedded spines of *C. rubra* could be a modification of the poikiloplasm as seen in *C. workmanae*, in which the thin rare layer of that material connecting spheres (pl. 6, fig. 6) becomes thick, and the spheres, becoming pointed and spinelike, have been differentiated from the thick lining in texture and color. This interpretation seems the only one that would explain the differences, but it is by no means certain that it is correct. Hamada's photograph suggests that the dark spines with their swollen bases are embedded in a thick fibrous wall quite unlike poikiloplasm in texture, but differentiation of the fibrous wall into a middle wall and inner stereozone is not clearly shown, and the reality of the distinction of these two layers seems doubtful. Such an interpretation offers no explanation for the differentiation of the septal spines or the enclosure of their swollen bases by the fibrous material. Obviously, there remain a discrepancy and a problem in the disparate nature of the two species that cannot be explained with certainty at the present time. In the case of numerous sections of *C. workmanae* it is evident that the figured material is amazingly well preserved, and that it is exceptionally free from alteration of original materials and textures; interpretation in terms of alteration of an original pattern similar to that of *C. rubra* is not possible.

Catenipora workmanae Flower, n. sp.

Pl. 5-7; pl. 8, fig. 1-8, 13; pl. 9-12, in part, with attached organisms

This is the characteristic *Catenipora* of the Second Value formation, developing large colonies in excess of 180 mm across and a height of 70 mm. Ranks single, never double nor with agglutinative patches. Corallites are quite thick walled; the wall, as measured in width, that is normal to the rank, is to the width of the corallite cavity as 1:3.0-3.2 in tabular regions; outer wall surface curved, as seen in cross-section, convex around each corallite, so that width from intercorallite region to corallite center is 3.0-3.5:4. Intercorallite region with balken prominent, broad; length across balken to length of corallite cavity 1:2.6-3.0. Septal spines commonly seen only in calicular areas, pointed, but not sloping upward; at base of calyx they are surrounded by spheres of poikiloplasm, and commonly in the tabular part of the corallite the spheres have resorbed the spines which they surround; spheres (and presumably the original spines) occur in 12 vertical rows around the corallite, commonly with 4-5 bodies in the space between two tabulae; there is no evidence here of zones in the corallite length with and without spines and spheres. Similar spheres grow on anterior faces of tabulae, and may appear as free in the corallite cavity in cross-sections. Tabulae transverse but irregular, arching both upward and downward, 6-7 in a length of 5 mm, but with short (4-5 mm) rather widely spaced zones containing 8-9 tabulae in that length. The crowded zones are short and widely, perhaps erratically, spaced. One corallite was observed with normal, distant tabulae throughout its length of 23 mm.

In cross-section corallites show considerable variation in proportions and outline, for which obliquity of occasional ranks is quite inadequate as an explanation. In the length of the rank, corallites are most commonly spaced 3 in a length of 5 mm, though extension of 3 in 6 mm, is not uncommon; rare examples of 3 in 4.6 mm have been noted. Corallites increase in width from the intercorallite region to the center of the corallites, the increase being typically from 0.8 mm to 1.2 mm. Very rare large individuals occur, the largest observed being 3 mm long and 2 mm wide (pl. 8, fig. 6). Normally, corallites have a maximum width-to-length ratio of 4:3; though the ratio of 7:5 has been observed. Width across the balken is slightly less than one-third the width across the corallite cavity, which is elongate elliptical, the ends rounded, not subquadrangular. The width of the corallite cavity is typically two-thirds the length or slightly less. In width of the corallite, the wall is one-third the corallite cavity or slightly less.

Variations occur. In Pate 6, figure 6, is shown a portion of a colony with exceptionally elongated corallites. In cross-sections through the calices, where the wall thins anteriorly, wall thickness is, of course, less than in the bases of the calices or in the tabulate part of the colony (see pl. 7, fig. 1, 2, 4, 6, for variation in longitudinal section, and pl. 8, fig. 13 in cross-section). Extremely broad, short corallites occur, shown in Plate 10, figure 7. Ordinarily the outer walls show a marked convexity, but one colony, shown in Plate 6, figure 5, and Plate 8, figures 3-5, shows extremely slender corallites only most faintly convex in outline in cross-section.

Walls show a uniform fibrous structure; in cross-section, fibers are parallel and radial in reference to the corallite center. Longitudinal sections show the fibers sloping obliquely down from the inner to the outer surface. Sections cutting calices show that the slope of the fibers is nearly at right angles to the slope of the steeply inclined inner surface of the corallite wall, the surface to which, with further growth, more fibrous material would be added (pl. 7, fig. 1, 5, and less clearly, pl. 5, fig. 5, and pl. 7, fig. 4, 6). Calices are shallow, their length equal to about one and three-fourths the diameter of the corallite. Sections showing the direction of the fibers and the corallites give a clue as to the nature of the balken. Plate 7, figure 1, is a section essentially longitudinal, but slightly inclined to the plane of the corallites, so that it cuts two corallite cavities, and between them, at the base of the figure and just above the center, it cuts through the common walls and balken. Fibers in the wall are uniform in sloping obliquely down from the inner to the outer surface, suggesting that small depressions, essentially similar to those observed in corallite calices, with the inner wall steeply inclined, occurred at the region of the balken. The balken show three longitudinal dark lines in longitudinal section, but the calcite that forms a background for these lines is commonly coarsely crystalline, and fails to show clear orientation of fibers. However, one section, Plate 7, figure 2, offers within one of the balken some indication that fibers arch up from the edges to the center, suggesting that the anterior part of the corallite skeleton here formed a shallow depression. Of the various sections that are very slightly inclined to the corallite axes there is none in which any one calicular depression can be identified as certainly the anterior end of one of the balken, but another section (pl. 8, fig. 2) cuts balken longitudinally, though with slight displacement, and shows a shallow depression analogous to that of the true corallite, with which apparently it was laterally continuous. The evidence suggests most strongly that the balken represent small, shallow mesocorallites, shallow depressions between the larger, deeper depressions of the true corallites, but that the mesocorallite cavity was filled in with solid material, instead of being traversed by discrete tabulae, as in *Halysites.*

Views on the balken have been diverse. Buehler (1955) doubted their organic nature, but it is evident that recrystallization is responsible for the seemingly erratic distribution and clarity, and that they are real organic parts of the coral skeleton, developed in many, but not all species of *Catenipora.* Hamada (1959) has recognized their original organic nature and has shown the variations which the balken show in cross-section in the various halysitid corals in which they have been observed. The nature of balken as possible intercorallite depressions, possibly occupied in life by mesocorallites, and the forerunners of similar cavities in *Halysites,* where they are traversed by tabulae instead of being filled with solid material, seems not to have been noted previously. The significance of the three dark bands, seen in our sections as somewhat irregular structures but certainly continuous longitudinally, remains obscure.

True septal spines commonly are not apparent in cross-sections through the tabular parts of the corallites; instead, in the position of the spines, forming 12 vertical rows around the corallite, and with four to five in the spaces between adjacent tabulae, there are spheres of poikiloplasm. The poikiloplasm appears most commonly as small spheres, round, narrowing toward their base, and looking a little like ball bearings glued to the inside of the fibrous corallite wall. In cross-section they vary slightly in shape, but the spherical bodies are the commonest, as shown in Plate 6, figure 8, Plate 5, figure 4, and Plate 10, figures 11, 12. Some show broad bases and truncated ends, being subquadrate as a result, as in part of Plate 6, figure 4, notably to the right of the center, and near the right of Plate 6, figure 8. Again, these bodies may be slightly elongated, as in the lower center of Plate 8, figure 13; rarely, extremely elongated bodies can be seen, as in Plate 6, figure 6. Commonly these bodies are discrete, but some sections show them connected by a very thin lining of poikiloplasm, clear calcite in which there is a liberal scattering of tiny dark granules; such linings are shown in Plate 6, figures 6 and 7. Those bodies that are attached to the corallite walls (pl. 6, fig. 1, 3; pl. 5, fig. 1) clearly occupy the position of the septal spines. Only in rare instances can true spines be seen upon which these bodies have grown. Such spines are indicated in the longitudinal section in Plate 10, figure 5, by the light centers of the spherical bodies, but this condition is exceptional. It must be concluded that the spheres develop upon true septal spines, but that the spines are resorbed as the spheres develop. True septal spines, extensions of the fibrous wall of the corallite, are exceptional in the tabular part of the coral; one is shown in Plate 11, figure 12. However, sections through the calices show spines, variable, of course, in development, because the plane of the section may not show the complete length of some spines, and may miss others altogether. Plate 6, figure 2, shows a series of spines in sections cutting a series of calicular cavities. In Plate 8, figure 13, are shown two calicular cavities in which the section shows long, extremely slender spines; in adjacent corallites poikiloplasm has formed spheres in the position of the septal spines in the tabular part of the corallites. Spines are shown in the longitudinal sections of calices in Plate 7, figure 1, where they appear only as small denticles in the lower left of the calyx, in Plate 7, figure 5, and, more imperfectly, in part of Plate 7, figure 4. There is every reason to believe that the spheres of poikiloplasm serve as a good indication of the original number and arrangement of the spines. If so, there is clearly not any such alteration of zones with and without spines as was reported for *C. rubra* by Sinclair. Neither are such true spines as have been observed pointed obliquely upward, nor has any such inclination of the bodies of poikiloplasm been observed.

Various corallites show in cross-section what are apparently free spheres of poikiloplasm. Plate 5, figure 4, shows a series of corallites, the one on the left containing several such small spheres, and another, just to the right of the center, showing one large sphere. Very abundant spheres of this sort are found in Plate 7, figure 7, and additional clusters are shown in Plate 6, figures 7 and 8. Longitudinal sections show no spheres scattered freely in the spaces between the tabulae, but show erratic examples of spheres growing on the anterior faces of the tabulae; it is apparently such bodies that appear as free spheres in the cross-sections. Spheres on the anterior faces of tabulae appear in the upper right of Plate 6, figure 1, and a few are shown in Plate 7, figure 3.

Specific relationships. There are few named species of *Catenipora* recognized in the Ordovician of North America, and present figures and descriptions are not altogether adequate for close comparison with most of them. Indeed, the only really adequately described and illustrated one is *C. rubra,* of the Selkirk limestone of Manitoba. I had fully expected to be able to recognize that species in the Second Value formation, but the prevalent form, *C. workmanae,* is very different. Corallite proportions are not dissimilar; *C. rubra* has corallites 2 mm long, expanding in width to 1.5 mm, which is slightly broader than in *C. workmanae;* tabulae, however, are given as 1 mm apart, considerably more distant than in our present form. The greatest differences are seen in the aspect of the corallites in cross-section. In *C. rubra,* common walls are very thin, balken are not clearly evident, and the corallite cavities are straighter at their ends, and subquadrate rather than elliptical in cross-section. Septal spines are long and pointed obliquely upward, and they appear distinct from the fibrous corallite wall, within which their swollen bases are quite evident (Hamada, 1959). No poikiloplasm replacing spines is apparent in this species, whereas it is one of the dominant features in our form.

Teichert's *C. aequabilis* has smaller corallites, 1.1 to 1.3 mm long, 0.4 mm to 0.7 mm wide, and ranks form regular circles around small lacunae, each circle composed of few corallites, from 6 to 10. *Catenipora* cf. *jackovickii* figured by Duncan (1956, pl. 27, fig. 1d-e) from the Burnam limestone has even smaller lacunae. No similar form has been found in the Montoya.

Three rather anomalous specimens from the Montoya seem somewhat different. One, a small specimen showing the early initial part of a colony, appears quite close to *C. workmanae,* differing mainly in that the width across the ranks does not increase materially from the edges to the centers of the corallites. An apparently distinct form with small rounded corallites is represented only by fragments (pl. 8, fig. 9), unfortunately considerably replaced, but we have been able to recognize *C. workmanae* in spite of replacement in the same association, and this form is quite different in the shape of the corallites. A third form, with much larger corallites, is represented by a single piece found loose on the surface of the Second Value formation. Its distinct proportions and peculiar lithology combine to suggest that the specimen came from a different horizon, and may be from the Aleman.

Types. Holotype and paratypes, NMBM No. 665-667.

Occurrence. From the Second Value formation. The species is abundant in the southern Franklin Mountains at El Paso, from which the holotype came. It has been found also north to Hembrillo Canyon in the San Andres Mountains, north to the vicinity of Alamogordo in the Sacramento Mountains, and west to the Cooks Range in south-central New Mexico. Probably conspecific but very poor specimens have been seen at Mud Springs Mountain, but cateniform corals have not been observed in the Black Range sections, in the vicinity of Silver City, nor in the Big Hatchet Mountains.

Catenipora cf. *workmanae*

Pl. 6, fig. 5; pl. 8, fig. 3-5

Under this designation is described a small portion of a colony, quite probably incomplete, showing ranks radiating from a common center near the base, and thus representing something very close to the initial growth stages of a colony. The specimen shows a height of 35 mm and a distance across of 58 mm. Ranks and lacunae are similar to those of *C. workmanae,* but cross-sections show corallites that are scarcely broader across the center of the corallite than at the region of the balken. Corallites vary in length parallel to the rank from 1.5 to 2.0 mm, but increase in width across the rank from 1.0 to only 1.2 or 1.3 mm. Walls are thick; corallites are oval, fairly well rounded at their ends; balken are well developed. Poikiloplasm has replaced most of the septal spines, but is not as strongly developed as is usual; some true spines can be seen in cross-sections, whereas some sections fail to show either true spines or poikiloplasm.

Discussion. The extremely slender corallites, the apparently rather distant septal spines, and the rather poor development of poikiloplasm set this apart from *C. workmanae,* which it resembles in other features. It is by no means certain, however, that these features, which do seem to lie outside the limit of variation exhibited in other colonies, might not be characteristic of early growth stages of a colony or the species.

Figured specimen. NMBM No. 668.

Occurrence. Second Value formation, from the nose in front of the Scenic Drive, El Paso, Texas.

Catenipora sp. (1)

Pl. 8, fig. 9

Under dolomitization and slight flowage, such as may occur where minor thrusting has occurred, the species of *Catenipora* become most difficult to interpret. The dolomites of Hembrillo Canyon have, however, yielded fragments of a form that appears somewhat different from *C. workmanae,* largely in the more strongly convex outlines of the corallites in cross-section, and the rather narrower intercorallite areas; balken are not seen here, but alteration may account for their apparent absence. Poikiloplasm is not apparent; again, alteration may be the explanation, but the same locality has yielded typical *C. workmanae* in which such bodies are apparent, though fainter than in the specimens from limestones. Corallites in this form vary in length from 1.5 to 2 mm; the common wall is less than one-fourth the distance across a corallite cavity. Corallite width increases with proportions of 3:4, but corallite length is to width about as 4:5.

Discussion. There is only one fragment showing the corallite proportions shown here; insufficient to permit a longitudinal section to determine whether there is any difference in tabular proportions distinguishing it from *C. workmanae,* but tabular spacing in general seems to show only very poor specific differences anyway, and the lack is not as serious as it might be.

Figured specimen. NMBM No. 786.

Occurrence. From the Second Value formation, Hembrillo Canyon, San Andres Mountains, New Mexico.

Catenipora sp. (2)

Pl. 8, fig. 10-12

Only a fragment of this form is available, showing a surface 25 × 55 mm, and a corallite length of 65 mm. Lacunae are rather large, commonly 9-11 mm wide and in excess of 20 mm long. Corallites are relatively large, 2.2 mm long on the average, three occurring in a length of 7 mm. Width increases from 1.5 to 1.9 mm and from 1.6 to 2.0 mm from the common walls to the corallite centers. Cross-sections show the usual rather thick fibrous walls. Common walls exhibit balken; in cross-section the common walls widen only slightly from the center to either end, and the corallite cavity is somewhat more nearly quadrate than in *C. workmanae.* Cross-sections show a few septal spines, clearly extensions of the fibrous corallite wall, but spines are not abundantly shown in any section; apparently they are rather widely spaced. They are not commonly replaced by spheres of poikiloplasm, though a few small spheres of this material have been observed in the longitudinal sections.

Tabulae transverse, slightly irregular, five, rarely six, in a length of 5 mm where spacing is wide, which is the general condition, spacing being uniform in one section over a length of 9 mm. Short zones of crowded corallites do occur, one being 4 mm long and containing six tabulae in that length.

Discussion. This form is not named, the present material being considered too fragmentary to serve as a basis of a species. It is clearly distinguished, however, from the common Second Value species by larger lacunae and considerably larger corallites; moreover, the corallite cavity is more quadrangular in cross-section, and true septal spines are retained in the tabulate part of the coral and are not replaced by poikiloplasm.

Figured specimen. NMBM No. 669.

Occurrence. This specimen was picked up loose on the nose in front of the Scenic Drive, El Paso, Texas. Its origin in the Second Value limestones there seems very dubious, first, because no similar forms have been found in place, and second, because the matrix, a fine-grained, light-yellow dolomitic limestone, is quite unlike the Second Value formation as developed there. The coral zone of the Aleman has shown one silicified *Catenipora* in place, on a flat surface where collecting was impossible, and it may be that the present form, though unsilicified, could be from that horizon; certainly no other nearby source is probable, the known Silurian being uniformly different from the lithology of this specimen, and a higher origin being impossible. Both silicification and extent of dolomitization in the Aleman coral zone show wide local variation, and that source, therefore, is deemed the most likely; there the limestones or dolomites commonly are light in color, and the fine texture is at least consistent with such an origin, though not in itself conclusive.

BACULAR CORALS

Here are placed together a few specialized genera characterized by quite solid skeletons, encrusting or ramose in habit. The solid skeletons and the small corallites, which may, indeed, be quite obscure, set these forms apart from other corals; indeed, in the field they may readily be mistaken for other types of organisms. The *Coccoseris* is easily mistaken for a stromatoporid, and *Pragnellia,* particularly in such a small species as the one here described, could be mistaken in casual examination for a ramose bryozoan. The three genera probably are more closely related than recent classifications indicate. Crucial genera, as yet unknown in the American Ordovician, are involved, and some of them rest upon rather inadequate descriptions and illustrations (Kiaer, 1904). At present any attempt to revise the group would be most inappropriate.

PRAGNELLIA Leith

Genotype: *Pragnellia arborescens* Leith

Pragnellia Leith, 1952, Jour. Paleont., v. 26, p. 794.

This is a colonial arborescent coral, the branches showing narrow internodes separating larger nodes. Corallites are small, circular, and surrounded by a circle of 14 or more septal ridges, which, on the surface, are elevated above the general level of the coenenchyme, which itself shows a surface of raised pustules less elevated than those bounding the corallite, but scarcely smaller.

Our present material of this genus supplies a new species, but is all in such an advanced state of silicification, and is so extremely fragmentary, that sections have not been possible. It is not possible, therefore, to contribute to the questions surrounding the morphology of this genus. Leith's sections suggest that the pustules are bacular rods or possibly free trabeculae. One can see in the aspect of the corallite edges some similarity with that of *Nyctopora,* but here the trabecular bodies are scarcely extended as spines or ridges into the corallite. Similar bodies in the coenenchyme are scarcely smaller, but are somewhat more widely spaced. Leith's transverse section shows light material in the centers of the corallites; possibly this represents bundles of bacular rods like those of some *Protrochiscolithus,* but if so, they are not apparent as elevations in the centers of the corallites on the surfaces, as is generally true in that genus. Leith also reports small, barblike structures or small, sharply pointed, triangular projections extending from the rods; unfortunately, preservation leaves the interpretation of the fine structures somewhat doubtful.

Pragnellia delicatula Flower, n. sp.

Pl. 15, fig. 1-7

Etching from the coral zone of the Aleman yielded a few fragments of a coral which, from its surface features, is closer to *Pragnellia* than to any other described genus, having small round corallites, ranging from 0.8 to 1.4 mm in diameter, the corallites being separated by coenenchyme, which varies considerably in width among the different fragments; six of the fragments show corallites separated by less than two-thirds their diameters, though one ramose fragment shows corallites more widely spaced, some separated by distances slightly in excess of their diameters. The surface shows numerous fine pustules in the coenenchyme; a ring of pustules, prominently elevated but scarcely larger, form an elevated ring around the corallites; such pustules may number as many as 20. They are widely variable in form, but their inner edges form septal ridges; they are, in this respect, very reminiscent of the shorter trabecular bodies seen in *Nyctopora,* but they are here only rarely pointed and never extended inward so as to give the corallite a stellate aspect. In number and brevity they are perhaps more comparable to the shorter ridges seen in some species of *Foerstephyllum*.

Our fragments are all small; indeed, at first it was believed that they pertained to an encrusting coral, some colonies of which were growing on ramose Bryozoa. However, closer examination showed that there was no differentiation apparent between central and peripheral structures, and the specimens showed corallites around their circumferences, indicating a colony that was ramose and perhaps arborescent. In relation to *Pragnellia arborescens*, the form has extremely delicate branches. One branch is only 2 mm across. A larger flattened branch measures 6 mm across; this is our largest fragment. A smaller one, 4 mm across, shows definite evidence of branching at its one end.

Discussion. Without evidence of internodal structures, assignment to *Pragnellia* may be considered somewhat tentative, but there is no other arborescent coral with which our present form agrees at all closely in surface features; indeed, there is no encrusting form that is really closely similar. Both *Acidolites* and *Pycnolithus* show coenenchyme that appears as a raised reticular network with small depressions, the reverse in relief of the pattern shown by *Pragnellia* and our present specimen. Further, both these genera show corallites that are more prominently stellate at their margins. *Diploepora* has similar raised, rounded corallite margins, but the rims are continuous ridges, not obviously a circle of trabecular or bacular elements; from these rims raised ridges radiate, fading out as they extend into the coenenchyme, faintly suggestive of the trabecular extensions in the more advanced species of *Calapoecia*.

Our form differs from *Pragnellia arborescens* in the extremely fine texture of the branches. The trabecular units surrounding individual corallites appear to be more numerous, 20 as against 14 in *arborescens*, and corallites seem in general to be somewhat more closely spaced in the coenenchyme. The absence of good evidence of internodal structures here is inconclusive; our specimens are too fragmentary to show such structures to be really absent.

Syntypes. Seven fragments, from etchings from a single piece; NMBM No. 732.

Occurrence. From the coral zone of the Aleman formation, from an outcrop at the southern end of the Franklin Mountains, about halfway up the hill just east of the mouth of McKelligon Canyon, at the edge of El Paso, Texas.

PROTROCHISCOLITHUS Troedsson

Genotype: *Protrochiscolithus kiaeri* Troedsson

Protrochiscolithus Kiaer, 1904, Vidensk. selsk. Christiana Skr., Math-naturv. Kl., 1903, n. 10, p. 47. (Hypothetical proposal only; not valid.)

———— Troedsson, 1928, Meddel. om Grønland, bind 72, p. 116.

———— Leith, 1952, Jour. Paleont., v. 26, p. 791.

This genus contains colonial encrusting corals, though colonies may attain an appreciable thickness. Surfaces show closely spaced stellate corallites, their edges raised above the surface of the surrounding coenenchyme, with 12 long and rather thick septa extending toward the center, the centers slightly raised and occupied by some sort of columella. Cross-sections show a rather thick common wall of trabecular elements, often closely packed polygonal bodies, baculi, which are only trabeculae thus modified. Similar polygonal bodies are commonly distinguishable in the septa, which are rather broad. Relatively narrow interseptal spaces exist. Tips of the septa join a columella. Two types of columellae have been found in the genus, one consisting of vertical bacular rods, the other of a vesicular network.

Vertical sections show the common walls composed of baculi in which a V-shaped, fine arrangement of the fibers is evident. Similar baculi form the septa, but these baculi are oblique, sloping forward from the bases to the tips of the septa. Those species showing a columella of vertical baculi will show some of the oblique baculi of the septa continuing, changing direction from oblique to vertical, in the columella; others are truncated by the columella; there is not room for all of them to continue in this way. Tabulae are confined to the interseptal spaces; they are transverse, though their edges are slightly upturned where they join the septa. Species with vesicular columellae have been observed only from somewhat replaced material in which textural features are altered to some extent. These forms suggest that the twisted plates of the columella are more similar to the tabulae than to the trabecular materials of the septa.

Discussion. The encrusting form, and the small stellate corallites with 12 rather than 8 or 16 septa, distinguish this genus from *Nyctopora* or *Billingsarea*. No columella is developed in the former genus; that of *Billingsarea* is composed of spheres of poikiloplasm. In neither genus are the trabeculae crowded to such a degree that they appear as rods so appressed that they are polygonal in cross-section. Also, the septa are simple extensions of trabeculae, and walls are only one trabecula in width. In *Protrochiscolithus*, on the other hand, walls are so broadened as to show corallites with raised margins above a narrow but generalized coenenchyme, and septa are composed of many oblique trabeculae, which show some variation in clarity of their edges, some appearing as distinct polygonal rods, and others appearing as trabeculae with poorly defined boundaries.

Coccoseris, in its simplest state, may be considered a *Protrochiscolithus* in which septa are so widened that interseptal spaces traversed by tabulae disappear. Without good surfaces showing raised corallite edges and their centers depressed, normally below the general surface of the coenenchyme, which is here somewhat broader than in *Protrochiscolithus*, but with slight central elevations formed by the columellae of vertical baculi, corallites can be recognized in sections only by the baculi, which slope from the corallite edges to the tips of the septa; where the septal baculi are steepened so that this contrast is no longer evident, corallites cannot be distinguished.

The present study, which has included examination of sections of the genotype, has failed to corroborate the presence of pores previously reported in the corallite walls. Longitudinal sections have showed only very faint, irregular, light bands common to septa and corallite walls, but their irregularity in form and distribution is quite at variance with any true pores known in other corals, and it is believed that replacement may account for the appearance that Troedsson observed.

Sections of *P. magnus* show considerable variation in the aspect of septa and corallite walls, though the sections observed are from a single colony. In some parts, the fine structure consists of V-shaped fibers forming simple monacanthine trabeculae, the margins of which are poorly defined. Others show these as closely packed bodies with definite polygonal outlines. Some such bodies retain V-shaped fine structure, but in others such fine structure is not evident. Some sections have shown large crystalline units, some comprising entire septa, without definitive centers of deposition, but others have exhibited septa composed of oblique units varying from trabeculae to baculi.

Completely unexpected at first was the striking discordance between the two types of columellae found in the genus. Those of *P. kiaeri* and *P. alemanensis* are vesicular, twisted strands enclosing many small hollow spaces, whereas *P. magnus* and apparently *P. hembrilloensis* have instead columellae of solid, closely packed vertical baculi, and are completely solid structures.

The first species of the genus to be made known as such is *P. kiaeri* Troedsson, from the Cape Calhoun formation of northern Greenland. Leith (1952) identified with this species additional material from the Selkirk member of the Red River formation of Manitoba, which he regarded also as identical with what Whiteaves (1897) had described as *Protarea vetusta* var. *magna.* Had this conclusion been correct, the trivial name of *magna* would necessarily be valid, for it has priority over *kiaeri,* and varietal names, unless definitely indicated as of sub-subspecific rank, have a status equivalent to species or subspecies for purposes of priority. (J. C. Bradley, *fide litt.*).

Two further complications develop. Whiteaves' species or variety needs to be reestablished on the basis of a lectotype selected from his several syntype specimens, and this species should be studied from sections. Leith's illustrations suggest most strongly that the moundlike encrusting colonies in the Selkirk limestone are not all one thing; some show the small stellate corallite cavities of *Protrochiscolithus,* but other show a fine granular surface without evidence of stellate corallites. Such corallites are commonly evident even when original surfaces are abraded, for the interseptal spaces appear strikingly different from the remainder of the skeleton. Forms showing only fine granular surfaces without evident corallites may belong to *Coccoseris* and not to *Protrochiscolithus.* Such specimens, figured by Leith on his Plate 114, Figure 7 and 8, are very reminiscent of our *Coccoseris astomata* of the Second Value formation.

The writer has been unable to agree with Leith that the *Protrochiscolithus* of the Selkirk limestone is conspecific with *P. kiaeri* from Greenland. The Greenland form has quite thin common walls, narrow septa, and interspaces wider than the septa, shows slight differences in corallite size, and has a vesicular columella, whereas that of the Manitoba form is composed of baculi. It is clear that the species are distinct, and others may conclude that the differences in the columellae should be recognized by separating the species into two different genera, a course not recommended, at least at this time. The genus is recognizable as it stands, species are few, and it is not clear that its division would result in more faunally significant groups. Tentatively, Whiteaves' trivial name of *magnus* is applied to the Selkirk limestone *Protrochiscolithus,* although if, as suspected, the suite of type specimens also includes a species of *Coccoseris,* the reviser of that material would be equally justified in designating either of the two included species as the lectotype, and if the *Coccoseris* is chosen, a new name for the Manitoba *Protrochiscolithus* would be needed. Perhaps selection of the *Protrochiscolithus* species as the lectotype would be preferable, for in referring his form to *Protarea,* Whiteaves was clearly influenced by the presence of stellate corallites on the surface, which are always found in the *Protrochiscolithus* but may not be evident on the *Coccoseris.*

Our single specimen from the Upham dolomite was at first regarded as conspecific with *P. magnus,* but it shows some differences, making its recognition as a distinct species preferable; largely differences in width of septa and interspaces, and the conspicuously larger and more prominently elevated columellae. A second form, represented by a single specimen from the Aleman beds, agrees closely with *P. kiaeri* in the narrow septa and wide interseptal spaces, as well as in the vesicular columella, but differs in corallite size, the much larger columella, and much thicker common walls.

Curiously, the two species of certain Red River age, *P. magnus* (Whiteaves) and *P. hembrilloensis,* have bacular columellae. *P. alemanensis* is of Richmond age. One can only wonder, in the absence of precise information, whether *P. kiaeri* came from the upper part of the Cape Calhoun "formation," in which upper beds are possibly of Richmond age.

As yet, *Protrochiscolithus* has been recognized only in the Cape Calhoun formation of Greenland, the Selkirk of Manitoba, and the two species of the Second Value and Aleman of New Mexico and Texas. The type of *P. alemanensis* is the basis of Duncan's (1956) citation of the genus in later Ordovician faunas of western North America, and was kindly offered for description in the present study.

Some question has been raised as to whether *Protrochiscolithus* and *Protarea* are distinct genera. Difficulty stems from the fact that typical *Protarea* of the Trenton and Cincinnatian of eastern North America is represented by colonies that are such extremely thin encrustations on other fossils, that longitudinal sections show some vertical baculi but are insufficient to show tabulae in interseptal spaces, and cross-sections are equally vexing, for a plane will show either matrix or the material on which the coral grew in many crucial regions. The writer's own sections of *Protarea richmondensis* suggest that the common walls are composed of larger and fewer crystalline units than are those of *Protrochiscolithus,* possibly originally large trabeculae. Septa are 12 in number as in *Protrochiscolithus,* but although corallite surfaces show a small central elevation that is clearly a columella, the best cross-sections show this structure only most imperfectly because of its extremely limited vertical development. This columella appears to be composed of rather loosely arranged trabecular pillars, not closely similar either to the bacular columellae of *Protrochiscolithus magnus* and of *P. hembrilloensis,* or to the vesicular columellae of *P. kiaeri* and *P. alemanensis.* No tabulae have been observed in the interseptal spaces of *Protarea.* It may well be that *Protarea* is specialized in that it has lost the ability to develop tabulae, a feature that would account for the development of colonies as only extremely thin encrustations. As noted above, there are also suggestions that *Protarea* has a somewhat different wall structure. Although not regarded as conclusive, the present observations suggest that *Protarea* and *Protrochiscolithus* are distinct genera, though quite possibly closely related.

The four species of *Protrochiscolithus* here recognized may be diagnosed briefly as follows:

kiaeri—Corallites 1.8 mm, less commonly up to 2.0 mm; septa thin, may be sinuate, narrowing gradually from base to tip, separated by interseptal spaces at least twice width of septa; common wall very thin, appears porous. Columella small, one-fourth to one-fifth corallite diameter, of vesicular anastomosing elements. Tabulae sparse.

magnus—Corallites 1.6 to 1.8 mm, rarely 2.0 mm; septa broad, gradually narrowing to tips; interseptal spaces narrow, rarely as broad as septa, irregularly elongate, may be parallel sided. Common wall thick, columella bacular, one-third corallite diameter. Tabulae close, 7 to 8 in 2 mm; about 18 in 5 mm.

hembrilloensis—Corallites 1.5 to 1.6 mm across; very thick walls; septa broad, narrowing gradually to columella; interseptal spaces very linear and narrow. Columella presumably bacular, very large, one-half corallite diameter, rarely as small as one-third of same. Tabulae not observed.

alemanensis—Corallites typically 2.0 mm, rarely 1.8 mm; septa contract rapidly from rather thick common walls, in their basal one-third or one-fourth; sides parallel for greater part of their length. Interseptal spaces usually twice width of septa. Columella one-third corallite diameter, structure vesicular. Tabulae sparse, 12 to 14 in 5 mm.

Protrochiscolithus magnus (Whiteaves)

Pl. 13 (entire); pl. 14, fig. 2-5; pl. 15, fig. 14

Protarea (*vetusta*? var.) *magna* Whiteaves, 1897, Canada Geol. Surv., Pal. Foss., v. 3, pt. 3, p. 155, pl. 18, fig. 2, 3, 3a.

Protarea vetusta var. *magna* Lambe, 1899, Canada Geol. Surv., Contrib. Canadian Paleont., n. 4, pt. 1, p. 91.

Portarea magna Kiaer, 1904, Vidensk. selsk. Christiana Skr., Math-naturv. Kl., 1903, n. 10, p. 50.

Protrochiscolithus kiaeri Leith, 1952, Jour. Paleont., v. 26, p. 792, pl. 114, fig. 1-6 (7-9?); pl. 115, fig. 1-4.

As noted under the generic discussion, the *Protrochiscolithus* of the Selkirk limestone of the Winnipeg region is recognized as distinct from the Greenland *P. kiaeri*, and it is tentatively retained under Whiteaves' name here, though it is recognized that restudy of the types is needed; although some of the specimens in Whiteaves' suite of types are clearly true *Protrochiscolithus*, it is possible that there may be some *Coccoseris* included also that have not been distinguished from the true *Protrochiscolithus*.

P. magnus has corallites commonly 1.5 to 1.8 mm across, with common walls much thicker than in *P. kiaeri*; septa broad, narrowing gently from common wall to columella. Interseptal spaces are never prominently broader than the septa; they may equal them in width or may be much narrower. The columella is larger than in *P. kiaeri* and is composed of polygonal solid baculi. Tabulae traversing the interseptal spaces are rather irregular in spacing; most commonly 6 to 7 in a length of 2 mm.

Rather extensive sections were made of this species to determine details of morphology, as the material by which it is represented is far better preserved than that representing either of our Montoya species, and the sections of *P. kiaeri* from the Cape Calhoun beds suggest that some replacement or recrystallization has obscured original structures there also. As noted in the generic discussion, cross-sections show columellae of a series of polygonal vertical baculi; they are surrounded by the 12 septa, which join the columella with truncated, sometimes appreciably broadened, tips. Ordinarily, each septum, together with its much broadened base, that joins an adjacent similar unit (commonly extended as a septum into the adjacent corallite) appears to be a single crystalline unit. These units, in size and distribution, recall the trabeculae that form septa and common walls in *Nyctopora*, except that here is was not possible to see the center of deposition and radial markings to be expected in a true trabecular unit. In other parts of the section, however, it was possible to make out fine divisions in each of these units. Cross-sections are shown in Plate 15, figure 14, and Plate 13, figure 5, at a relatively low enlargement, and in greater enlargement and more detail in Plate 14, figure 5. Longitudinal sections show the columella uniformly composed of vertical baculi (pl. 13, fig. 1, 2, and to the right of fig. 9; pl. 14, fig. 2-4), but there is considerable variation in the structure of the common walls and septa. Some show only obscure V-shaped markings, the center of the V always located at the base of the septum, in the thickened part that forms a common wall to the corallites; this is shown well in the lower right of Plate 13, figures 1-2, and in figure 9 on the same plate. Other septa show definite oblique bacular units, best shown on the left side of Plate 13, figures 1-2, and again in the center of figure 4; evidently it is such bacular units, which are not everywhere clearly defined, that result in the appearance of finer divisions in the large "trabecular" bodies comprising each septum and its broadened base, in the cross-sections. Oblique, quite irregular, light lines are seen occasionally in the septa (pl. 13, fig. 9; pl. 14, fig. 4), but they are quite irregular in form and distribution, and seem to be phenomena of replacement or recrystallization, and not pores or any other organic structures. The illustrations show amply the rather irregular spacing of the tabulae, which are slightly upcurved at their edges. Curvature may be relatively minor where the section is more or less normal to the interseptal space and the space is narrow, but is more pronounced where the space is broader, and where the section passes more or less parallel to its axis, as in the lower right of Plate 14, figure 4 (also middle right of fig. 3, which is the same section). In Plate 13, figure 6, the section cuts the septa below, but passes obliquely above into broad interseptal spaces, where tabulae are markedly curved. In figure 7 of the same plate, there is a series of narrow tabulae, one broadening markedly above as the plane of the section passes into its axis. Figure 8 of the same plate shows a series of light interseptal spaces below, but above, the plane of the section passes from interseptal spaces into walls and septa; here V-shaped patterns are seen, the lowest points of which represent centers of common walls. In places only the oblique arrangement of structures is evident; in others, the oblique elements are seen as significantly large, and within them are traces of fibers showing them to be in themselves oblique, rodlike baculi. Their upper ends terminate where they touch the vertical baculi of the columellae. Some of the oblique baculi of the septa, as in the lower part of Plate 13, figure 1, become vertical and extend upward as parts of the columella. Others (pl. 13, fig. 1, 2) are necessarily truncated at the columella. This relationship is shown again in Plate 14, figure 4.

The figured specimen is a colony that encrusted an endoceroid siphuncle. It had a maximum corallite length of 10 mm and extended for 100 mm along the length of the siphuncle, being confined to one side, evidently that which lay uppermost.

Figured specimen. NMBM No. 733.

Occurrence. From quarries of the Selkirk limestone at Tyndall, east of Winnipeg, Manitoba.

Protrochiscolithus hembrilloensis Flower, n. sp.

Pl. 14, fig. 1; pl. 16, fig. 2

Our type of this species is a single silicified crust from etched material from the Upham dolomite. Neither the maximum observed corallite length of 7 mm, nor the maximum length of the colony, 40 mm, is probably diagnostic. Corallites measure quite uniformly 1.5 mm from center to center, with very little variation; none have been seen as large as those of 2.0 mm, which are dominant in *P. alemanensis*. Columellae are uniformly large and well elevated, averaging half the corallite diameter. Beyond them, septa are broad, interseptal spaces extremely narrow. Common walls are well elevated, individual bacular units elevated. Though there is some variation in the aspect of the walls, and the possibility of slight alteration by the accretion of extraneous siliceous material must be considered, there is a definite and uniform contrast between the broad, raised trabecular units of the wall of this form and the rather narrow, raised margin observed in *P. magnus*. Sections have not been possible in our only specimen, but there can be little doubt that the large and well-elevated columella is bacular as in *P. magnus*.

Holotype. NMBM No. 734.

Occurrence. From the basal 10 feet of the Upham dolomite member of the Second Value formation, Hembrillo Canyon, San Andres Mountains, New Mexico.

Protrochiscolithus alemanensis Flower, n. sp.

Pl. 15, fig. 8-13

This species is based upon a single incomplete colony that is encrusting; corallites with a maximum length of 22 mm, the colony with a maximum width of 50 mm.

Corallites range in diameter from 2.0 mm down to 1.6 mm, the larger ones being the more common. Thickness of wall makes the boundaries of corallites difficult to measure; measurements are taken from the center of one columella to that of another, a much more accurate procedure. Common walls are conspicuously thick, with the bases of the protruding septa broadly triangular for a short distance, and then slender and parallel sided to their tips, which are truncated or even somewhat broadened where they join the columella. In cross-section the columella shows light and dark patches, which could be interpreted as baculi altered somewhat by replacement, but longitudinal sections (notably that at the extreme left and another just left of the center in pl. 15, fig. 10) show that the columella is made up of short, rather irregular longitudinal elements in which it is impossible to distinguish septal and tabular structures. Interseptal spaces are wider than the main parts of the septa that separate them; in longitudinal section they are traversed by tabulae, irregular in spacing, but rather more widely spaced than in *P. magnus*, and transverse, but slightly upturned as their edges join the septa; tabulae in adjacent interseptal spaces are not always perfectly opposed one to the other. Tabulae occur 12 to 14 in a length of 5 mm.

Discussion. The vesicular columella indicates that this form is more allied to *P. kiaeri* than to *P. magnus*. From *P. kiaeri* it is distinguished by the somewhat larger corallites, the much thicker common wall, and the appreciably larger columella, here one-third the diameter of the corallite, rather than one-fourth or one-fifth as in *P. kiaeri*. From *P. magnus* and *P. hembrilloensis* the form is distinguished by the narrow septa and broad interseptal spaces; probably, also, both of these species have bacular columellae.

Holotype. U.S. National Museum.

Occurrence. From the "middle of the Montoya, three miles west of Helms West Well, in the Hueco Mountains, in the upper part of Long Canyon, Cerro Alto quadrangle, Texas." Both lithology and reported position indicate that this is from the Aleman and not from the Second Value formation. It is this specimen that was the basis of Duncan's (1956) citation of *Protrochiscolithus* in western North American faunas.

COCCOSERIS Eichwald

Genotype: *Coccoseris ungerni* Eichwald

Coccoseris Eichwald, 1860, Lethaea Rossicae, v. 1, p. 442.
———— Lindström, 1899, Konigl. Svenska Vetensk. Akad., Handlungen, n.f., bind. 32, p. 106.

This coral forms encrusting cerioid colonies like those of *Protrochiscolithus*. Typical species show surfaces in which the edges of the corallite cavities are raised slightly above the coenenchyme; corallite centers are depressed, with a slight central elevation marking the columella. Skeletons are composed of baculi; those in the walls and columellae are essentially vertical, whereas those in the septa slope obliquely upward from the walls to the tips of the septa, which terminate at the columellae. As in *Protrochiscolithus*, there are 12 septa, but the septa when fully grown are so broad that they touch each other, and there are no interseptal spaces to be traversed by tabulae. Without good surfaces, only the slope of the baculi in the septa, together with some differentiation in size of these baculi, distinguishes the corallites.

The species of the genus previously known are few, and all show clear evidence of calyces such as have been described. They are *C. ungerni* Eichwald, from the Upper Ordovician of Norway, *C. tumulosus* Hill (1953), from the encrinite limestone of Norway, *C. ramosa* Hill (1955), from the Ordovician of Ida Bay, Tasmania, and *C. speleana* Hill (1957), from the Clifenden Caves formation of New South Wales.

The single species here described supplies the first record of the genus in North America, but Miss Helen Duncan had previously recognized it in the Burnam limestone. The two occurrences appear to represent very similar forms, and they may well be conspecific. Our form is anomalous in that it is not possible to recognize corallites. Surfaces that, if original, might have shown corallites as depressions, have been altered; clearly the surface was smoothed by abrasion prior to burial. Thinsections alone fail to show clear corallite definition. This matter was a source of some preplexity. However, only a slight modification of the previously known species is required to produce this effect, the steepening of the baculi forming the septa until they are no longer oblique, but are parallel to those of the walls and the columellae. With this change has occurred another, for baculi of walls, septa, and columella are so similar in size that they cannot be differentiated.

Some justification could be found for separating the present species as a new genus, but with the relationships evident, at present such a procedure would serve no good purpose.

Coccoseris astomata Flower, n. sp.

Pl. 16, 17, 18

This *Coccoseris* formed a skeleton of vertical baculi that show only slight differentiation in size and texture, and in which corallites cannot be identified with certainty. In part, this effect is produced by steepening of the normally oblique baculi of the septa, until they are essentially parallel with those of the columellae and with any straight baculi that may have developed in the common walls. Even so, it may well be that on the original surface of the colony corallites were depressed and may have had raised margins, but the one Montoya colony shows a surface that seems to have been smoothed by abrasion prior to the burial of the colony.

The holotype is an encrustation with a maximum thickness of 30 mm on the surface of the holotype of *Crenulites duncanae* (pl. 16, fig. 1), the two together forming a nearly hemispherical mass about 200 mm across. In opaque section the baculi appear as fine vertical lamellae, intersected by occasional obscure lines of growth.

The surface of the colony is largely weathered. Under low magnification (pl. 16, fig. 4) it shows fine pustules, the ends of the baculi, but scattered on the surface are larger, ring-shaped bodies, which proved to be foreign to the coral; they possibly represent *Lichenocrinus*, the bases of crinoid stems. These particular ones are unusually small in size, few exceeding 1 mm across. The fine pustules representing baculi show under higher magnification (pl. 16, fig. 3; pl. 18, fig. 5) obscure grouping suggestive of corallites, but the groups are so vague that no two observers could agree on the identity or limits of corallites thus defined. The pustulose effect is the result of recent weathering. One portion of the surface (pl. 18, fig. 5) shows the etched outline of pustules at a relatively low level; at a higher level, shown in the lower left side of the figure, the surface is smooth. Clearly, the smoothing is the result of abrasion prior to burial. Etching which shows the pustules is the result of recent weathering.

Vertical sections show baculi commonly parallel (pl. 16, fig. 5; pl. 17, fig. 2, 3), with some textural differentiation, most of which seems to be the result of slight recrystallization rather than original. In some, V-shaped or, where the section is off center, U-shaped fibers can be seen; in others, fibers are obscure or only most faintly indicated. Only a few sections show any serious discordance in the direction of the baculi (pl. 17, fig. 1, 3), but nowhere are there any consistently oblique baculi similar to those comprising the septa of other species of the genus or the quite similar baculi in the septa of *Protrochiscolithus*. In cross-section (pl. 18, fig. 1-4), baculi appear as polygonal bodies, some clear, others showing centers of deposition and radiating fibers. There is slight and obscure variation in size and aspect of the baculi, but such differences fail to resolve themselves into recognizable corallites.

Cross-sections show a number of rounded bodies in the corallites, apparently homologues of the *Lichenocrinus* seen on the surface. Such bodies on the surface are seen in Plate 17, figure 2. Surprisingly, some similar bodies deeper in the sections (pl. 17, fig. 1) appear to have been hollow spheres. Also seen in the longitudinal sections are vertically elongated oval cavities filled with matrix, obviously the work of some foreign organism (pl. 17, fig. 3, 4).

The base of the colony is sharply defined (pl. 17, fig. 1, 4), lying upon a layer of fine-grained calcitic material, which, if organic, had nothing to do with the *Coccoseris*. At some points in the colony, instead of such material, there is some bryozoan material, and at some points the *Coccoseris* is only narrowly separated from the *Crenulites*, but in most regions there is a definite layer of intervening material, indicating that the *Coccoseris* encrusted a dead rather than a living *Crenulites*.

Several cross-sections were made across the base of the colony. These show some differentiation of materials and occasional lobed edges of the bacular coral material (pl. 18, fig. 6), but even here no corallites can be differentiated.

Discussion. As noted under the generic discussion, this species is distinguished by the development of baculi so uniform in size, texture, and direction that corallites cannot be differentiated with certainty. It seems probable that such differentiation would be quite apparent had the original colony surface been preserved. In the absence of obvious corallites, and with the appearance of only faint irregularities on the weathered pustular surface, this form is not readily recognizable as a coral; indeed, prior to the study of thinsections, it was believed to be some sort of stromatoporid. Miss Helen Duncan is responsible for the recognition of the genus from this material.

Holotype. NMBM No. 670.

Occurrence. From the Second Value formation of the Montoya, from near the crest of the Scenic Drive, El Paso, Texas.

CERIOID CORALS WITH FIBROUS TO TRABECULAR WALLS

The simpler genera of this group form colonies in which corallite walls are conspicuous, though relatively thin, and the unsuspecting may regard them as favositids in the Ordovician. Walls thicken, and short septa develop in *Nyctopora*; in *Calapoecia*, walls thicken to a porous coenenchyme. Probable relationships of the genera have already been discussed. The genera here discussed may be separated briefly as follows:

I. Walls fibrous, with axial plane, slightly crenulate, crenulations variously thickened as short septal ridges; pores present, tabulae largely transverse and simple.
Saffordophyllum.

II. Walls of fibers either centered on short discrete vertical planes, or on linear axes; trabecular units are thick centrally, thinner marginally; the walls show alternate thick and thin regions, but each wall is expanded equally on the two sides at the same point. Tabulae relatively simple.
Trabeculites.

III. Walls of trabeculae on linear axes, trabeculae extended, alternately on one side of the wall and then on the other, into septal ridges; 8 to 16 in a corallite; when 16 are present, septa may or may not alternate in length.
Nyctopora.

IV. Trabecular walls greatly thickened, developing pores formed in regular, intersecting horizontal and vertical rows; septa reduced to columns of discrete spines. Coenenchyme may be thin and corallites polygonal, or wide, with corallites rounded, commonly with conspicuously raised rims.
Calapoecia.

SAFFORDOPHYLLUM Bassler

Genotype: *Saffordophyllum deckeri* Bassler

Saffordophyllum Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 267.

——— Duncan, 1956, U.S. Geol. Surv. Bull. 1021-F, expl. of pl. 24.

This genus contains cerioid corals with rather thin, fibrous common walls, fibers V-shaped in longitudinal section, and axial plane variable in clarity. Walls are crenulate in cross-section, the convexities variously thickened into short septal ridges, commonly with smooth edges, but slight serration develops in some species. Pores occur; they are commonly but not universally located at corallite angles. They are sparsely distributed vertically, but seem aligned, for although they are not commonly evident, a section showing one will usually show others in adjacent corallites. Tabulae are mainly transverse, but develop various irregularities in form and spacing.

Discussion. In gross aspect, *Saffordophyllum* appears to be intermediate between *Lichenaria,* in which no septal ridges are apparent, and *Nyctopora,* in which the ridges are more prominent. If this were all, it would be possible to look upon these three genera as progressive stages in the development of septa, and some gradation would be expected. *Lichenaria,* however, is distinctive in lacking pores and showing instead faint, light, longitudinally continuous lines in the corallite walls, which have no counterpart in *Saffordophyllum.* Its walls are apparently simple and fibrous, and otherwise like those of *Saffordophyllum. Nyctopora,* however, has walls in which fibers are aligned as inverted cones about linear axes, instead of along a continuous axial plane in the center of each wall segment. Longitudinal sections of *Nyctopora* show light longitudinal bands between trabeculae, suggestive of those found in *Lichenaria.* That genus has failed to show true pores.

Trabeculites is erected for species resembling *Saffordophyllum* superficially in corallite size, but in which walls show alternating thick and thin regions, and are composed of trabeculae essentially like those of *Nyctopora,* rather than fibers aligned along axial planes. One species, *T. maculatus,* shows fibers arranged in inverted cones, the centers of which are more commonly vertical planes of short lateral extent than linear axes, and suggests how the transition from fibrous to trabecular walls took place, as already noted.

Poikiloplasm has been observed in the genus, though it is prevalent only in a few species. In *S. deckeri* it can be seen as a thin, continuous, uniform lining inside the corallite walls, but longitudinal sections show it as occasional free spheres formed on anterior faces of tabulae; such spheres, when encountered in cross-section, appear as free bodies scattered in the corallites (Bassler, 1950, pl. 14, fig. 4).

In *Saffordophyllum crenulatum* similar linings are seen in some sections, but others show the poikiloplasm markedly darker and slightly thicker where the material curves around septal ridges. Sections of this form are shown here (pl. 31, fig. 7-12), and the species is discussed briefly below. Spheres were observed on the anterior faces of tabulae in *Saffordophyllum tabulatum,* and again in *Saffordophyllum* sp. from the English Head of Anticosti. *S. goldfussi* shows spheres commonly attached to the walls and, more rarely, on anterior faces of tabulae.

Quite probably all of the species of *Saffordophyllum* are not yet known, as the genus has been recognized only recently. Thus far, only one European species is recognized, *S. kiaeri* Bassler of the Upper Ordovician coral limestone of Norway. Bassler (1950) has summarized the previously recognized species of the American Ordovician. In comparing with thinsections in the U.S. National Museum, it became evident that some species formerly assigned to *Nyctopora* had fibrous walls with axial planes instead of trabecular walls, and transfer to *Saffordophyllum* was required. This and other investigations have brought to light a few additional occurrences, and sections of *S. tabulatum* suggest, but are not adequate to prove, that this species may belong not to *Saffordophyllum* but to *Trabeculites.*

The essential distinguishing features of the species involve corallite proportions, and are summarized in the following table. Additional notes on the species are supplied.

S. deckeri Bassler—A notation on the label of the types by A. S. Loeblich, who collected them, indicates that they came from the McLish formation, and not from the Bromide as stated by Bassler. *S. deckeri* is the genotype and also the oldest species yet known. Under the "holotype" are included two complete colonies that have never been sectioned, and some broken pieces from which the sections were made. It is impossible, however, to say whether the pieces represent parts of two or possibly three distinct colonies. Thinsections show some corallite walls definitely crenulate and typical of *Saffordophyllum,* but others show the crenulations so reduced that cross-sections are very similar to those of *Lichenaria;* the variation occurs among individual corallites in single thinsections and represents real variation within the species, and not variation between individual colonies. Poikiloplasm may line corallites and appear as spheres on anterior faces of tabulae, as noted above. Pores are present in the walls.

S. crenulatum (Bassler)—This species is redescribed briefly below. It is of special interest not only for the fibrous walls, which require its transfer from *Nyctopora,* to which it was originally assigned, but for the thickening and darkening of the poikiloplasm lining of the corallites over regions of the septal ridges. The types are from Hermitage limestone of Tennessee. Pores are present.

S. tabulatum Bassler—This species of the Lebanon limestone of Tennessee is somewhat puzzling. The extremely thin walls of the corallites show local thickenings rather than crenulations, and it may be that the species should be transferred to *Trabeculites.* Recognition, however, of trabecular units in the walls was suggested rather than certain, and for the present the species is left in *Saffordophyllum.* Pores have not been found.

S. undulatum Bassler—The types are from the Platteville limestone of Illinois, but the species is cited also from the Tyrone limestone equivalent in Tennessee. Walls are strongly undulate; pores readily apparent in the type. Poikiloplasm has not been observed. This is the first and oldest of the species in which 12 spetal ridges can be observed in individual corallites with certainty.

S. newcombae n. sp.—This form, described below from the Second Value formation, has walls similar to those of *S. undulatum,* but is distinctive in proportions and shows alternate thickening and thinning of the walls in growth. Pores are present, and septal ridges are 12 in number.

S. franklini (Salter)—Troedsson (1929) and Bassler (1950) have figured under this name a good *Saffordophyllum* from the Cape Calhoun formation. Walls are undulate and fibrous, and pores are present. Until Salter's type is examined, the propriety of applying this name to the Cape Calhoun form is somewhat uncertain, for identification rests on corallite size and tabular spacing. The type of *Trabeculites maculatus* shows essentially the same proportions; it is from Akpatok Island. Salter's type came from Cape Riley, Wellington Channel, about as far from one of these localities as from the other.

S. goldfussi (Billings)—Material labeled as *Nyctopora goldfussi* in the U.S. National Museum shows fibrous walls and 12 septal ridges similar to *Saffordophyllum,* and its trans-

TABLE 1. *SAFFORDOPHYLLUM*

SPECIES	PORES[1]	CORALLITE DIAMETER[2]	SEPTAL NUMBER[3]	SEPTAL EDGES[4]	TABULAE					POIKILOPLASM[7]
					WIDE-SPACED[5]		CROWDED[5]		REGULARITY[6]	
					*	†	*	†		
deckeri	x	1.8	8	sm	9	2-3	11	4-5	a, c, f	l, st
tabulatum	–	2.0	18-20	ser?	6	2	10	6-7	a, c, e	–
crenlatum	x	1.0	16-18	sm	6	1.5	7-8	2	b, c, f	l, c
kiaeri	x	1.0	8-10	sm	13	3	18	5-6	a, c, e	–
franklini	–	3.0	12	sm	7	4	13	7-8	b, d, e, g	–
newcombae	x	2.0-2.4	12	sm	7	4	15	5-7	b, d, f, g	–
undulatum	x	2.0	12	sm	5	2	8	5	a, c, e	–
goldfussi	x	1.0	12	ser?	6	2	8	3	a, c, e	sw, st

1. x, pores present; –, pores absent.
2. In millimeters.
3. Small, immature corallites ignored.
4. sm, smooth; ser, serrated.
5. *, number of tabulae in 5-mm length;
   †, number of tabulate in length equal to width of mature corallites.
6. a, crowded zones erratic; b, crowded zones rhythmic.
   c, transition gradual; d, transition abrupt.
   e, contrast slight; f, contrast marked.
   g, crowded zones very short.
7. –, wanting, not observed; l, lining in corallites; c, lining thickened and darkened into caps over septa; sw, spheres on walls; st, spheres on tabulae.

fer from *Nyctopora* is required. Forms from Lake St. John and from Gaspé show septal ridges relatively prominent, whereas forms from Ohio and Kentucky show faint ridges and slight differences in proportions, both suggesting that possibly two species are at present included under this name. As yet, Billings' types have not been restudied from sections. Bassler (1950) referred to this form as *Nyctopora (Proheliolites) goldfussi,* noting that the 12 rather than 8 or 16 septa, as well as the presence of small tubules or small interspaces, suggest *Proheliolites.* The question as to whether the affinities with *Proheliolites* are real is an avenue of investigation that could not be explored here. The tubules seem to be only slowly enlarging, budding individuals. Septal ridges are continuous, though some spheres of poikiloplasm suggest serrated edges. Nothing approaching the downward-pointing septal spines of true *Proheliolites* is known in the species, and with the transfer to *Saffordophyllum,* required by the wall structure, the species now rests in a genus in which a number of other species are known to have 12 septal ridges in each corallite. The possibility that *Proheliolites* might be derived from *Saffordophyllum* requires fuller investigation.

Saffordophyllum sp. A single specimen in the collections of the U.S. National Museum, No. 90991, labeled as *Paleofavosites prolificus* from the English Head formation of Anticosti, shows the typical simple, fibrous, slightly crenulated walls and pores of *Saffordophyllum.* Here again a problem surrounds the identity of the species, described by Billings in 1865 and never figured. It is doubtful whether Billings' original material is all conspecific, for no coral species is known to range this widely; it was cited as ranging from the English Head formation, which Sinclair (1956) regards as of Maysville age, to the Chicotte, which is probably of late rather than early Middle Silurian age. Twenhofel (1914) and Bassler (1915) cited the species as a synonym of *Paleofavosites aspera* d'Orbigny, based upon material from the Silurian Wenlock limestone of England, a species that also seems to have escaped study of the type by sections. Stearn (1956) has figured and described material from the Stonewall formation of Manitoba as *P. prolificus.* Obviously, revision of the Anticosti material is required; attributed range suggests most strongly that more than one species is involved, and the present specimen suggests that some species may prove to belong to *Saffordophyllum* and others to true *Paleofavosites.*

One other occurrence of the genus is indicated. Foerste (1914) included several different things in *Columnaria alveolata discreta* of the Benson limestone, near Brannon, Kentucky. One of his figured specimens (Foerste, 1914, pl. 4, fig. 1F) shows thin undulate walls highly suggestive of *Saffordophyllum.* Other forms include (1) a species with very long septa, probably a *Cyathophylloides* rather than a *Favistina* (his pl. 4, fig. 1E) and (2) a form suggesting crenulate tabular margins and amplexoid septa highly suggestive of *Crenulites* (his pl. 4, fig. 1A, C, D, and G).

It is of interest that the later Ordovician forms of *Saffordophyllum, S. newcombae, S. franklini,* and *S. goldfussi* show 12 septal ridges in the corallites, but this feature is shared by *S. undulatum* of the Platteville. Septal ridges are more numerous, but apparently variable in number, in *S. crenulatum;* in forms with ridges only faintly developed, their number is not readily apparent.

Two genera, *Angopora* Jones and *Corrugopora* Stearn, are possible descendants of *Saffordophyllum,* with which they agree in having 12 septal ridges or columns of spines, more or less crenulate walls, and pores. *Angopora* has moderately thin, crenulate corallite walls, and short, strongly serrate septal ridges, which, from the strength of serrations, approach the condition of septal spines very closely. *Corrugopora* has thicker walls and longer septal spines, which are definitely discrete. Wall thickness and prominence of spines give cross-sections much the aspect of those of *Nyctopora.*

Both genera have been assigned to the Favositidae. Information on whether they have simple fibrous walls or whether the axial plate is developed would decide the matter; unfortunately, known material is preserved in dolomite, a medium in which fine structure is commonly altered or lost altogether, and typical material is not likely to yield the needed information.

Saffordophyllum crenulatum (Bassler)

Pl. 31, fig. 7-12

Columnaria crenulata Bassler, 1932, Tennessee Div. Geol. Bull. 38, pl. 13, fig. 3, 4.

——— Bassler, 1935, Washington Acad. Sci. Proc., v. 25, p. 405.

Nyctopora crenulata Bassler, 1950, Geol. Soc. Amer. Mem. 44, p. 261, pl. 13, fig. 11-14.

Corallites are dominantly 1.2 to 1.5 mm across, rarely 1.0 mm over any considerable portion of the colony. Walls are thin, fibrous, and crenulate in cross-section, convexities highly variable in thickening; most commonly the ridges do not double the width of the wall in intervening spaces, though some exceptions have been found. Cross-sections show fibrous walls, though the axial plane is rarely clear. Corallites are lined with poikiloplasm, clearly distinct from the fibrous walls. In many sections only a thin lining, uniform in thickness and texture, is seen; in some sections the limit of the poikiloplasm and the distinction from inorganic calcite in the corallites may be obscure (pl. 31, fig. 7), but in others the boundary is well marked and quite clearly defined. Many sections show the lining unmodified as it curves around septal ridges (pl. 31, fig. 7-9), but others show the material significantly darker and slightly thicker where it surrounds the ridges; in strong lighting, such sections show the appearance of top-shaped or mushroom-shaped bodies capping septal ridges, with the intervening lighter connecting material not readily obvious (pl. 31, fig. 10-12). In some sections obscure lineation of the tiny dark granules of the poikiloplasm is indicated. This condition is of particular interest in that it supplies a transition from a uniform lining of poikiloplasm to the condition seen in *Catenipora,* in which large spheres are connected by a thin lining, not apparent in all sections, or there are free spheres without such lining connecting them.

The illustrated sections also contain some examples of pores (pl. 31, fig. 8, 9), though only one such pore, clearly removed from the corallite angles, is shown in the accompanying figures.

Tabulae are spaced 1-2 in a length equal to the corallite width, 4-7 in a length of 5 mm; zones of crowded tabulae are poorly defined, not contrasting strongly with intervening zones of widely spaced tabulae.

Discussion. This species, formerly assigned to *Nyctopora,* shows fibrous rather than trabecular walls and pores, both foreign to that genus and typical of *Saffordophyllum.* The sections figured here are designed primarily to show the pores and the unusual development of the poikiloplasm. Cross-sections too thick to show differentiation of fibrous walls and poikiloplasm show both together as forming septal ridges more consistent in prominence with those in *Nyctopora* than with those in *Saffordophyllum.*

Figured specimen. USNM No. 78234, from the Hermitage limestone, 4 miles north of Carthage, Tennessee.

Saffordophyllum newcombae Flower, n. sp.

Pl. 24 and 25

This is a cerioid coral with small corallites 2.0 to 2.3 mm and rarely as large as 2.5 mm across. The walls are fibrous and crenulated, but with wide variation both in thickness and in development of the crenulations. Walls are seen in cross-section varying from one-tenth to one twenty-fifth the width across the corallites, measurement being made in each case to the middle of the common walls. Crenulations are commonly so faint and irregular that they are not easily counted around any one corallite, but the number seems to be 11 or 12, and possibly in a few corallites there are as many as 14. Cross-sections show rare pores at the angles of the corallites, but where one pore occurs, others are commonly found in nearby corallites, suggesting that pores are rather widely spaced but occur at fairly uniform levels in adjacent corallites (see pl. 24, fig. 9, 10).

Longitudinal sections show tabulae generally transverse but rather irregular; in crowded zones two or three tabulae occasionally may be joined. Where tabulae are widely spaced, a condition which pertains in general to early portions of the colony, there may be 7 tabulae in a length of 5 mm, but where they are more closely spaced, a condition which holds throughout the distal portion, there may be 15 or 16 tabulae in 5 mm. In relation to the corallite width of 2 mm, there may be three or four tabulae in the basal part in that interval, and five or more adorally. Longitudinal sections show a rhythmic thickening and thinning of the wall (pl. 24, fig. 4; pl. 25, fig. 4); in general, the thickened portions are short, 3-4 mm long, separated by considerably wider spaces in which the walls are thin. Cross-sections that cut obliquely through such regions will show such wide differences in the aspects of the corallites as to cause surprise that they could occur in a single species, to say nothing of a single colony. Tabular edges seem to be generally transverse, but may be slightly upturned or, more rarely, downturned. In some cases, apparently where the more common, upturned condition occurs, the tabulae are faintly crenulate at the edges (pl. 25, fig. 1, 2), presenting an appearance, except for the absence of conspicuous septa, suggestive of *Crenulites.*

In cross-section, walls are fibrous, though where they are thickest there may be some recrystallization, which is true of the lower part of Plate 24, figure 5. In general, however, even where the walls are quite thick the fibrous condition is simple, and there is only the faintest suggestion of a light axial line where the obliquely sloping fibers of the two fused walls meet. In longitudinal section, such walls will show fibers varying from those sloping obliquely up from the common center to the inner surface of the corallite wall, to those in which the fibers are nearly horizontal.

Our two colonies of this form are both incomplete, but indicate a corallite length of 65 mm and suggest that colonies were considerably larger than the holotype, which is 200 mm across.

Discussion. As the only true *Saffordophyllum* in the Montoya, this species can be recognized among its associates by the characters of the genus, the slightly crenulated walls, producing septal ridges, the diameter of the corallites, and the spacing of the rather simple transverse tabulae. *Trabeculites keithi,* which is similar in general aspect, has trabecular corallite walls and both larger corallites and more widely spaced septa. The occasional crenulated edges of the tabulae may cause some confusion with *Crenulites,* but in that genus the edges of the tabulae are consistently downturned and strongly scalloped between the septa, and though some cross-sections may fail to show the amplexoid septa, the walls are never crenulate. Commonly the axial plate is clear but the fibrous "sclerenchyme" is obscurely similar to calcite in the matrix. Most sections will show the amplexoid septa, by which the genus is readily distinguished. When well preserved, the wall is clearly of the rugosan type. Poikiloplasm has not been observed in the species.

From other species of *Saffordophyllum* this one is distinguished by corallite proportions and spacings of tabulae, but more particularly by the consistent rhythmic variation in the corallite walls, which produces an almost bewildering diversity of the aspect of the corallites in cross-section. Altogether, four species of *Saffordophyllum* are recognized having 12 septal ridges; of these *S. franklini* has larger corallites, 3 mm across, with 10-13 tabulae in a length of 5 mm. Like *newcombae* it shows a trace of undulate thickening of the walls, but the undulations are not as extreme and do not produce an equally wide variation in the aspect of corallites in cross-section. S. *undulatum* has corallites 2 mm across as in *newcombae*, but tabulae are much more widely spaced, the walls are thinner, the undulations as seen in cross-section are more pronounced, and the rhythmic thickening of the walls in longitudinal section is very slight. S. *goldfussi*, though probably more than one real species has been included under that name, has smaller corallites, averaging 1 mm across; the septal ridges are rather more prominent, so that the cross-sections suggest *Nyctopora* rather than *Saffordophyllum*, and the edges of the septa are appreciably serrated. Tabulae occur 6-8 in 5 mm.

I have named the species for Ethel Newcomb, concert pianist, artist, and teacher, superfluous as any such trivial memorial may seem.

Holotype, NMBM No. 675.

Occurrence. In the Second Value formation, Montoya group; the type and one other colony are both from near the crest of the Scenic Drive, El Paso, Texas.

TRABECULITES Flower, n. gen.

Genotype: *Trabeculites keithae* Flower, n. sp.

This genus is erected for rather thin-walled cerioid corals superficially resembling *Saffordophyllum*, but with walls composed of alternating thick and thin regions, instead of showing crenulations extending alternately into adjacent corallites. Closer examination reveals that the wall is not composed of fibers aligned along a continuous axial plane, but the plane is either broken up into vertical planes of short lateral extent, separated, and with fibers sloping obliquely up in the regions between as well as from their sides, or the short planes are reduced to vertical linear axes, true monocanthine trabeculae.

Tabulae are transverse, somewhat irregular, tending in general to have their edges slightly upturned; slight crenulation of the edges may develop, but the condition is not uniform.

Discussion. In gross aspect this genus may be mistaken for *Saffordophyllum*, but instead of having walls crenulate as seen in cross-section, they are composed of alternating thin and thick regions, the thick regions extended equally into the corallites on either side. In *T. keithae* the fibers are arranged in inverted cones about linear axes and form true monacanthine trabeculae, but in *T. maculatus* the axes may vary from lines to short planes, and under alteration some sections of the wall may show short planar units only narrowly separated. This species supplies something of a transition from the fibrous walls with continuous axial planes, as in *Saffordophyllum*, to the walls of *T. keithae* and *Nyctopora*, in which trabeculae of fibers arranged on linear axes are developed. As in *Nyctopora*, where walls thin between trabeculae, it is difficult to tell whether light calcitic material is organic or inorganic; such intervals in longitudinal section commonly appear as light continuous bands between trabeculae.

Three species are recognized: (1) *T. keithae*, of the Second Value formation, with large corallites 3.0-3.5 mm across, walls of swollen trabeculae with narrower zones of contact or near-contact, and tabulae of moderate spacing, with edges dominantly though narrowly upturned and slightly crenulate. (2) *T. maculatus*, from beds of late Red River or early Richmond age on Akpatok Island, has corallites 2.0 to 2.5 mm, walls less prominently narrowed between trabecular centers, trabeculae with axes varying from short planes to vertical lines, and tabulae closer in spacing, with only vestigial marginal crenulation. Differential alteration of thin and thick parts of the walls has given every known representative of this species a curious mottled effect. (3) *T. akpatokensis*[16] has tiny corallites, 0.15 to 0.25 mm across, with close, slightly downcurved tabulae. It is known only at an elevation of 450 feet on Akpatok Island, in beds with an associated fauna of Shamattawa and Richmond aspect.

Trabeculites is regarded as marking the transition between the simple fibrous walls with fibers aligned along axial planes, and the trabecular walls in which fibers are arranged conically around linear axes.

As noted under *Saffordophyllum*, it is possible that S. *tabulatum* Bassler, or the Lebanon limestone of Tennessee, might prove to be a representative of the genus. In cross-sections it shows walls of alternating swollen and thin regions, but closer examination of the fine structure is needed before such a change of generic assignment can be certain. Unlike typical *Saffordophyllum*, no pores have been found in *Trabeculites*; none have been observed in this dubious species.

Trabeculites keithae Flower, n. sp.

Pl. 26 and 27

Corallites are rather large, ranging commonly in diameter from 2.5 mm to 3.0 mm, and very rarely slightly larger. Walls are relatively thin; in cross-section at low magnification the walls appear to be composed of alternating broad dark and thinner lighter regions. The dark patches represent trabeculae; commonly they cause the wall to expand equally on both sides, though examples of such bodies projecting one on one side of the wall and the next on the opposite side have been observed, but the condition is not general nor is it at all common. Commonly there are 20-22 trabeculae around a corallite. At high magnification the bodies show wide variation in aspect; evidently recrystallization plays some role in this variation, but there appears to be a real difference between relatively thick walls with dark areas marking the trabecular centers and light areas between (pl. 27, fig. 5), those in which the trabeculae are broad, the areas between lighter and much thinner (pl. 27, fig. 4), and relatively thinner walls in which the trabeculae appear in varying clarity (pl. 27, fig. 6-8).

In longitudinal sections the tabulae are largely transverse, but quite irregular and variable as to form. They may be irregular and joined one to another, but are more commonly free and transverse over the greater width of the corallite. Edges that are slightly upturned seem common, and such edges may be slightly crenulate, as shown in the cross-sections in Plate 27, figures 2 and 3 particularly; crenulations in longitudinal section are shown in the left of Plate 26, figure 7, where, below the center, the plane of the section is well off center, and near the lower part cuts corallite walls tangentially. Tabulae are rather variable in spacing; near the base of the colony, where the widest spacing was observed, there are 6 tabulae in 5 mm; adorally, there are commonly 8-9 tabulae in an equal length. In the upper third of the type colony, there is a narrow zone of crowded, irregular tabulae (pl. 26, fig. 1). Longitudinal sections showing walls commonly exhibit fine, shallow

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[16] Oakley (1936) described this as a species of *Chaetetes*.

V-shaped structure; where the plane of the section cuts a wall tangentially, as in parts of Plate 26, figures 5, 6, and 7, shallow V-shaped fibers can be seen in the individual trabeculae composing the walls.

Colonies are tightly cerioid; probably our present observations of a length of 120 mm and a measurement across the colony of 140 mm can be exceeded.

Discussion. This species, which we had at first considered a *Saffordophyllum,* with walls bulging equally on both sides into adjacent corallites, rather than a distinct genus allied to *Nyctopora,* can be differentiated in the Montoya from *S. newcombae* by its rather larger corallites; in proportions it is easy to confuse it with *Crenulites,* particularly *C. duncanae,* which has corallites of much the same dimensions, but in that genus the tabular edges are consistently downturned at the edges and strongly crenulate. Also, except in colonies weathered to a sugary white calcite, which obscures most structures, any *Crenulites* will show the amplexoid septa megascopically on weathered surfaces.

As noted under the generic discussion, *T. maculatus* has slightly smaller corallites, and those of *T. akpatokensis* are very much smaller. *T. maculatus* is further differentiated by having fibers arranged commonly about short discontinuous planes; thickening and thinning of the walls in cross-section is much less marked in *maculatus,* and tabulae are less modified at their edges and fail to show clear crenulation.

Having named the preceding species for a musician of rare ability, I have named this one for another, Mrs. Richard Keith, in grateful recognition also of her exceptional teaching.

Holotype. NMBM No. 674.

Occurrence. From the Second Value formation, Montoya group. The holotype and two other colonies are from the upper part of the formation, near the crest of the Scenic Drive, El Paso, Texas. I have as yet encountered the species only in the southern Franklin Mountains.

Trabeculites maculatus Flower, n. sp.

Pl. 28; pl. 31, fig. 5, 6; pl. 45, fig. 10-12

Corallites of this species are slightly smaller than those of *T. keithae,* ranging in diameter from 1.9 mm to 2.7 mm, but most commonly from 2.0 mm to 2.5 mm. Walls show alternating broad and narrow regions; in rare examples, expansions on the two surfaces are not opposed, but alternate as in *Saffordophyllum.* Where walls are calcitic, the common mode of preservation, cross-sections show a curious mottling of the walls, with dark-gray patches, commonly in the broad regions, and light yellowish areas between them. The gray material, which retains fibrous structure, radial in cross-section, V-shaped in longitudinal section, plainly approaches the original condition of the corallite walls; the lighter material, in which fibers are obscure or destroyed, represents a replacement, which began in the narrow areas and spread to varying extents. In cross-section the walls show wide variation in fine structure; typical replacement, with dark patches in the broader areas (trabecular centers), is shown in Plate 28, figure 7. Here radial structure is largely obscure. In Plate 28, figures 8 and 9, a silicified portion of a colony is seen. Here fibers are obscured, but their centers of deposition are retained and shown as short discontinuous lines. In Plate 31, figure 5, a portion of wall is seen in which the axial plane appears continuous for some distance, as in *Saffordophyllum,* whereas in Plate 31, figure 6, axes are reduced very nearly to vertical lines. Longitudinal sections show V-shaped fibers in the walls, and where some portion of the wall is parallel to the plane of the section, individual trabecular units are seen, with V-shaped fibers, or, where the centers are not quite attained, a U-shaped pattern of fibers may be apparent (pl. 28, fig. 10; pl. 45, fig. 12). Expansions of the walls generally are slight; the most extreme development of septal ridges is seen in Plate 28, figure 12, where ridges are suggestive of those of *Foerstephyllum,* whereas crenulation of the wall is suggestive of *Saffordophyllum.*

Tabulae are largely transverse, but show great variation in minor irregularities. Commonly 10-12 tabulae are found in a length of 5 mm; in many cases 5 tabulae occupy a length of 3 mm. There are short regions, rarely over 1 mm long, in which such extremes of spacing are found as from 2 to 5 tabulae in 1 mm, but such restricted regions produce only slight variation in counts of tabulae in a 5 mm interval. Several sections passing close to corallite margins show crenulate tabulae (pl. 28, fig. 3). Longitudinal sections commonly show alternating light and dark regions in the length of the corallite wall; in part from sections passing from trabecular to intermediate areas, in part from variations in spreading of the light-yellow replaced material.

Discussion. This is clearly a *Trabeculites* differing from *T. keithae* slightly in corallite size and tabular spacing, but one in which thickening of the trabecular centers in the walls is relatively slight, and in which trabecular axes show wide variation from linear to short planar axes; rarely, axes may continue for some distance without apparent breaks, as in *Saffordophyllum.*

It should be noted that this species is close in corallite size and septal spacing to *Columnaria franklini* Salter. Troedsson (1929) and Bassler (1950) have accepted as that species a form from the Cape Calhoun beds with slightly larger corallites, crenulate walls showing it to be a typical *Saffordophyllum,* and tabulae slightly more closely spaced. In accepting these identifications, the present species is regarded as a new one, for it is certainly distinct from the Cape Calhoun form. It may be noted, however, that until Salter's type is studied from sections, the correctness of this interpretation must remain somewhat uncertain. As that species is based upon a specimen from Cape Riley, Wellington Channel, about equidistant from Cape Calhoun and Akpatok Island, its identification with either species seems about equally probable, and from the very similar proportions alone one cannot be certain which of these two species the type resembles the more strongly.

The types of *T. maculatus* consist evidently of small pieces of cerioid colonies, showing a maximum corallite length of 20 mm, and the largest transverse dimension of a fragment of a colony is 55 mm. The material suggests rather small colonies, but is hardly conclusive.

Types. Holotype, SCM No. 50687; paratypes, No. 50684-6.

Occurrence. From the Ordovician of Akpatok Island. All types came from an elevation of 325 feet and are without any reported associated forms. From sea level to an elevation of 300 feet the fauna is one of Red River aspect; from 350 to 450 feet a fauna suggests early Richmond, in particular, Shamattawa and Stony Mountain affinities. That another species of the genus, *T. akpatokensis,* occurs at the 450-foot elevation would lend some faint support to regarding *T. maculatus* as belonging with the lower Red River fauna, but is hardly conclusive.

NYCTOPORA Nicholson

Genotype: *Nyctopora billingsi* Nicholson

Nyctopora Nicholson, 1879, Tabulate corals of the Paleozoic period, London, p. 182.

——— Bassler, 1915, U.S. Nat. Mus. Bull. 92, v. 2, p. 860.

——— Bassler, 1950, Geol. Soc. Amer. Mem. 44, p. 260.

——— Duncan, 1956, U.S. Geol. Surv. Bull. 1021-F, pl. 24 and expl.

——— Hill, 1959, N. Mex. Inst. Min. and Technology, State Bur. Mines and Mineral Res. Bull 64, p. 16.

Nyctopora is generally recognized as a colonial coral with quite small corallites and thick walls from which septal ridges protrude; there are typically 8 major and there may be 8 minor septa; ridges are commonly serrated at their edges; tabulae generally transverse, though tending to be somewhat erratic in curvature. As such, *Nyctopora* seems to lie between *Saffordophyllum*, in which the septal ridges are fainter, being mere thickenings of convexities in the somewhat crenulate corallite walls, and *Foerstephyllum*, in which the septa, though dominantly short and wedge shaped, are much more numerous. There remains, however, a much more fundamental difference, found in the wall structure. In cross-section the walls of true *Nyctopora* are composed of trabeculae, some of which are extended as septal ridges, whereas others remain small. They are polygonal and commonly show radial structure; in longitudinal section fibers show a V-shaped pattern and are formed in inverted cones about linear axes. Septal ridges are simple extensions of individual trabeculae, except in *Nyctopora*(?) sp., shown on Plate 21, figures 5 and 6, but this form is unique, and possibly should be a separate genus. Hill (1959) reports minute pores connecting the corallites. Duncan (1956) states that mural pores are absent. Our material has shown in cross-section light bands, generally poorly defined between trabeculae, and in longitudinal section such bands seem continuous longitudinally. It is not possible to say whether material in the light bands is organic or inorganic calcite, but the structures are original and seem analogous to the longitudinal light bands of *Lichenaria*. Certainly neither Montoya nor comparative material has shown any pores comparable to those of *Calapoecia*, or even of *Saffordophyllum*. Cross-sections of *N. mutabilis* (pl. 44, fig. 6, 7) at high enlargement show indications of the fibrous arrangement of the trabeculae, but continuity of the trabeculae in septal ridges is evident.

In gross aspect, *Saffordophyllum* and *Nyctopora* seem to show progressive development of spines, leading to *Foerstephyllum;* such a simple relationship is opposed, however, by the fine structures, showing *Saffordophyllum* leading through *Trabeculites* to *Nyctopora*, in modification of simple fibrous to trabecular walls, whereas the common simple fibers of *Saffordophyllum* persist into *Foerstephyllum*, within which genus the axial plate develops, as discussed more fully under *Foerstephyllum.*

Trabeculites shows in *T. maculatus* a transition from the fibrous walls of *Saffordophyllum* to the advanced monacanthine trabeculae; in *T. keithae*, in which such trabeculae are perfected, the relatively thin corallite walls and the vestigial expansion of the walls into the corallites supply the main distinctions setting the genus apart from *Nyctopora*. Although such differences are matters of degree, the species of the genera are widely dissimilar in appearance, *T. keithae* showing narrow walls, beaded in cross-section, and *Nyctopora* having thick walls in which septal ridges are always of appreciable extent and prominence.

The valid species of *Nyctopora* in North America show considerable range and may be summarized as follows:

N. vantuyli Bassler—Upper Chazyan, Champlain valley.
N. cystosa Bassler—Chaumont, Black River valley.
N. virginiana Bassler—Holston-Murat and Wardell limestones, Virginia.
N. billingsi Nicholson—Kirkfield of Ontario and Curdsville of Kentucky.
N. buttsi Bassler—Black River beds of Virginia.
N. foerstei Bassler—Waynesville of Ohio.
N. mutabilis, n. sp.—Second Value of New Mexico.
N. nondescripta, n. sp.—Aleman of New Mexico.

To these should be added those species that are distinguished by a columella formed of piles of spheres of poikiloplasm on the anterior faces of tabulae; such spheres extend nearly or completely the distance from one tabula to the next. Species showing such "columellae" have been placed in *Billingsarea* Okulitch. *B. parva* is recognized in the Chazyan of the Champlain valley, continuing north into Quebec; specimens assigned to the species occur in the Appalachians in beds identified as Ottosee. Bassler (1950) assign *Columnaria parvituba* Troedsson to *Nyctopora* (?*Billingsarea*) *parvituba*. It is doubtful whether *Billingsarea* should be treated as more than a subgeneric group in *Nyctopora*, but certainly the species assigned to it, including *parvituba* of the Gonioceras Bay formation, are relatively old, Chazyan or early Mohawkian in age.

Barnes, Cloud, and Duncan (1953) indicate two undescribed *Nyctopora* in the Burnam limestone. *N. mutabilis* is the only form found in the Second Value, where it occurs in considerable abundance. Hill (1959), however, has figured a somewhat replaced colony from the Second Value formation in Arizona, which has appreciably smaller corallites; no comparable form has been found in the typical Montoya as yet. A dolomitized specimen, somewhat distorted, probably tectonically, was recognized in the Second Value equivalent in the Fish Haven dolomite near Logan, Utah. As yet, the genus has not been recorded from the Fremont or Bighorn sequences, nor is it known in any part of the Ordovician of southern Manitoba, the Hudson Bay section, or the various arctic occurrences, including the Cape Calhoun series. In the east, the Upper Ordovician has thus far yielded only one species, *N. foerstei*, typically from the Waynesville of Ohio, though material from Snake Island, Lake St. John, Quebec, has been assigned to the species. Quite possibly future work will show the genus more abundantly developed in western faunas.

Spheres of poikiloplasm have been noted in several species of *Nyctopora*, where they may be attached to the inside of corallite walls, septal ridges, or the anterior faces of tabulae. Two forms, *Nyctopora* (*Billingsarea*) *parvituba* (Troedsson) and specimens from the Ottosee limestone of Tennessee, show spheres piled only in the centers of the corallites, and these spheres supply an explanation, previously lacking, of the nature of the columella in *Billingsarea.*

Nyctopora mutabilis Flower, n. sp.

Pl. 20, fig. 6, 7; pl. 21, fig. 1-4; pl. 22; pl. 44, fig. 6, 7

This is a common species of the Second Value, with corallites 1.5 to 1.8 mm in diameter, rarely larger, and only rare scattered immature individuals are smaller. Corallites show in cross-section unexpectedly wide variation in the thickness of the wall and development of septal ridges shown in general in Plates 21 and 22. Remarkably thin walls, exceptional in the species, are shown in Plate 22, figure 2; the thickest appear in Plate 21, figure 1. Septal ridges show no serration at their margins (pl. 21, fig. 3, 4), but in cross-section show wide variation in aspect; tips range from pointed (pl. 22, fig. 2-5), showing wide variation in thickness and length, to subquadrate (pl. 21, fig. 2); others are blunt and rounded (pl. 21, fig. 1). There is also wide variation in relative lengths of major and minor septa. Commonly both major and minor septa are developed, the two together totaling 16 in number, but in Plate 22, figure 2, minor septa are suppressed, and major septa cannot be seen in some corallites.

Tabulae are transverse but quite variable in their irregularities, curving either up or down; occasionally adjacent tabulae are joined, though such fusion is incomplete and most irregular in form. Spacing of tabulae is generally rather uniform, but rare erratic zones of crowded tabulae occur, none more than 2 mm in length. In a length of 5 mm there are 9 to 11 tabulae. Sections slightly oblique to the longitudinal axis of the corallites show septa as linear extensions of the walls, with no trace of serration at their edges.

Our largest colony, which is incomplete, shows a width of 40 mm and a maximum length of 40 mm.

Discussion. The wide variation in wall thickness and in length and cross-section of the septal ridges is characteristic of this species. The *Nyctopora* sp. figured by Hill (1959) from the outlier of the Montoya in Arizona, evidently also from the Second Value formation, is quite unlike this one, having relatively tiny corallites not exceeding 1 mm in diameter. Of the valid representatives of *Nyctopora* in older beds, both *N. billingsi* and *N. virginiana* have much smaller corallites; in the latter species longitudinal sections are similar, for tabulae are similar in proportionate spacing, but much closer in actual measurement. In *N. cystosa,* which has corallites approaching the present species in size, tabulae are commonly cystose and much more irregular in form, and crowded zones of tabulae are frequent and rhythmically repeated. In C. *vantuyli* the walls are relatively thick, septal ridges short, and tabulae quite distinctive in their wide spacing. *N. buttsi* is close to the present species in corallite diameter, but septa are shorter, major and minor septa being subequal in length, and have prominently serrated edges. *N. foerstei* is comparable again in corallite diameter, and is characterized by abundant development of spheres of poikiloplasm, which indeed, caused Bassler (1950) to question the generic assignment; septal ridges are short, wedge shaped in cross-section, subequal in length; tabulae are highly irregular in form and variable in spacing. Forms with spheres of poikiloplasm piled in the centers of corallites, and thus assignable to *Billingsarea,* are distinctive in that feature. Only two such species are recognized, *Nyctopora (Billingsarea) parvituba* (Troedsson) of the Gonioceras Bay formation and *Nyctopora (Billingsarea) parva* (Billings) of the Chazyan, also identified in the Appalachians in beds regarded as Ottosee.

The most remarkable section of *N. mutabilis* is that shown in Plate 22, figure 2; had it not come from the same colony that yielded other more typical sections, its identity as this species or even the genus *Nyctopora* would have been questioned. Here some corallites show septal ridges suppressed and very thin walls; some, indeed, seem to be composed of dark, rather broad units, probably trabecular, with lighter narrower interspaces, and thus approach the general aspect of *Trabeculites.* One is tempted to suggest that in early growth stages the features of *Trabeculites* might be thus approached, but regrettably in making numerous sections it is not possible to say that this one came from the basal part of the colony.

Types. Holotype, NMBM No. 676; paratypes, No. 677, 678.

Occurrence. The species is quite common in the Second Value formation in the southern Franklin Mountains. Types are from near the crest of the Scenic Drive, El Paso, Texas.

Nyctopora nondescripta Flower, n. sp.

Pl. 23

This *Nyctopora* has small corallites, 1.0 mm to 1.2 mm and, more rarely, 1.4 mm in diameter. Walls moderate in thickness, averaging 0.2 mm, and about one-sixth the width across the corallite cavity. The best preserved portions show eight major septa, their tips pointed, wedge-shaped in section, with minor septa so short as to be vestigial (pl. 23, fig. 8), but other sections through the same colony show 16 septa subequal in length (pl. 23, fig. 6). Tabulae are transverse, quite regular in form and somewhat variable as to spacing, but crowding is irregular, not confined to definite zones at the same level in all corallites; tabulae range from 13 to 16 in a length of 5 mm. Longitudinal sections show the corallites crowded with sphaeroidal bodies, but replacement is extensive in all the material, and the organic nature of these bodies, which suggest spheres of poikiloplasm, is not demonstrable in the present material.

Coral colonies of this form are large; specimens with corallites 50 cm long have been observed, with a colony width as much as 10 cm, and these colonies were incomplete. In size and aspect of the colonies, this form resembles the associated *Paleofavosites,* although of the two associated species even the smaller one has corallites of a slightly larger diameter.

Discussion. This species is quite generalized in aspect, and it is rather surprising that it could not be identified in terms of some previously described form. The Richmondian *N. foerstei,* the only American species of equivalent age, has serrated septal ridges, of which our present species shows no evidence; spheres of poikiloplasm are abundantly developed, and corallites are nearly half again as large; tabulae are similar in proportion, but actually much more widely spaced in these larger corallites.

Species with comparable small corallites are *N. billingsi* and *N. virginiana.* The first of these forms is rather similar in the aspect of its cross-sections, but although both forms show some variability, the present form has septal ridges with broader bases. In longitudinal section the tabulae in *billingsi* are more erratic in spacing and more predominantly irregular in form. *N. nondescripta* resembles parts of *billingsi,* showing the closer spaced tabulae, but is not comparable at all to frequent regions in that species in which tabulae are much more widely spaced. *N. virginiana* has also somewhat more distantly spaced tabulae, and in cross-sections the major septa are appreciably longer than in the present species.

Our material occurs in dolomite, and parts are either dolomitized or somewhat silicified; either condition obscures and alters original structures, and the replacement is responsible for much, but not all, of the variation shown in the aspect of the cross-sections. There appears to be real variation in cross-sections between regions with major septa long and minor septa extremely obscure, and regions in which major septa are somewhat shorter and the minor septa about equal to them in length.

Holotype. NMBM No. 750.

Occurrence. From the coral zone of the Aleman. The holotype is from the slopes just east of the mouth of McKelligon Canyon, El Paso, Texas.

Nyctopora (?) sp.

Pl. 21, fig. 5, 6

Under this appellation are figured some thinsections from a *Nyctopora*-like form that appears anomalous in several features. Cross-sections of corallites show to varying degrees small, round bodies of poikiloplasm mainly on septa. In longitudinal section such bodies are sparse on anterior faces of tabulae, but where the plane of the section approaches close to the septal tips or to walls, similar bodies are encountered, showing alignment in which oblique rather than vertical rows first strike the eye. Where sections pass through the walls, as at the left of Plate 21, figure 6, prominent light bands are seen between the trabeculae. In cross-section the species is unusual in that walls and septa may be more than one trabecula in thickness, a condition not encountered in other members of the genus, where, on the contrary, septa are simple modifications of otherwise essentially columnar trabecular units. Also, the small trabecular bodies are separated by light areas between, with a distinctness not observed in other species of the genus.

Discussion. This form, from the Burnam limestone, shows fine structure that is unique, and the species is not closely similar in proportions to *N. mutabilis* or to *N. nondescripta.*

The colonies so far observed are all rather small and are apparently broken fragments. A maximum height of 10 mm and width of 20 mm has been observed.

Figured specimen. NMBM No. 745.

Occurrence. Burnam limestone, Burnam ranch, Barnet County, Texas.

CALAPOECIA Billings

Genolectotype: *Calapoecia anticostiensis*

Calapoecia Billings, 1865, Canadian Naturalist and Geologist, n. ser., v. 2, p. 425.

——— Bassler, 1915, U.S. Nat. Mus., Bull. 92, v. 1, p. 154. (Summary of intervening references.)

——— Cox, 1936, Canada Geol. Surv., Bull. 80, p. 2 ff.

——— Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 275.

Citations of *Calapoecia* are numerous, and only a few of the more significant references are given here. Others can be found in these references.

Calapoecia is a colonial coral with trabecular walls pierced by abundant pores, the pores arranged in intersecting longitudinal and horizontal rows in the corallites, and separated by transverse and longitudinal ridges, which at their intersections are produced into conspicuous septal spines; ordinarily 20 columns of such spines occur in a corallite. Walls are trabecular; where they are thin, they differ from those of *Nyctopora* in being traversed by numerous pores; where walls widen, they form a porous coenenchyme in which there are simple horizontal tubes outlined by a blending of horizontal elements comparable with tabulae, and longitudinal elements ("costae") comparable to septa. Undulations of both longitudinal and transverse elements present an almost bewildering variation of aspect in sections, but in finely etched material the structure is apparent as a regular, coherent pattern. In forms with broad coenenchyme corallites are free and rounded, and may show definite walls, raised on the surface of the colony and clearly evident in sections; septal spines, where developed, project in from this ring.

Discussion. Our present interpretation of this genus is somewhat different from those previously offered. The difference lies mainly in that here it is recognized that the corallite wall is a fundamental structure, primitively fibrous, but with fibers modified into monacanthine trabeculae; the transition is seen in *Trabeculites* and *Nyctopora.* Previous interpretations have been based on the assumption that there is no corallite wall, and that the structures here are modifications of the septa. Septa develop, it is true, but they are never more than discrete columns of spines; with broadening of the coenenchyme, the "costae," which resemble septa extending from the periphery of the corallites, are specializations within the walls, which are here, as in *Nyctopora,* true common walls, and their similarity to septa is regarded as adventitious. The objection of Cox (1936) to recognition of a true coenenchyme here is not valid, and is opposed by the development of clear walls around the corallites in the more advanced types, a matter that his interpretation does not explain.

There has been much confusion as to the distinctness of the species; Cox (1936) claimed that there was only one species, and Bassler (1950) recognized six, *C. canadensis, C. huronensis, C. coxi, C. ungava, C. anticostiensis,* and *C. arctica.*

Recognition of only a single species in the genus rests upon two assumptions: (1) that the species intergrade, intergradation being shown within colonies in some instances, and (2) that corallite size and colony size are features of no significance. The first contention is true, but ignores matters of coral ontogeny that are deserving of consideration. Although colonies may contain at every level new budding individuals, there is in the colony, and in associations of colonies of potential taxonomic value, a maximum corallite size that is attained; this has been found of value in specific recognition throughout the present study. Early stages of colonies where budding is rapid and growth is more markedly radial than is commonly found in later stages, may show individuals of slightly less than normal size, but at a distance of 10-15 mm from the point of origin of the colony, a maximum size is developed which is commonly maintained. Similarly, it is at about the same point that a general mature thickness of corallite wall and a mean distance between corallite cavities are developed, which are not commonly found earlier. In later stages of the colonies, the corallite diameter and distance between corallites, where they are separated by an appreciable coenenchyme, is generally maintained, but there are new budding individuals appearing at every level. Such individuals have been found to enlarge rapidly in size in the first 2-3 mm of their length, beyond which point enlargement is much more gradual until mature diameter is attained. Similarly, the budding individuals are at first in contact with the parent individuals; they diverge rapidly at first, then more gradually, finally attaining the average distance from the parent as well as from adjacent neighbors. It is interesting to note that the same general phenomena hold in the phaceloid *Paleophyllum,* but there corallites are free and not connected by coenenchyme. Curiously, the situation of budding individuals and an attempt to determine species by a general average rather than an average mature proportion, in which young budding individuals are necessarily neglected, has proved perplexing in *Calapoecia*, but has never caused similar perplexity in species differentiation in *Paleophyllum*, possibly in part because *Paleophyllum* has received less attention, and partly because species are established there by characteristic patterns of septa and tabulae, which show wide variation in length, number, and form. However, as in *Paleophyllum*, when mature features are considered, with the recognition that extremely early stages of colonies and of individuals cannot always be differentiated with certainty, and that budding individuals from later stages of colonies undergo an ontogeny that is similar, though not identical, to that found in early astogenetic stages, a much better basis for recognition of species is found than was apparent before.

Colony size is, of course, variable because of a number of factors hard to estimate. The budding individual that starts a colony is potentially immortal, but there are none of these forms that develop colonies measurable in rods or even in yards; there are definite limits. Further, it is evident that there is for the colony also a mean maximum size, which is not surpassed, though an association may contain many small colonies that die before they attain this size. Nevertheless, to attribute the contrast between the colonies that are characteristic of the occurrence of *Calapoecia* in the Black River beds, as noted by Foerste, and the appreciably larger colonies that characterize Richmond associations, to simply ecological considerations, seems not only an extreme of conservatism and a disregard of the facts, but it is also the attributing to mysterious and undefinable factors of environmental control variations that are unjustified from all that can be learned of the ecology of this succession of long departed seas. Why should such a condition exist? The Black River beds of the Paquette Rapids are pure limestones, with only fine, black, organic mud released upon solution of the rock. The sediments that enclose the Richmond corals yield, by contrast, much more clastic material and material that is considerably coarser; it is generally regarded that a rain of sediments upon the sea floor produces conditions unfavorable for the growth of corals. Why, then, should the Richmond corals living in such an environment produce the larger colonies? To claim that such differences may have no specific significance, and to attribute them to mysterious ecological factors, seems to substitute the unknown for a perfectly reasonable explanation. Some years ago there was discussion with one of my colleagues who claimed that the cameral deposits of cephalopods could be deposition of material inorganically in shells; further exploration yielded the further elaboration of this view, that since we knew so little of the conditions governing details of such deposits, and there were undoubtedly a number of variables that could not be estimated, inorganic deposition could account for almost anything. In both cases, the substitution of an unknown cause of unknown but great potential scope, for an explanation in terms of known limiting organic factors seems to be substituting witchcraft for science; in the present case, as well as in the case of the cephalopods, facts of distribution and growth relations amply demonstrate the correct solution; here evidence is less clear, but colony size is a known potential factor at the specific level, and much factual evidence indicates that it is of significant value.

Differentiation of species. In the present work it has not been possible to approach a revision of the genus, but some unrecorded facts have come to light that may have a significant bearing upon such work. Material of *Calapoecia coxi* shows moderately thick walls composed of rounded to irregular trabeculae; where spines are seen, they are simple extensions of the trabeculae, which thus are extended into the corallites at rhythmically repeated intervals. All sections show trabeculae the centers of which are either linear axes or are very short planes of no appreciable horizontal extent. Sections of *Calapoecia anticostiensis* show an interesting variation of this pattern. Here the corallite walls are developed into conspicuous rings of closely appressed trabecular elements. As in the preceding species, septal spines are simple extensions of the surfaces of individual trabeculae, which remain relatively short. However, on the outer surface of the corallite wall "costae" develop that are similar but much longer projections into the coenenchyme. They are extensions of individual trabeculae, and the trabecular center is prolonged into an axial plane, discernible as a light median line in cross-sections. The development of "costae" as extensions of individual trabecular units results in an appearance, in cross-sections, of the fibrous structure of the simpler genera *Lichenaria* and *Saffordophyllum*.

The *Calapoecia* common in the Richmond of Cincinnati, now generally regarded as *C. huronensis*, shows an interesting departure from the simple trabecular pattern of *C. coxi*. Cross-sections of this species show a highly varied aspect; in some regions the walls are made up of trabeculae of small horizontal extent, very much as in *coxi*, but in other regions trabecular axes elongate in the plane of the wall segments, and in many parts of the sections these elongated axes not only join, but may overlap slightly. In still other portions, there appears to be only a light axis extending for the length or nearly the length of a segment of the wall, undulate or zigzag, but appearing as a continuous unbroken axis similar to that found in those corals with simple fibrous walls. Indeed, the wall structure in this form is rather suggestive of that figured for *Lyopora* by Bassler (1950).

At the specific level it seems necessary to reject the conclusion of Cox (1936) that only a single species is involved, and a comprehensive revision of the genus should be attempted again; no small task, for the genus is widespread geographically and ranges from beds of Black River to others of late Richmond age. Bassler (1950) has summarized the widely scattered occurrences already known. It is evident, however, that the following species can be recognized:

Calapoecia canadensis Billings—This is the only species at present recognized in beds of Black River age. According to Foerste, colonies are characteristically rather small. Corallite cavities range from 3.0 mm to 3.4 mm across; walls are rather thick, so that corallite centers are commonly 4.0 mm apart. The material thus far studied by thinsections has been silicified, and fine structure of the walls is altered, but the appearance presented suggests an original condition closely similar to that observed in *C. coxi*. Tabulae are irregular in form and spacing, but rather consistently sparse, 4-5 occurring in a length of 5 mm, in relation to other and younger forms.

Calapoecia huronensis Billings 1865 is regarded as having *C. cribriformis* Nicholson 1874 and *Hougtonia huronica* Rominger as synonyms, though checking of this matter is eminently desirable. Our present diagnosis is based upon material from the Richmond of the Cincinnati arch, specifically from the Bardstown coral beds of Liberty age, and a specimen from the Saluda of Madison, Indiana. Corallites range from 3.0 mm to 3.5 mm in mature diameter; walls are dominantly, indeed remarkably, thin, so that corallite centers are rarely more than 3.5 mm apart. As noted above, in this species trabecular axes tend to fuse and are elongated transversely along the plane of the corallite wall, so that the condition of simple fibrous walls is approached. This form commonly shows small, round, vertical tubes; they are common, appearing in every section. Our material shows most such tubes in the narrow corallite walls, which are only locally broadened enough, and then usually at the region of corallite angles, to be considered good coenenchyme; but some tubes have been noted attached to the inner surfaces of corallite walls. The tubes may divide by lateral budding, and as longitudinal sections rarely show any appreciable length for the tubes, it appears that their course is a meandering one. Sections also show their walls as dark, amorphous material rather different from the remainder of the corallite. Irregular spacing, meandering growth, division, and the different texture of their walls suggest that they are not a true part of the coral, but rather were the abode of some commensal organism. As cross-sections fail to show septal spines around the entire circumferences of corallites in most examples, it appears that the spines are not only short, but rather widely spaced in vertical columns. Tabulae are rather irregular; adjacent tabulae are commonly joined for a good part of their extent and vary in spacing; from 5 to 9 in a length of 5 mm. Rhythmic variation in spacing has not been noted.

Calapoecia coxi has corallites 3.0 mm to 3.5 mm across, their centers 3.5 mm to 4.0 mm apart. Walls are of essentially columnar trabeculae. Septal spines, short, wedge-shaped, broad, and nearly confluent at their bases, are apparent in every section; as usual, 20 occur in a corallite circumference. Spines are evidently not only more prominent, but also more closely spaced than in *C. huronensis*. Tabulae are rather irregular, adjacent ones commonly fusing, but quite regular in spacing if fused individuals are counted separately, 5-6 in a length of 5 mm. Typical material from Akpatok Island is calcitic and does not show the vertical spacing of spines and pores clearly, but suggests that both are quite closely spaced. Cross-sections have shown very rare small, rounded tubes in the walls similar to those that are larger and more abundant in *C. huronensis*. Typical material occurs on Akpatok Island from the 350- and 400-foot elevations. To this species is assigned the common *Calapoecia* of the Cutter, described and illustrated below.

Calapoecia ungava Cox. This form, first differentiated by Cox as a variety, is based upon material occurring on Akpatok Island from sea level to an elevation of 350 feet. Corallites are well rounded; two different colonies show differences in diameters, one showing a range from 3.0 mm to 3.5 mm, the other a range from 3.5 mm to 4.0 mm. Corallites are close together, the maximum width of coenenchyme observed being 1.5 mm, so that corallite centers range from 3.5 mm to 4.5 mm, and rarely 5.0 mm, apart. Vertically 7-8 pores occur in a length of 5 mm; between them horizontal elements apparently continuous with tabulae are quite regular, but in the corallites tabulae are irregular, and quite commonly adjacent ones are partly fused, 9-11 occurring in 5 mm.

C. anticostiensis Billings, represented in our material by specimens from Akpatok Island and from the Selkirk limestone of Manitoba, shows well-rounded corallites up to 3 mm across, well separated, with centers up to 5.5 mm distant. In longitudinal section coenenchyme shows 7-9 pores in 5 mm, separated by quite regular horizontal elements, but in the corallites tabulae are highly irregular, extensively joined, and anastomosing, 10-14 in a length of 5 mm. The species is very widely cited, ranging from the Cape Calhoun formation of Greenland through Akpatok Island to the Selkirk limestone of Manitoba, and thence south to the limit of these later Ordovician faunas. One specimen from the Second Value is tentatively identified as this species, with which it agrees in corallite size. It shows slightly broader coenenchyme than is indicated by other material, but it is not evident that this alone would justify its recognition as a distinct species. Cox (1936) gives as the proportions of the type of *C. anticostiensis* corallites with a maximum diameter of 2.5 mm, and 10-12 tabulae in a length of 5 mm.

Troedsson (1929) recognized three species in the Cape Calhoun beds of northern Greenland. A form with small corallites 1.5 mm to 2.5 mm across he identified as *C. huronensis*. Corallite diameter is small both for typical *huronensis* and for *C. coxi*, but the form appears to be close to the latter in wall thickness, aspect of the coenenchyme, and prevalence of septal spines; one could wish for fuller illustrations of sections before making a final decision as to its possible relationships. Cox (1936) dismisses this form too summarily as a synonym of typical *C. canadensis*.

C. borealis Troedsson has rounded corallites separated by rather narrow coenenchyme, and appears in this respect similar to *C. ungava* of Cox. Corallites range from 3 mm to 4 mm across; their spacing in the coenenchyme seems to grade from the condition of *C. ungava* to that of *C. anticostiensis*. In longitudinal section the aspect of the transverse elements of the coenenchyme and the tabulae in the corallites is essentially that of *C. ungava*.

Calapoecia cf. *anticostiensis* Billings

Pl. 34, fig. 1-6, 10, 14, 15

Calapoecia sp. Hill, 1959, N. Mex. Inst. Min. and Technology, State Bur. Mines and Mineral Res. Bull. 64, p. 15, pl. 2, fig. 9.

The Upham contains a *Calapoecia* in which the corallites tend to be raised on the surface of the colony, with a thick wall, which may appear externally as a solid or nearly solid tube. Corallites on the same surface may be contiguous or may be separated by as much as 1 mm of coenenchyme. Corallite cavities are normally 2.5 mm to 3 mm apart, obviously young, budding individuals being discounted. In a few instances, however, the tubular wall of the corallite is extremely thickened, and the opening may be reduced to 1 mm; in such cases the corallites are separated rather widely, and their centers are 4.5 to 5.0 mm apart, as are those with wider, more typical openings. Eleven to thirteen tabulae occur in a length of 5 mm; they are not as markedly curved down centrally as in the Cutter species, nor are they commonly irregularly fused one with another. The interior of the corallite wall, when etched, shows prominent transverse bands, evidently bases of the tabulae, but there are no longitudinal raised bands representing septal spines. Pores occur, which are round, some appearing slightly broader than high. The preservation of the present material does not permit a count of these in the circumference, but they appear numerous, probably averaging 25 rather than 20, as in the succeeding species.

Discussion. Our single colony from the Upham is not very revealing; it was silicified and removed by etching prior to study; sections were not possible, but the etched material is perhaps more revealing, showing the regularity of pores, their course through the coenenchyme, their slightly transverse nature, and the relative prominence of transverse ridges rather than longitudinal ridges, on the corallite interior. The only feature in which this differs from C. *anticostiensis* as represented in material from the Selkirk limestone is a slightly wider spacing of corallites in the coenenchyme. There is no good reason to regard the local form as apart from the one in the Selkirk limestone, though admittedly at present the species *anticostiensis* is perhaps rather broadly defined; yet the situation seems better here than with some other species in the genus. As yet, no differentiation is apparent among specimens attributed to *anticostiensis* from Red River or from overlying Richmond beds. In the Montoya, forms of this type have been found only in the Red River Second Value formation.

Figured specimen. NMBM No. 806.

Occurrence. From the Second Value formation, Hembrillo Canyon, San Andres Mountains, New Mexico. Though *Calapoecia* has been cited from the lower Montoya, I have not found it common, and the figured specimen is at present the only representative of the genus from this horizon in our collections.

Calapoecia cf. *ungava* Cox

Pl. 33, fig. 6

The only representative of *Calapoecia* from the Aleman formation is a small portion of a colony silicified and with rather coarse replacement. The fragment shows a maximum width of 50 mm across and maximum length of 30 mm. It shows small rounded corallites with raised rims on the surface, the corallites 2 mm across. Some are contiguous or nearly so, corallites are most common 2 mm apart or less, and an extreme of 3 mm between corallites is noted at one point only. From the weathered surface no septal spines are apparent, but they can be seen in a transverse section, not figured, though they are obscure and small. The section shows evidence of pores, but coarse silicification makes impossible a close evaluation of their form or spacing.

Discussion. Any specific reference of such a fragment is necessarily most tentative. In corallite form and spacing this specimen is closest to C. *ungava* Cox, the type material of which is from Akpatok Island. The corallites are rather small for that species. More and better material may show this form to be specifically distinct.

Figured specimen. NMBM No. 791.

Occurrence. From the coral zone of the Aleman formation, from the southern Franklin Mountains, northeast of McKelligon Canyon.

Calapoecia coxi Bassler

Pl. 34, fig. 7-9, 11-13

Calapoecia canadensis Cox, 1936, Canada Geol. Surv., Bull. 80, p. 7, pl. 2, fig. 2a-b, 8 (pars).

Calapoecia coxi Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 276, pl. 20, fig. 5-6; pl. 17, fig. 20.

The discussion of the genus contains a description of C. *coxi* based upon topotype material, and including Bassler's type. The Cutter dolomite at several places in New Mexico has yielded a *Calapoecia* that is here attributed to that species. Corallites range up to 3.0 mm and 3.5 mm across. Every cross-section shows usually 20, but rarely 19 or 21, septal spines projecting into the corallite; they are slightly smaller and more slender than those of topotype material of C. *coxi*, but the difference, though consistent, is slight. Corallite walls are generally thin, the broadest area of coenenchyme being 1 mm across between two corallites of 3 mm, so that their centers are 4 mm apart, the greatest distance observed, even where corallites are somewhat larger. Cross-sections show round cavities in the coenenchyme not uncommon, but smaller and more sparse than the "disruptive canals" in C. *huronensis*. Some are certainly canals of this sort, some showing definite thickening and darkening of the wall. Fine structure is altered, as all specimens known are replaced by silica, but sections suggest a trabecular structure like that of *coxi*, rather than the modified almost fibrous pattern developed in *huronensis*.

Owing to silicification, which commonly does not preserve tabulae, only a few occasional tabulae are indicated on etched corallites, but a longitudinal section revealed tabulae that are irregular and rather commonly joined. Tabular count varies, depending on whether one counts two tabulae that are joined over most of their course across the corallite; with such tabulae counted, there are 10-12 in a length of 5 mm, but otherwise there would be 6-8 in that length. The spacing and aspect of tabulae are identical with those shown by Bassler (1950, pl. 12, fig. 6) in his type; another specimen from Akpatok shows tabulae more widely spaced, 5-6 in 5 mm, and only occasionally anastomosing. The coenenchyme shows 11-12 rows of pores in a length of 5 mm; between them are quite thick, regular horizontal bands, which appear to be tabular continuations, with septal extensions, or outgrowths of the vertical trabecular elements, separating the vertical rows of pores. Etched surfaces show the corallite interiors with remarkable fidelity; evidently replacement was gradual, and excess silica was not deposited on the surfaces. In most instances pores are clear perforations through the walls. Such pores show a slight but quite uniform vertical elongation. Between the pores there are transverse bands, which are crossed by more elevated vertical bands. The vertical bands bear the septal spines. Though spines may not always be fully expressed in this material, their fragile tips being lost, and perhaps in some cases the whole surface being reduced slightly, it is evident not only that the septal ridges are extended into spines at their intersection with the lower horizontal bands, but that septal spines are produced also at the level of each pore; there are thus twice as many spines as pores in any given length. This feature cannot be seen in typical C. *coxi*, but the condition probably exists there. It is evident from the Cutter material only because silicification and etching expose the inner surfaces of corallite walls, which cannot be done with the calcitic material from Akpatok Island. The close spacing of spines in relation to pores supplies a logical explanation for the visibility of the full complement of 20 spines in the circumference of every corallite in cross-sections.

Colonies are generally small, the largest observed showing a maximum corallite length of 45 mm and being 60 mm across.

Discussion. Wall character, general aspect and general prevalence of septal spines, spacing and aspect of tabulae, spacing of pores, and aspect of coenenchyme all agree closely with type material of C. *coxi*. Though C. *huronensis* has corallites of much the same general size, the walls are predominantly thinner; septal spines are sparse and not evident in cross-sections with sufficient continuity to be counted readily.

From sections, the spacing of pores is not as evident, and there is a suggestion that they are more widely spaced in *C. huronensis*. The two species do not show significant differences in the rather variable spacing and form of the tabulae, but longitudinal sections of *C. huronensis* show a much less dense aspect, suggesting that pores were considerably larger. The round tubes present in the Cutter form are smaller and less numerous than in *C. huronensis;* they have not been recognized previously in *coxi,* but such small round cavities are apparent in Bassler's figure on the right center of *C. coxi* (Bassler, 1950, pl. 20, fig. 5), and an additional section (SMC No. 6689d) shows at least one other. They are sparse and small, and lack definite thickening and darkening of the wall, but could hardly be the tubular extensions of the pores thus exhibited in a cross-section.

Figured specimens. NMBM Nos. 797-799.

Occurrence. This species is abundant only in the coral bed of the Cutter in Tank Canyon, about 12 miles northeast of Hillsboro, New Mexico. Additional specimens, more poorly preserved, have been found in the Cutter at the box of Percha Creek just southeast of Hillsboro, in the Mud Springs Mountains, at Lone Mountain, and in the Hueco Mountains; these occurrences largely involve finds of single specimens, and nowhere except at Tank Canyon has the species been found in abundance.

CERIOID CORALS WITH AXIAL PLANES

Here are described those cerioid corals in which simple fibrous walls are separated by a thin dark band of different material. As already noted, this band, which appears to develop within the genus *Foerstephyllum,* is retained in two main descendant stocks. One consists of corals in which septa become long, and these genera have been treated as Rugosa, and regarded differently in various classifications. Wang (1950) considered *Favistina* (as *Favistella*) as a subgenus only of the Devonian genus *Columnaria,* and *Paleophyllum* as a subgenus of *Streptelasma.* Hill (1956) places *Paleophyllum* next to *Streptelasma* in the Streptelasmidae and the Streptelasminae, while placing *Favistina* (*Favistella*) and *Cyathophylloides* in the Stauriidae assigned to the suborder Columnariina. The present material suggests a close relationship of *Favistina, Cyathophylloides, Crenulites* and supports most emphatically a close relationship between *Favistina* and the cerioid genus *Paleophyllum.* This last genus, as purely phaceloid and thus obviously different from the dominantly cerioid types, is placed in a group by itself, but the grouping is artificial.

Genera in this group may be summarized as follows:

Foerstephyllum—Septa are numerous short ridges, about 20 in number, reduced in advanced types to discrete septal spines; tabulae primitively transverse, but irregular, and downcurved in more advanced types. Primitive forms without pores; pores present in advanced species, but such forms provide a transition into *Paleofavosites.*

Paleofavosites—Simple cerioid corals with short septal spines or no septal structures; tabulae simple, pores largely or completely confined to corallite walls. Present specimens lack septal spines completely.

Favistina—Eight or more long major septa, commonly not reaching the corallite center, though their tips may join in small irregular groups; minor septa commonly developed. Tabulae variable, commonly downturned at their edges.

Cyathophylloides—Major septa generally more numerous, reaching corallite centers where they join, usually twisting slightly; minor septa developed. Tabulae commonly uparched conspicuously.

Crenulites—Major septa amplexoid, continued, if at all, as only vestigial septal ridges; minor septa commonly present. Tabulae with edges downturned most between septa, scalloped.

FOERSTEPHYLLUM Bassler

Genotype: *Columnaria? halli* Nicholson

Foerstephyllum Bassler, 1941, Geol. Soc. Amer., Bull. v. 52, no. 12, p. 1961.

——— Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 269.

——— Duncan, 1956, U. S. Geol. Surv. Bull. 1021-F, expl. of pl. 24, fig. 3.

——— Hill, 1956, Treatise of Invertebrate Paleontology, pt. F, Coelenterata, p. F458.

This genus contains Ordovician cerioid corals with rather thick walls, advanced species showing the axial plate developed, with numerous short septal ridges or spines, commonly 20 or more in number. Alternation of major and minor septa is present in some forms, wanting in others. Tabulae are simple and transverse in older forms, tending to become irregular in form and spacing in younger types. Pores are typically wanting in older forms, but younger species with pores have been included here.

The genus is simple in concept, but shows wide and perplexing variation. The apparent absence of the axial plate in the older forms has already received comment; it is believed that the development of the plate took place within the genus as recognized on gross features. I recognize here two species groups, the group of *F. halli* and the group of *F. vacuum.* In the former septa are ridges, the edges serrated only moderately, though some variation exists among species. Tabulae are fairly regular and transverse. Black River forms, which make up the nucleus of this group, have been assigned to one species, *F. halli,* but our examination of specimens assigned to that species show variations comparable to specific differences in other corals, and there is little doubt that the species as defined at present is far too broad. I have not attempted a revision, feeling that such work should depend upon more abundant material than was available for this study. The differences involve corallite diameter; number, length and cross-section of the septal ridges; and spacing of tabulae. Wells (1958) has pointed out that Rafinesque's species *Tubipora striatula* has priority over Hall's *Columnaria alveolaris,* which, being preoccupied by a species of the same name described by Goldfuss, was replaced by *Columnaria halli* Nicholson. It seems that in revision it would be possible to retain both names by using Rafinesque's for the species from the Amsterdam limestone, and by applying Hall's name to the older Chaumont species, or, for that matter, to the species different from either the Amsterdam or Chaumont species from the beds at Newport, which, as equivalents of the Rockland, are of essentially the age of the Amsterdam form. There are certainly three species here. A fourth species of the group, undescribed, occurs in the Richmond at Streetsville, Ontario, and is the only form of this type, with regular tabulae and septal ridges, known to me in the higher

Ordovician.[17] Wall structures of members of this group are shown on Plate 45.

Three species of the *F. halli* group have been differentiated. *F. magnificum* (Okulitch) has extremely large corallites, 8 mm across, with 32 septal ridges, the edges faintly serrated, and tabulae fairly regular in spacing, with extremely limited crowded zones, some tabulae joining. It is widely recorded by Bassler (1950), largely from beds of Chaumont or Rockland age, but one occurrence in the Lowville is reported. *F. parvulum* Bassler is small, with corallites 2.5 mm across, containing 24 septa, with short ridges, their edges faintly serrated; tabulae are moderately close and regular. It is recognized only in the Nagany limestone of Pennsylvania. *F. simplissimum* Okulitch has corallites 4 mm across, with usually 24 septal ridges, their edges more strongly serrated; tabulae show many undulations of very slight relief, occasionally two being joined, but spacing is fairly regular.

Foerstephyllum vacuum, described from material from the coral beds in the Liberty near Bardstown, Kentucky, is strikingly distinct. Septal structures are reduced to spines, so widely separated that one may sometimes search for them in vain in cross-sections showing numerous corallites. Tabulae are more widely spaced and, in general, considerably more irregular in form. In cross-section, segments of corallite walls are commonly curved, not straight as in the *halli* group or, indeed, in most of the cerioid corals discussed so far.

Curved rather than straight wall segments and distant but irregular tabulae constitute a characteristic pattern, not found in many coral species. This combination of features occurs in the species *Paleofavosites sparsus*, of the Second Value formation of the Montoya. This species shows pores at corallite angles. Its wall structure is identical with that of advanced *Foerstephyllum*, but the fibrous walls are not extended into septal spines. Could this form be a modified *Foerstephyllum* instead of a *Paleofavosites?* Illustrations and descriptions of *Paleofavosites* failed to reveal any details of wall structure, and the previous discovery of pores in *Saffordophyllum* suggested that genus as the possible ancestral radical of *Paleofavosites* and thence of the Favositidae. However, examination of more specialized *Paleofavosites* from Montoya material offered indication that these forms had walls with axial plates separating simple fibrous layers, and Swann (1947) has shown structures in *Favosites* related to the walls of *Foerstephyllum* and the structures shown less clearly in our *Paleofavosites*, suggesting most strongly origin of the Favositidae from *Foerstephyllum* rather than from *Saffordophyllum*.

The Akpatok Island material yielded two species that supplied an even closer connection between *Foerstephyllum vacuum* and *Paleofavosites sparsus*. They had axial plates lined with fibrous material, corallite walls with segments commonly curved in cross-section, and irregular tabulae, lax, distant, and downcurved in early growth stages. The fibrous sclerenchyme was extended into septal spines, more frequent in the young, giving them the aspect of *Foerstephyllum*, but in later stages spines are scarce, presumably being smaller and more distantly spaced, and pores, not particularly evident in young stages, become common. Undoubtedly, these species supply a transition, but it is such a close transition that it is questionable whether they should be put in *Paleofavosites* or in *Foerstephyllum*. The latter assignment is made here, though it is recognized that others may argue that the appearance of pores is the one feature distinguishing *Paleofavosites* from *Foerstephyllum*, and that the alternate course should be followed. When one deals with material in which pores can be seen only from sections, the chances of finding such pores, if they are infrequent and widely spaced, injects some subjective matters into the problem. I have failed to find pores in *F. vacuum*, but remain unconvinced that they are, for this reason, completely absent, especially in view of the number of corallites of *Saffordophyllum* examined in cross-section, in which only 3 or 4 pores were found in sections showing perhaps 200 corallite cross-sections.

Other possible solutions were considered, but rejected for one reason or another. Segregation of the forms with curved walls, and irregular tabulae and pores, into a genus by themselves was considered, which would include *Paleofavosites sparsus*, *Foerstephyllum porosum*, and *F. minutum*. The wisdom of such a course seemed somewhat questionable, inasmuch as these criteria, though they produce a striking resemblance among the species, are considered superficial. Also, from want of detailed descriptions and adequate figures, it was not evident whether any of the spinous species previously assigned to *Paleofavosites* should be placed in such a genus. Certainly there are some such forms with relatively straight walls and more regular tabulae that do not seem closely related to these three species. The same perplexity made unsatisfactory an attempt to separate generically spinous species formerly assigned to *Paleofavosites*. In the end, the two species with strong septal spines, but with pores, are retained in *Foerstephyllum*, because of their evident resemblance to *Foerstephyllum vacuum*, leaving possible revision to others. This is plainly one of those cases where close relationships between generic groups present problems as to the exact limits of the genera.

The present study shows the need for a comprehensive restudy of *Foerstephyllum*, with a critical review of the species in mind as well as further observation of wall structure; also needed is much wider knowledge of the species and the wall structures in *Paleofavosites*. As noted under *Saffordophyllum*, that genus is involved in one specimen, at least, identified as *Paleofavosites prolificus* from Anticosti, a species that is almost certainly too broadly defined at present.

Foerstephyllum porosum Flower, n. sp.

Pl. 32, fig. 1-4; pl. 45, fig. 9

Corallites of this form attain a diameter of 4.5 mm, but sections and surfaces show many smaller individuals. In cross-section the walls are commonly curved rather than straight, and pores are commonly seen at the angles of the corallites; they must have been abundant and closely spaced. Walls show a thin, dark axial plate, rarely with its two components distinct, and fibrous sclerenchyme. In cross-section the septal spines are not shown; they are evidently not only discrete but quite widely spaced. In longitudinal section the corallite walls are moderately undulate; here may be seen short, rather acicular septal spines, which are sparse, spaced 0.8 mm to 1.2 mm apart in various parts of the section. Tabulae in the basal part of the colony are wide spaced, 2 mm apart, and lax, gently but prominently curved down. In the distal part tabulae are highly irregular in form and in spacing; they may be turned

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[17] Since the completion of this text, C. W. Welby has described *Foerstephyllum wissleri* (Jour. Paleont., v. 35, no. 2, March 1961), the first *Foerstephyllum* to be found in beds older than the Black River. The species is from the Chazyan of the Champlain valley. The species has the serrated septal ridges of the group of *F. halli*.

up or down or may be slightly oblique; here they average slightly less than 1 mm apart, and distally 7 occur in a length of 5 mm.

Only two colonies of this form have been observed, both probably incomplete. The larger, the holotype, is 30 mm across; length of corallites is only 15 mm, but the colony is weathered and incomplete adorally.

Discussion. In corallite size this form is not unlike *Foerstephyllum vacuum*, but the cross-sections show more common and more prominent curvature of the corallite walls, and common pores, which have not been observed in typical *vacuum*; septal spines are much more common, and are short and acicular. In longitudinal section the undulation of the walls is more marked, and the tabulae are more erratic in curvature and spacing; characteristic apparently are the downcurved tabulae, which are quite widely spaced in early stages of the colony.

In general aspect of the sections, *Paleofavosites sparsus* is much more similar to the present species than is *Foerstephyllum vacuum*, but the corallites are somewhat smaller, and no septal spines have been observed.

Types. Holotype, SMC No. A50676; paratype, No. 50677.

Occurrence. From Akpatok Island, 800 feet above sea level, localities 93 and 90, at the Harp Burn.

Foerstephyllum minutum Flower, n. sp.

Pl. 31, fig. 1-4

This is a *Foerstephyllum* of the *vacuum* group, with small corallites averaging 2.0 mm, with smaller individuals common, and the largest observed being 2.2 mm across. The cross-section of the holotype shows, near the center of the colony, rather thick-walled corallites, and though septal spines are discrete, they are evidently closely spaced, for nearly every individual in the section shows spines, but that they are discrete spines and not ridges is shown by their nonuniform distribution around the corallites. Here pores are occasionally seen at the corallite angles, but they are not common. A more distal part of the colony is preserved only on one side; here the corallite walls are thinner, pores are common, and spines are less common, suggesting that they are somewhat more widely spaced here. Spines cannot be counted with certainty from the section, but there are certainly 18 and probably 20 or more in the circumference of a corallite.

Only two short longitudinal sections are available. One, from the holotype, shows tabulae rather irregular in form, with 2 to 4 in 1 mm; a paratype shows somewhat smaller corallites, the spacing of the tabulae being still closer, varying from 3 to 5 in a length of 1 mm.

Discussion. This species is distinctive in the *vacuum* group for the small size of the corallites. *Foerstephyllum parvulum* Bassler, of the Nagany limestone of Pennsylvania, is comparable in corallite size, but its septa are serrated ridges, the tabulae are more regular, and the species belongs in the group of *Foerstephyllum halli*. Stearn's (1956) *Angopora manitobensis* seems somewhat similar to the present species; there is, as noted under *Paleofavosites*, uncertainty as to the affinities of the genus in the absence of information on the detailed structure of walls and septa, but this is a form with small polygonal corallites, with short septa broken not quite completely into columns of discrete spines, and with pores common at corallite angles but occasionally present elsewhere in the walls as well. The corallites of *A. manitobensis* are consistently smaller than those of *F. minutum*, tabulae appear more regular in spacing, curved corallite walls and tabular irregularities of *F. minutum* have no counterparts in *A. manitobensis*.

Both of the specimens, though possibly not complete, represent small colonies. The holotype colony is 30 mm across and 25 mm in height; one other specimen is an even smaller fragment.

Occurrence. Akpatok Island, from an elevation of 800 feet at the Harp Burn.

Types. Holotype, SMC No. A50682; paratype, No. A50683.

PALEOFAVOSITES Twenhofel

Genotype: *Favosites aspera* d'Orbigny

Paleofavosites Twenhofel, 1914, Canada Geol. Surv. Mus. Bull. 3, p. 24.

——— Bassler, 1915, U.S. Nat. Mus. Bull. 92, v. 2, p. 941.

——— Twenhofel, 1928, Canada Geol. Surv. Mem. 154, p. 125.

——— Stearn, 1956, Canada Geol. Surv. Mem. 281, p. 59.

Favosites (*Paleofavosites*) Duncan, 1956, U.S. Geol. Surv. Bull. 1021-F, expl. of pl. 26.

Paleofavosites Hill, 1959, N. Mex. Inst. Min. and Technology, State Bur. Mines and Mineral Res. Bull. 64, p. 11.

Paleofavosites was originally set off from *Favosites* to contain those species, formerly included in that genus, in which pores were confined to the angles of the corallites. There appears to be no mention of the fine structures of the corallite walls for the genus, but our material indicates an axial plate with a thick lining of sclerenchyme. This is consistent on the one hand with *Foerstephyllum* and on the other with splitting of the axial plate into two narrowly separated "primary walls" in younger Favositidae, as described by Swann (1947).

As such the genus contains cerioid corals with rugosan walls, pores largely or completely confined to corallite angles, and simple tabulae. The genus has included species both with and without septal spines, but as noted under *Foerstephyllum*, two anomalous species with such spines are included under that genus. No attempt seems to have been made previously to separate forms with and without septal spines.

Our knowledge of wall structure in *Paleofavosites* rests only upon the few specimens described in the present work; if studies have been made of other species, the results have not been published. Probably much of this seeming neglect stems from the fact that, in North America at least, the favositids of the very latest Ordovician and those of most of the Silurian occur largely in dolomites. Specimens are either external molds from which the material has been removed, or are variously replaced; neither mode of preservation is conducive to the preservation of original fine structures. Devonian forms are commonly much better preserved, and more of these forms have been studied by section, but these younger forms are of course more advanced, and no *Paleofavosites* are known from beds of that age.

As noted under the discussion of that genus, the discovery of pores in *Saffordophyllum* seemed to suggest that that genus was the oldest of the Favositidae, and it was something of a surprise to find later in the investigation such gradation between *Paleofavosites* and *Foerstephyllum* that it is difficult to say where the boundary between the genera should be drawn. The perplexity seemed the greater because these forms agreed with *Foerstephyllum* and other genera of rugosan aspect in having walls with fibrous materials separated by an axial plate. Both origins of the Favositidae could not be true, unless the Favositidae as at present understood prove to embrace two distinct but highly homeomorphic stocks. However, Swann (1947) has studied walls of Devonian favositids in some detail, and if vexations of conflicting terminologies are bypassed momentarily, the structures he reports are readily interpreted as slight modifications of the wall structure of *Foerstephyllum* and the anomalous *Paleofavosites sparsus*, whereas identical structures are indicated, though less conclusively because of replacement of available materials, in more regular and more typical *Paleofavosites*. As already noted, the structures described by Swann differ primarily in the splitting of the axial plate, which there was reason to regard as consisting of two separate layers, though such separation was not ordinarily apparent to the eye, with a thin band of light calcitic material between. Ross (1953) has shown other sections of Devonian favositids suggesting that the separation of the parts of the axial plate is not constant, and these sections for the most part show a close accord with the "rugosan" wall observed in the Ordovician material of the present study. It seems, then, that in the main at least the present family Favositidae is a natural group, and one stemming from *Foerstephyllum* through *Paleofavosites*.

Hill (1959) has summarized the characters of known occurrences of species of *Paleofavosites* in the North American Ordovician and Silurian. Again, distinction must be made bespecific comparison attributed to certain species, and the cited described species themselves, which are in some cases virtually unknown.

Twenhofel, when he described *Paleofavosites*, had in mind specimens from the Ordovician and Silurian of Anticosti, specimens of the sort that Billings had used in describing two species, *Favosites prolificus* and *F. capax*. Twenhofel succumbed, however, to the then popular practice of identifying Anticosti materials with European species, and he considered both these forms as synonyms of *Favosites asper* d'Orbigny, typically developed in the Wenlock of England. He therefore designated that species as the genotype of *Paleofavosites*, and the designation is unqualified and must stand; that this identification involves some dubious assumptions which are now generally rejected is quite beside the point.

The Anticosti species *Paleofavosites prolificus* and P. *capax*, though they have been cited widely in faunal lists, are both most inadequately known, and typical Anticosti materials have never been illustrated or, apparently, studied very closely. Reputedly, *Paleofavosites prolificus* ranges throughout the entire Anticosti section, appearing in the English Head formation, which Sinclair (1956) regards as of Maysville rather than Richmond age, to the Chicotte, which is latest Clinton or possibly Racine, late rather than early Middle Silurian in age. Today it is recognized that no adequately studied species has proved to have such a wide stratigraphic range, and that almost certainly restudy would show that several species are involved in what has been called P. *prolificus* on Anticosti. Clearly, restudy is needed, based upon Anticosti materials of known stratigraphic origin, and involving the selection of a type studied from thinsections. Elsewhere in this work attention is called to a specimen, No. 90991 in the U.S. National Museum, labeled *Paleofavisites prolificus* from the English Head formation of Anticosti, which is not a *Paleofavosites*, but a *Saffordophyllum*. Similar restudy is required for *Paleofavosites capax*, a species reputedly ranging from the English Head to the Ellis Bay formations of Anticosti. Stearn (1956) has figured and described specimens from southern Manitoba in terms of these species, and though the identification must remain somewhat doubtful pending a more thorough study of Anticosti materials, one can at least make comparisons with the Manitoba forms.

Paleofavosites capax of Anticosti is described (Twenhofel, 1928) as having corallites 2 mm to 3 mm across, tabulae depressed at the edges, forming small marginal pits, and small mural pores at corallite angles. Stearn (1956) attributed to the species forms with corallites ranging from 3.0 mm to 4.3 mm, with simple horizontal tabulae and rare short, scattered septal spines.

Paleofavosites prolificus involves specimens showing wider variation. Twenhofel did not agree closely with Billings' original description in regard to corallite size, Billings attributing to *prolificus* forms with corallites 4 mm across, and Twenhofel including specimens with corallites 1.0 mm to 1.5 mm across. Twenhofel also reported tabulae less than 1 mm apart, and sparse septal spines present. Stearn attributed to the species specimens from the Stony Mountain, Stonewall, and Interlake beds of southern Manitoba. His descriptions and figures permit comparison with his form, which has corallites 2.1 mm to 2.5 mm across, short septal spines, tabulae 20 in 1 cm or 10 in 5 mm, septal spines short, rudimentary. With present problems at the specific level one could wish for more figures, and perhaps more detailed information on the spines, but at least one can make comparisons with these two species of southern Manitoba at the specific level, which is more than can be said of the typical Anticosti material on which these specific names have been based. Clearly, none of the Montoya species are closely comparable.

Paleofavosites okulitchi Stearn (1956) is a species without septal spines; mature corallites average 3.7 mm across; pores at corallite angles but also some well removed from the angles; tabulae close, rather irregular; the edges are commonly downturned and may be slightly scalloped. Hill (1959) tentatively identified the common *Paleofavosites* of the Cutter with this form, but more material suggests the species to be distinct, which is in a way regrettable from the viewpoint of correlation.

Paleofavosites poulseni Teichert (1937) was described from Silurian beds from the hinterland of Douglas Bay, King William Land; a species with very prominent septal spines, corallites 1-2 mm across, tabulae varying from 0.3 mm to 1.0 mm apart. Probably the statement that walls are 1 mm to 1.5 mm thick involves clerical misplacement of a decimal point. The figures show corallites with wall segments straight in cross-section; in longitudinal section walls are relatively regular and tabulae, though variable in form, relatively evenly spaced. This form is not closely similar in these features to the bothersome species P. *sparsus* and *Foerstephyllum porosum* and *minutum*. Stearn (1956) has attributed to this species a form common to the Stonewall and Fisher Branch formations, a form with similar small corallites and prominent septal spines, but figures suggest the spines to be shorter and broader, the walls thicker, and the tabulae much more closely spaced.

Possibly involved with *Paleofavosites* are two other genera, although without definite information on wall structure, one cannot be certain whether they belong with *Paleofavosites*, or whether they are instead relatives of *Saffordophyllum*. *Angopora* Jones is defined as a tabulate coral resembling

Favosites, but with discontinuous lamellar septa breaking up into spines on their edges. Stearn (1956) has described *A. manitobensis* from the Stonewall formation of Manitoba, a species with corallites 1.6 mm to 2.1 mm across, pores abundant in corallite corners, rare in the walls, tabulae flat, 20-30 in 10 mm, and 12 septal ridges. Stearn suggests that spines are formed by breaking up of septal ridges, and that what he identified in younger beds as *P. poulseni* might have developed in this way from this *Angopora.* In the present work the same transition from septal ridges to spines has been noted in the change from *Foerstephyllum* of the *halli* type to those of the *vacuum* type. However, one reservation concerning *Angopora* should be noted. In having pores not always confined to corallite angles and 12 rows of septal spines it agrees with the group of *Saffordophyllum* species that are dominant in the higher Ordovician, and without information as to whether walls are simple fibrous types, or rugosan types with axial plates, one cannot be sure whether *Angopora* is a favositid or whether it is a development from *Saffordophyllum.* The species is known from dolomitic material unlikely to yield such information.

Corrugopora Stearn (1956) is involved in the same dilemma. It is known from two species from the East Arm dolomite, *C. rhabodta* and *C. praecursor.* Walls are crenulate in cross-section, convexities thickened into 12 septal ridges in each corallite, which is very reminiscent again of *Saffordophyllum;* pores are present. Walls are thick and septal ridges prominent; sections suggest *Nyctopora* rather than *Saffordophyllum* in aspect, but *Nyctopora* does not have pores. Here again observation of the fine structure of the wall is needed to determine whether this is possibly a Silurian specialization stemming from *Saffordophyllum,* or whether it is a true favositid, but it will not be easy to observe adequately preserved walls, as the known material is dolomitic.

Paleofavosites sparsus Flower, n. sp.

Pl. 32, fig. 5-6; pl. 33, fig. 7-9

Of this form we have only one small colony, 35 mm across and with an estimated height of 25 mm. The corallites on the surface or in any section show a wide size range, as is common in colonies in which the corallites show a definitely radiating pattern, but the maximum size range is 2.5-3.0 mm. Cross-sections show polygonal corallites in which segments of the walls between corallite angles are more commonly slightly curved than straight; pores at the corallite angles are apparently rather closely spaced, for several are shown in the one transverse thinsection made from the type colony. Walls show a dark axial plate, varying somewhat in thickness from one part of the colony to another, with a lining of sclerenchyme, rather thin, not extended into septal spines, varying somewhat in thickness in the colony. In places the sclerenchyme is poorly differentiated from calcite of the matrix; clearly a preservation phenomenon and of no real taxonomic significance. In longitudinal section the corallite walls are somewhat undulate, the sclerenchyme generally thin, somewhat variable, but without clear rhythmic phenomena governing thickness; tabulae are commonly downcurved but highly irregular in form and spacing, the distance between two of them ranging from 1.2 mm to 2.0 mm, and there may be 4-5 in a length of 5 mm. As is usual, spacing of tabulae seems to have no relation to corallite diameter, being uniformly irregular in both large and small individuals. Tabulae are downcurved and conspicuously widely spaced in early growth stages.

Discussion. This species is distinctive as the only *Paleofavosites* in the Second Value formation of the Montoya. The only known colony is small, a rather nondescript form, and in corallite size it ranges a little larger than *Saffordophyllum newcombae* and about the same size as *Trabeculites maculatus.* Without thinsections, it should be possible to differentiate this form on the basis of the curvature of the walls as seen in cross-section between the corallite angles, and in longitudinal section by the highly irregular form and spacing of the tabulae.

In comparison to the younger *Paleofavosites* of the Montoya this species shows more marked curvature of segments of walls between corallite angles in cross-section; in longitudinal section none of the younger *Paleofavosites* are known to show such irregularity in spacing or form of the tabulae; downcurved tabulae are never prevalent; rather the tabulae are dominantly transverse and relatively regular, with rhythmic variation in spacing evident in some forms.

As noted under the discussion of *Foerstephyllum* and in the introduction, this species, in the aspect of the colony in both longitudinal and cross-section, is highly suggestive of *Foerstephyllum* of the species group of *F. vacuum.* In typical topotype material of *F. vacuum* corallites average larger, 4 mm across; cross-sections show slight curvature of the wall segments, but the condition is less marked than in the present species, and pores are either wanting in *vacuum* or are so sparse in vertical distribution that our sections have failed to show any good openings between corallites that are not possibly either adventitious breaks in the walls or connections between a parent and a young budding individual. In *F. porosum* of Akpatok Island, described in the present work, sections are much more like those of *P. sparsus* in curvature of walls, frequency of pores, and, in longitudinal section, undulation of walls and form and spacing of the highly irregular tabulae. However, both longitudinal and cross sections of *P. sparsus* show the sclerenchyme commonly extended into short septal spines, and there is a wide difference in maximum size of the corallites; *F. porosum* has corallites 4 mm across.

In *F. minutum* tabulae are lax and irregular in form and spacing, walls are undulate in cross-section, pores are present, and wall segments commonly show some curvature. This species has much smaller corallites, the largest being only 2.2 mm across; in the young stages of the colony, walls are thicker, spines are long and frequent; in later stages, walls are thinner, segments more curved, and spines somewhat more sparse but still relatively long and large in proportion to the corallite diameter.

In fine wall structure *P. sparsus* agrees with species of the *F. vacuum* group. Details of the wall structure of true *Paleofavosites* are not available in the literature, and the younger, more typical, species of the genus available for the present study are somewhat inconclusive, for they all show some replacement, largely by silica or by dolomite. As far as can be deduced, however, they also had walls seemingly formed of a single, simple axial plate lined on either side with sclerenchyme, rather than with the axial plate divided into two "primary walls" by an intermediate region of light calcitic material, as reported by Swann (1947) for *Favosites.*

Holotype. NMBM, No. 679.

Occurrence. From the Second Value formation of the Montoya group, from near the crest of the Scenic Drive, El Paso, Texas.

Paleofavosites prayi Flower, n. sp.

Pl. 35, fig. 1, 3-8

Corallites cerioid, polygonal, commonly 1.5-2.0 mm, rarely as much as 2.2 mm across. In thinsection it is seen that segments of the wall between corallite angles are commonly but slightly curved. Septal spines are wanting; pores are present at corallite angles, though sparse. Vertical sections commonly show the walls as undulate; variability in this respect results from the accentuation of undulations as corallite angles are approached, but even midway between the angles the walls remain definitely sinuous. Tabulae are dominantly transverse or slightly arched upward, but sections show wide variability in the extremities, some being turned down, others transverse, and others turned slightly up. Weathered tabulae show that this perplexing variation in longitudinal sections is due in large part, for real irregularity and variation exist, to slight crenulation of the edges of the tabulae. The type shows zonation of spacing of the tabulae. Near the base 9-10 tabulae occur in 5 mm, a condition shown in the basal 8 mm; following this is a zone of very widely spaced tabulae; here irregularity of the edges and form is most marked, and tabulae occur 4 in 5 mm, a condition maintained for a length of 20 mm. Adorally a crowded zone appears abruptly with 9-10 tabulae in 5 mm, which persists throughout the adoral 14 mm of the sectioned portion. Actual measurements are given, but cannot be expected to be uniform.

The type colony, which is nearly complete, shows a length of 50 mm and a width of 100 mm. The extreme base is wanting; the length was perhaps 60 mm when complete.

Discussion. The type colony is calcitic, a condition that makes exposure of pores on weathered walls practically nonexistent. One section shows pores that are quite widely spaced, 1.4 mm apart, but ordinary specimens do not show this, and the form, seeming to lack pores and having rather small corallites, is one that, on that basis, one would be tempted to refer to the older genus *Lichenaria.* Though wall structure is somewhat altered in our material, largely by recrystallization it seems, there is indication that the walls consist of axial plates with a lining of sclerenchyme; here the sclerenchyme is, in most sections, poorly differentiated from the calcite filling the corallites.

The small corallites serve as a ready means of recognition of this species in the field, and the only form with which it can be confused readily is the associated *Nyctopora nondescripta,* but even with considerable replacement, that form is recognizable on the basis of the thicker walls and pronounced septal ridges.

Holotype. NMBM No. 685.

Occurrence. From the coral zone of the Aleman, north Franklin Mountains; also observed at the southern end of the Franklin Mountains, near El Paso, Texas.

Paleofavosites cf. *prayi*

Pl. 37, fig. 1, 3-5

The Cutter has yielded a number of colonies of a *Paleofavosites* in which corallites are commonly 2.0 mm or less in diameter and very rarely as much as 2.4 mm, and in which the tabulae are relatively distant, 3-4 (rarely 5) occurring in a length of 5 mm. The specimens are silicified, and some show mural pores on etched surfaces. The pores are commonly confined to corallite angles and vary in spacing from 0.8 mm to 1.0 mm. One corallite is of particular interest in that it shows some pores that are not at the angles, but this is a face of a large corallite behind which are two small corallites, and the pores are at the angles of these small individuals. As a consequence, the presence of pores in the face of the larger individual wall seems to lack significance as indicating a transition from *Paleofavosites* to *Favosites.* The tabulae vary in form, but commonly are arched down in early stages and are more transverse adorally; adorally, some tabulae are turned down in marginal pits, but the size and number of the pits are variable, as is the extent of this development. Spacing of tabulae is as in typical *prayi.*

Discussion. The Cutter material agrees with *P. prayi* in small corallite size and dominantly rather distant tabulae. The colonies show some features not shown by the typical Aleman form, but material of the Aleman form is limited, and more material may show these differences to be gradational and negligible. The differences are the somewhat larger size of the corallites, which here are not uncommonly 2.0 mm and may be larger, and the crenulated tabular edges.

The latter I believe to be a real difference, and it is one that is strongly developed only in late growth stages, being found in the distal but never the proximal parts of the colonies. In addition the Cutter form shows tiny young corallites as much as 0.5 mm in diameter, which appear as thick-walled round tubes; they enlarge rapidly and assume the usual polygonal form when a diameter of 1.0 mm is attained.

Figured specimens. NMBM No. 796, 797.

Occurrence. From the Cutter formation, observed at Tank Canyon, in the Mud Springs Mountains, and near Helms West Well in the Hueco Mountains. The form is much less abundant than the larger, associated *P. mccullochae.*

Paleofavosites kuellmeri Flower, n. sp.

Pl. 36

Corallites with diameters ranging commonly from 2.0 mm to 2.5 mm, commonly over 2 mm. Cross-sections show wall segments with a prevalent though not universal curvature in segments between corallite angles. Considerable alteration of wall structure is apparent in most material, but in some parts silicified walls show an axial plate bounded by lighter material, which was sclerenchyme; but such walls show commonly a secondary thickening by the addition of extraneous silica to the surface, and the true width is exaggerated (pl. 36, fig. 4, 5). In other parts the wall appears as fine granular material and is much thinner; apparently here identity of sclerenchyme and axial plate is lost. It appears probable that the full thickness of the wall is not shown under such preservation, the boundary merging into the calcite or silica of the matrix, and being proportionately much thinner than the other regions lead one to expect.

Longitudinal sections show walls with undulations much finer and closer than in *P. prayi,* with convexities on one side 1.0 mm to 1.5 mm apart. Clearly, the undulations, though prevalent in every thinsection, are by no means universal, and are vestigiail or wanting in sections cutting the walls midway between corallite angles. However, sections cutting walls close to or at the angles show the undulations of the walls strongly developed. Undulations are much more closely spaced than in *P. prayi,* the distance between convexities on one side ranging from 1.0 mm to 1.5 mm, but the interval of 1.0 mm is the commoner of the conditions. A number of sections are shown cutting corallites at or close to the angles, and here the pores are well displayed (pl. 36, fig. 3, 6, 7). Pores are commonly 1 mm apart, but in one place three instead of two are included in that length. One section (pl. 36, fig. 8) shows what appear to be exceptionally large pores; the section is one cutting the corallite wall so close to the angles that, owing to the undulations, the material, here replaced and showing only a fine granular texture, appears continuous across the corallite angle at regular alternating intervals, and the enlarged openings between are those that, were the section a little closer to the angles, would be expressed as true pores of less than half the size shown; these undulations in the wall, which would in an etched surface appear as shallow pits with pores at their bases, are what have been termed poral processes.

Tabulae are generally transverse and relatively straight; downcurved tabulae are prevalent but far from universal in the early part of the colony; in the anterior part the transverse condition is more general, with only slight variations in relief. Weathered specimens show that in the anterior part of the colony, the edges of the tabulae are slightly but definitely crenulate, a condition not found in the basal portion. Tabulae are much more regular in spacing than in *P. prayi* and also slightly more closely spaced in general, a condition that appears the greater because of the slightly larger diameter of the corallites in the present form. The type colony shows basal tabulae generally spaced 6-7 in 5 mm, though somewhat irregular, and at one point only 4 tabulae occur in this length. This interval is followed by a general zone of crowding, only 9 mm long, with 9-10 tabulae in 5 mm; beyond this region tabulae are generally moderately spaced, commonly 7, rarely 6 or 8, in a length of 5 mm, to the anterior end of the colony.

Discussion. This species contrasts strongly with the associated *P. prayi* in the larger corallites, the more closely and regularly spaced tabulae, which are more regularly transverse, and the closer undulations in the corallite walls. Apparently pores, well shown in this species but less generally displayed in *P. prayi,* are here much more closely spaced, as are the undulations of the corallite walls, most apparent near corallite angles.

The type colony shows corallites 50 mm long, possibly as much as 80 mm when complete, and a width of the colony of 70 mm, probably 100 mm when complete.

Holotype. NMBM No. 686.

Occurrence. Coral zone of the Aleman formation, northern Franklin Mountains, Texas.

Paleofavosites mccullochae Flower, n. sp.

Pl. 37, fig. 2, 6-9

This *Paleofavosites* develops corallites that commonly attain diameters of 2.5 mm to 3.0 mm, individuals as large as 3.2 mm being most exceptional. In cross-section wall segments of mature corallites are commonly straight; where any curvature is developed, it is extremely slight. Tiny budding individuals, however, appear as small rounded tubes up to 0.5 mm in diameter, but as they enlarge they assume the usual polygonal form. In longitudinal section walls show close crenulations, most marked at corallite angles, but commonly present also in the centers of wall segments. The crenulations develop at the corallite corners into poral processes. Pores are commonly 0.8 mm to 1.0 mm apart. Only very rare pores have been observed in the middle of wall segments; one is shown in the center of Plate 37, figure 8. Where such pores are developed, they do not apparently represent juncture of a large corallite with two smaller ones. Tabulae are variable in spacing, but commonly 5-6, rarely 4, occur in a length of 5 mm. Short zones of crowded corallites occur; the zones, 5-8 mm long and apparently nonuniform, are present in some colonies but definitely absent in others of comparable sizes; in these crowded zones; 8-9 tabulae may occur in the same length. Tabulae are mainly horizontal, but weathered surfaces commonly show the edges downturned in a series of shallow marginal pits, a condition quite general but not shown in tiny colonies, and not developed in the basal 10-15 mm of the colonies.

Discussion. This is the common favositid of the Cutter, where colonies are found silicified. The silicification is highly variable, sometimes preserving structures with great fidelity, sometimes destroying tabulae completely, and sometimes developing artificial thickening of both septa and tabulae. It is this form that Hill (1959) identified tentatively as *Paleofavosites okulitchi.* Our material, however, has shown consistent differences. The corallites are smaller, those of that species ranging from a mean diameter of 3.79 mm. Pores are confined to the corallite angles with only the rarest exceptions. Septa are completely wanting. Tabulae are not recorded as to spacing in *okulitchi,* but in our present form they would hardly be described, as they were in that species, as crowded. One of Stearn's figures (1956, pl. 8, fig. 3) shows *P. okulitchi* as having marginal depressions in the tabulae similar to those in our form, but Stearn did not find this condition prevalent (*fide litt.*) and did not attach much importance to it. In our present form it has been found quite characteristic, though subject to variations in preservation and not developed at all in initial stages of the colonies.

P. kuellmeri of the Aleman is close to this form, but has corallites smaller, commonly from 2.0 mm to 2.5 mm in diameter; tabulae in normally spaced regions are not quite as far apart; crenulation of the tabulae is not developed.

The species produces colonies that are commonly 60 mm in corallite length and perhaps 80 mm across, but large colonies have been found with corallites 120 mm long and 150 mm across.

Young stages are very difficult to distinguish from colonies of the smaller associated form, for corallites of 15 mm or less in length will show many small individuals and only occasional corallites 2.0 mm across or larger. This is not a good basis for uniting the species; it is not uncommon for the young of congeneric species to be virtually indistinguishable. However, at a corallite length of 15 mm, individuals of 2.0 mm appear, and individuals of slightly larger size may develop, but at a corallite length of 20 mm or more the usual corallite size of 2.3 mm to 3.0 mm is dominant.

Types. NMBM No. 800-805 and 569-570 (figured as *P.* cf. *okulitchi* by Hill).

Occurrence. Common in the Cutter formation in New Mexico and western Texas. In the Hueco and Franklin Mountains, and again at Lone Mountain, several zones of silicified corals, dominantly of this species, occur in the Cutter. They occur in the blue limestones of the Cutter in the Mud Springs Mountains but are far more abundant as silicified specimens 30-35 feet higher in the section. The coral bed of Tank Canyon has yielded the species; it occurs in the Black Range in Pierce Canyon and in exposures near North Percha

Creek. Specimens have been obtained from the box of Percha Creek, not far from the type locality of the Box member of the Devonian. In the San Andres the species has been obtained from Rhodes and Hembrillo Canyons, and it is present in the Cutter of the Sacramento Mountains near Alamogordo. One excellent colony, here figured, is from the section at Lake Valley, shortly west of the famous Mississippian exposure. Strangely, the form has not been noted in the Cooks Range nor in the Florida Mountains, where good thicknesses of the Cutter occur.

FAVISTELLA Dana

Genotype: *Columnaria alveolaris* Van Cleve, ms.

Favistella Dana, 1846, Zoophytes, Wilkes U.S. exploring expedition, p. 538.
——— Hall, 1847, Paleontology of New York, v. 1, p. 275.
——— Bassler, 1915, U.S. Nat. Mus., Bull. 92, v. 1, p. 257.
——— Lang, Smith, and Thomas, 1940, Index of Paleozoic coral genera, British Mus. Nat. Hist., p. 60.
——— Stumm, 1948, Michigan Univ., Mus. Paleont., Contrib., v. 7, no. 1, p. 1.
——— Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 251.

Favistella was briefly described by Dana in 1846, who named as the genotype *Columnaria alveolaris* Van Cleve, a species then in manuscript and still unpublished, and it is today highly uncertain what that species is. Hall, in 1847, in the first volume of the "Paleontology of New York," proposed the name *Favistella* as a new genus, the genotype of which is, by monotypy, *Favistella stellata,* a species then described and illustrated, and based upon material from the "Hudson River group" of Madison, Indiana. The occurrence of these corals at Madison is confined to several biostroms in the Saluda beds there. Subsequent authors for about 25 years employed the genus *Favistella,* but usually referred to it as *Favistella* Hall; Dana's description was not generally known. From about 1875 to 1940 the generic name fell into disuse, because of a general belief that it was a synonym of *Columnaria* Goldfuss. In that period much uncertainty existed as to the proper scope of coral genera, particularly of the genera of the Paleozoic. However, the confusion gave way to a general conviction that it was unlikely that a single genus ranged without change from the Ordovician into the Devonian. It became evident that *Columnaria* was based not upon an Ordovician form, but upon *Columnaria sulcata* of the Devonian of Germany. Lang, Smith, and Thomas (1940) revived the name *Favistella,* but believed Hall's description to have priority, a matter that was corrected by Stumm (1946), who pointed out the priority of Dana's description. Stumm concluded, however, that *Columnaria alveolaris,* a name used in manuscript by Van Cleve, was an error for *Columnaria alveolata* Goldfuss, a conclusion to which it is necessary here to take exception. Bassler (1950) redefined *Favistella,* accepting *F. alveolata* Goldfuss as the genotype. The genus, as defined by Bassler is a perfectly good and valid genus of Ordovician corals. Great difficulty, however, was encountered at the specific level. In part this was due to variation which is found in corals in various associations, but in large part the confusion stemmed from uncertainty as to what *Favistella alveolata* really is. The only descriptions and figures of the type of this species are old and too general to be of much use in a precise comparison at the specific level. The original stratigraphic occurrence is unknown; the specimen Goldfuss described was picked up at Seneca Lake, New York, from the glacial drift, and even if topotype material should be found, it would be valueless. It has been suggested that the specimen came from some part of the Black River, inasmuch as such beds with marine faunas and occasional corals are exposed north of Goldfuss' "type locality," whereas there is no marine Richmond north of the region, but this conclusion is an assumption. Actually, enough is not known of the type to determine whether it has the characters attributed to *Favistella* by Bassler, or even whether it came originally from Ordovician rocks. Bassler (1950) has refigured the genotype of *Columnaria, C. sulcata.* It differs from *Favistella,* as previously conceived, in no important features in the cross-sections, but longitudinal sections show a marginarium of small dissepiments, and a central tabularium with tabulae so irregular and so anastomosing that one is tempted to call them dissepiments also. It is not demonstrable that *Favistella alveolata* is a true *Favistella* to the exclusion of *Columnaria;* it seems not impossible that the drift of Seneca Lake, New York, might have yielded a specimen derived from the Onondaga limestone, exposed at the northern end of that lake; indeed, in the Upper Devonian terrane at the southern end of the Finger Lakes, pieces of Onondaga, some containing corals, are not uncommon.

With the acceptance of *Favistella alveolata* as a genotype, a species so generally known that comparison at the specific level could be only most general, and even then involving some assumptions, the species had to be accepted as having very largely the scope of the genus; it was believed to be a variable form, one ranging widely over North America in the Ordovician, and ranging, as does the genus, from Black River to Richmond. Some other trivial names had been proposed, but they were in part regarded as simply synonyms of *alveolata,* or as subspecies, some of dubious value (Bassler, 1915, under *Columnaria,* cites these forms). Bassler (1950) recognized as subspecies of *Favistella alveolata* seven trivial names, some differentiated by corallite size, but most of them differentiated by the form of the colony, a matter in which ecological control always looms as an unpleasant possibility. He did recognize two new forms as specifically distinct, *F. magister,* a form from the Arnheim of Tennessee with very large corallites, and *F. undulata,* a species from the Plattesville with sinuous walls and undulating septa.

The only possible genotype for *Favistella* is *Columnaria alveolaris* Van Cleve. However reasonable the inference is that Van Cleve intended to identify his material with *Columnaria alveolata* Goldfuss, the conclusion is still an inference, and is not at this date capable of proof. Van Cleve's descriptions were never published. His plates, and presumably his manuscript, came into the possession of the Indiana Geological Survey, but apparently his specimens did not, for two emended summaries of his work appeared which were by no means in agreement with one another. White (1881-82) published the Van Cleve plates, but revised the text because, as he stated correctly, many of the manuscript species of Van Cleve seemed to have been described by other authors under different names. Among White's forms was one assigned to *Favistella stellata* Hall; this is what subsequent authors have taken for *alveolaris,* but that name does not appear anywhere in White's text. In the next year Hall (1882-83) published further descriptions involving White's plates and species. He included figures of *Favistina stellata,* one of which might have been a better drawing of the specimen figured by White, but other figures showing details are reminiscent of, and were quite possibly based upon, material figured earlier by Hall (1847) in the "Paleontology of New York," the original material of *Favistella stellata.* Hall did not mention the name *alveolaris* in connection with this Ordovician form at all, but in the same work he cites from the "corniferous limestone" of the Devonian *"Favosites hemisphericus* = *alveolaris* (Goldfuss) Van Cleve." It is not at all evident that Van Cleve's specimens were available either to White or to Hall, but it is interesting to note that Hall believed this species to be one from the Devonian and never thought of identifying it with the Ordovician *Favistella stellata.*

Obviously, *Favistella,* as defined and outlined by Bassler (1950), is a perfectly good Ordovician genus, but the question arises as to what it should be called. The problem is purely a nomenclatorial one. Three courses are possible: (1) a petition to the International Commission of Zoological Nomenclature to retain *Favistella,* applying it to an adequately known genotype; (2) the suppression of *Favistella,* its scope to be taken over by some other generic name already in existence; or (3) the proposal of a new name. It seems inadvisable, and indeed absurd, to request the International Commission to validate a generic name described in 1846, but which did not come into general use until about a century later. Indeed, it is only in the last 15 years that there was any serious work done in Ordovician corals, and one could hardly say that any generic name was in "general use"; rather, they all seemed to suffer from general neglect.

Other procedures seem possible under the former International Rules of Zoological Nomenclature, but these rules have been in the process of revision since about 1950, and so many revisions of the revisions have developed, that the best guide at present as to what the rules will be when they are finally adopted seems to be rumor not untinged with prophecy, and it seems inadvisable at present to attempt any very intricate proposals. In one sense, *Favistella* Dana is clearly based upon *Columnaria alveolaris* Van Cleve, and no other designation is possible. Inasmuch, however, as *Columnaria alveolaris* Van Cleve remains unpublished, the type is not known, and we can never be sure what the specimen really was, it could be argued that *Favistella,* having no published genotype, is actually without a genotype, no unpublished species having any standing as to availability. Under such circumstances the former rules, at least, held that the genus contained all the species fitting the generic description, and that a subsequent worker was at liberty to select a genotype from among the first species assigned to the genus. This procedure has always seemed a little odd, and results of application of this ruling have been, upon occasion, absurd and highly unsatisfactory, such as the excavation from a well-deserved oblivion of Plummer's *Aulacera* of 1843, and the suppression of the well-known *Beatricea* as a junior synonym. In this particular case the use of any early citations of *Favistella* is complicated. The same name was proposed, as already noted, by Dana in 1846, and by Hall in 1847, but most subsequent citations up to 1946 cite *Favistella* Hall; this is unavailable, being a junior homonym of *Favistella* Dana. That it was possibly a synonym also, is beside the point. Citations of Stumm (1948) and Bassler (1950) of *Columnaria alveolata* Goldfuss rest upon the assumption that *C. alveolaris* was a *lapsus calami* for that species; they are clearly not intentional designations. Indeed, with our present vague concept of the morphology of the species, and lack of knowledge concerning its original stratigraphic origin, such a designation would leave the species of *Favistella* still a horrible dilemma; actually, until the type is restudied, we would not be justified in assigning any other species to the genus.

Any reader can see that further pursuit of the problem could lead to almost endless discussion and argument; it may be questioned whether it would be worthwhile. Nine-tenths of the present investigation of the genus has been given over to a purely legalistic problem in nomenclature, and this is the sort of time-consuming labor with which no respectable paleontologist should have to be concerned. As Sinclair (1955) remarked in another connection, "After all, paleontology is a study of fossils, and not the study of the names of fossils." It seems far better to allow *Favistella* to die the natural death of a genus based upon an unknown species, and to start over again.

Is there a possible generic name proposed that could be given the scope of *Favistella?* Only one such possible genus is known, *Cyathophylloides* Dybowsky, based upon *C. kassariensis* Dybowsky 1873; Bassler (1950) has refigured sections of this species. *Cyathophylloides* is regarded as differing from *Favistella* in having long septa that meet in the corallite centers, twisting somewhat as they do so, and having also many more major and minor septa than *Favistella.* Further, it has tabulae that are strongly sinuate and arched upward prominently in the corallite centers. The genera have been recognized as distinct by Bassler (1950), Duncan (1956), and Hill (1956), and it seems better at this time to propose a new name with the scope of *Favistella* as used by these authors. In doing so, however, the writer feels that there is some degree of intergradation between these generic groups, and that it would not be surprising if future work should show more fully the advisability of increasing the scope of *Cyathophylloides* and suppressing the new name *Favistina* proposed below, as a junior synonym.

FAVISTINA Flower, n. gen.

Genotype: *Favistella undulata* Bassler, 1950

Cerioid corals, with walls of axial plates and sclerenchyme, the sclerenchyme extended as 10 or more primary septa of considerable length, but not completely joining at the centers of the corallites; minor septa may develop between major septa; tabulae generally horizontal, but irregular, some with edges narrowly downturned, some with slight median depressions, and some faintly arched upward.

Discussion. Favistina is little more than a new name for the group of Ordovician corals formerly included under the name *Favistella.* Under the heading of that name are summarized the nomenclatorial problems involved, which lead to the proposal of a new generic name; however, *Favistina* has essentially the scope of *Favistella* of Bassler (1950).

Foerstephyllum is differentiated by the shorter septa, which are commonly broad at the bases and wedge-shaped in cross-section; such septa range from septal ridges, with essentially smooth edges, to serrated septa and finally discrete septal spines, the last found only in the group of *F. vacuum,* a specialized late Ordovician group in which are forms trending toward *Paleofavosites,* losing septal spines and developing pores. *Favistina* has always long major septa, rarely extending less than halfway to the corallite centers; further, the species of *Foerstephyllum* most like *Favistina* in septa, the group of

F. halli, possess closely spaced and quite irregular transverse tabulae.

As noted under the discussion of the name *Favistella*, the genus *Cyathophylloides* is differentiated from *Favistina* in that major septa are long and join at corallite centers, twisting slightly as they do so, and that tabulae are prominently arched upward. At present, though there is some suggestion of intergradation, the usage of previous workers is followed in regarding *Favistina* and *Cyathophylloides* as distinct genera.

It was originally planned that the genus *Favistina* should be based upon *Favistella stellata* Hall; the species is abundant and is of known locality and horizon, coming from Madison, Indiana, where such corals are extremely abundant in the Saluda formation. Inquiry has failed, however, to locate the type of Hall's *F. stellata* in any institution known to contain parts of Hall's collections. It seems quite possible that in the years in which *F. stellata* was regarded as a synonym of *Columnaria alveolata* Goldfuss, that designation of the seemingly unimportant type may have been lost. With the view toward designating a neotype, some material was accumulated, including some specimens formerly from Hall's collection in the American Museum of Natural History. The material, however, was not uniform. It consisted of eight pieces under one number, at first believed to belong to a single colony, but after preparing sections from two of these pieces discrepancy appeared in corallite size and length of septa, and also some variation in tabulae, and it seemed wiser to avoid possible confusion that would develop, for at present it could not be demonstrated whether such variation could occur in a single colony or not; and if it could not, whether there were differences here that might later prove to be of possible specific or subspecific significance. It therefore seems better to delay this designation until more material can be studied, and preferably a type should be selected of a large colony, various parts of which had been fully examined by means of sections.

Favistella stellata proved rather unsatisfactory as a type for the genus. Therefore, it has seemed best to bypass this species, which would have had one real advantage: the name was proposed at an early date, and should future workers conclude to group together forms here regarded as distinct and valid species, always a tiresome possibility in view of confusion and varying opinions as to what should be recognized as species among the Paleozoic corals, the name would have a greater probability of remaining unchanged. *F. stellata* has one serious disadvantage; if both *Favistella* and *Cyathophylloides* are to be recognized, following current usage, the genotypes should be distinctive, and it is in those forms of the Richmond of the Cincinnati region, at present included in *F. stellata*, that the lengthening of septa and arching of the tabulae approach *Cyathophylloides* most closely.

Previous treatments of the species of the present genus (see *Favistella*, Bassler, 1950) have been colored by attempts to recognize the virtually unknown *Columnaria alveolata* Goldfuss. Since there is no very precise information available on this species, the only possible way it can be identified involves the assumption that it is to be defined in such general terms as to have very nearly the scope of the genus. Bassler (1915) cited most of the trivial names of forms falling under *Favistina* as here defined, as subspecies of *Favistina alveolata*. A few trivial names were regarded as synonyms of *alveolata*, but the species there treated as distinct are those that fall into other genera today, *C. carterensis*, which is a *Lichenaria* (Bassler, 1950), *C. halli* and *C. vacua*, now assigned to *Foerstephyllum*, and *C. stokesi* and *C. thomi*, phaceloid species now assigned to *Paleophyllum*. *Columnaria calicina* is the only *Favistina* there regarded as a distinct species. Later Bassler (1950) included the following trivial names as subspecies of *Favistina: Favistella alveolata calicina* Nicholson, *discreta* Foerste, *interventa* Foerste, *minima* Foerste, *minor* Bassler, *rigida*, Billings, and *stellata* Wilson. The only forms regarded as specifically distinct from *alveolata* are two then new species, *F. undulata* of the Platteville limestone, and *F. magister* of the Arnheim of Tennessee.

What is clearly needed is a complete revision of *Favistina* in the Ordovician of North America, but it became evident that although comparative materials were employed extensively, neither time nor materials permitted the extension of the present study to this length. Particularly needed is a critical reinvestigation of the seemingly generalized forms that have up to now been considered simple *Favistella alveolata*. Further, previously proposed trivial names must be investigated to determine whether they are applicable to groups of at least potential value as species. As usual, difficulties are encountered; namely, lack of precise information on types of these possible species and subspecies, and unavailability of some of the types, without which it is not possible to resolve some of the forms with certainty, necessary to attain stable nomenclature. At least, however, the present material shows something of the characters of some of the different intermittent and often isolated occurrences of the genus *Favistina* in a good part of the Ordovician in eastern North America. Information on forms from western North America in the literature is not at all precise; except for *Columnaria alveolata stellaris* Wilson (1926), no western forms have been named, described, or illustrated. *Columnaria blainvilli* Billings, formerly regarded as a synonym of *C. alveolata*, and *C. rigida* Billings, regarded as a subspecies, are not only good species but the first is probably, and the second is certainly amplexoid, and both are transferred to *Crenulites* and discussed under that genus.

Stratigraphically, our earliest *Favistina* is the form here described as *Favistina paleophylloides* of the Lowville, from Fourth Chute, near Eganville, Ontario. The occurrence is in a small downdropped block of Paleozoic in the dominantly Precambrian terrane, and the locality is about halfway between Ottawa and the larger and better known outlier at the Paquette Rapids of the Ottawa River. This form develops rather small nodular colonies, cerioid throughout most of their development, the tips of mature corallites, however, becoming round and free. This general sort of thing was called *Columnaria alveolata discreta* by Foerste, but his material is of late Black River age; ours is early. The only figures, those of Okulitch, who had material, typical in age, from the Paquette Rapids, are materially different. *Favistella discreta* requires further study from sections, and apparently there was never any designated type.

Reports of *Favistella alveolata* from Black River beds could not be checked from lack of material; the identification presupposes a perfectly cerioid type, with corallites about 4 mm across and major septa terminating well before they attain the corallite center. It seems possible that forms of this type may be related to *Favistina undulata* (Bassler), a species so far recognized only in the Platteville. It remains for future work to show whether there are several allied species here, or whether there is perhaps one, which might well be accommodated under *F. undulata,* with some emendation of our recognition of the scope of morphological variation in the species.

F. undulata (Bassler, 1950) is shown by the original description and illustrations to have 12-14 major septa, not joining at the center and somewhat undulate in cross-section, walls dominantly straight in cross-section, minor septa vestigial or wanting. The tabulae are dominantly horizontal, but some show edges and centers most faintly downturned.

Columnaria alveolata interventa Foerste, which Bassler assigned to *Favistella,* is based upon material that, from Foerste's original illustrations, includes (1) a probable *Crenulites,* (2) an evident *Saffordophyllum,* and (3) a form with such long and numerous septa that it seems better assigned to *Cyathophylloides* than to *Favistina.* The species requires revision; all material is from the Benson member of the Cynthiana limestone from near Brannon, Kentucky.

Favistina minima (Foerste), of the Millersburg member of the Cynthiana, is a distinctive form, but one hovering close to *Cyathophylloides* in the long septa; tabular arrangement has not been described.

Favistina minor (Bassler), of the Carters and Hermitage of Tennessee, is rather generalized in the short major septa and transverse but irregular tabulae, and is distinctive mainly for its small corallites. It seems, however, a valid species.

F. stellaris (Wilson), of the Beaverfoot formation of British Columbia, is a potentially valid species, but available information falls short of our present requirements for comparison at the specific level.

Favistella calicina (Nicholson), formerly differentiated by colony form, corallites tending to become free and circular in section, is here studied from sections; septal and tabular features indicate it to be a distinct species.

F. magister was described by Bassler (1950) from the Arnheim of Tennessee; in the present work there is described a second specimen, this time from Madison, Indiana, and probably from the Saluda beds there; the known geographic and possibly the stratigraphic range of the species are increased.

A form from the Whitewater of Weisburg, Indiana, notable for crenulate walls and somewhat twisted septa, and reminiscent of *F. magister* though having smaller corallites and rather different tabulae, is described as *F. crenulata.*

A problem requiring further investigation is that surrounding the forms with corallites 4-5 mm across occurring in the late Richmond of the Cincinnati arch. Hall's species *Favistella stellata* is included in this material, but our few colonies show variation, and it is not certain, though we include them temporarily under *F. stellata* (Hall), whether there is a single rather variable species here or whether slight differences in corallite size and length and number of major septa, and possible differences in the tabulae, may indicate the presence of more than one form here, curiously, the colonies from the Bardstown coral reef of the Liberty of Kentucky commonly show smaller corallites with major septa which are longer and, on the average, more numerous, than are those of the forms developed in the Saluda, though future work may show these differences nonuniform.

Favistina stellata Hall

Pl. 38, 39, 40 (pars)

Favistella stellata Hall, 1847, Paleontology of New York, v. 1, p. 275, pl. 75, fig. 1a-c.

Columnaria alveolata Bassler, 1915, U.S. Nat. Mus., Bull. 92, v. 1, p. 258 (Includes intervening references under both *alveolata* and *stellata.*)

Favistella alveolata (pars) Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 271, pl. 16, fig. 13.

As at present conceived, this species is based upon material from the type locality and horizon the Saluda beds of Madison, Indiana, but includes material widely present in the late Richmond of the Cincinnati arch, and includes material from the Liberty near Bardstown, Kentucky. As noted under the discussion of the genus, material from the Cincinnati arch shows some variation, but it is not certain as yet whether there is more than one form here deserving of specific or subspecific recognition, or whether actually a single variable species is involved. It has also been noted that although *Favistina stellata* is raised from its long oblivion, having been considered a synonym of the unknown *Columnaria alveolata* Goldfuss, it still remains, Hall's type being apparently lost, to reestablish the species on the basis of a neotype. It was intended to accomplish this task now, but our topotype material consisted of one small part of a colony, and several pieces from the Hall collection of the American Museum. These last showed such variability in features commonly important at the specific level, such as corallite size, length and number of major septa, prevalence of minor septa, and the spacing and configuration of tabulae, that it seemed wiser to delay this task, for it is not certain that these parts represent a single colony; if they should prove to represent different species, such a step would be of little value. It is hoped to continue the present study later with examination of more material from the type locality, preferably using as a neotype a large colony adequately studied with reference to possible variation of these features from early to late growth stages.

As presently conceived, corallites are cerioid, ranging in diameter from 4 mm to 5 mm; there are 10-14 major septa, some colonies showing dominantly 11, others 12, 13, and 14. Minor septa are always short, but variable, being commonly present between pairs of major septa in some colonies, but in others there are only rare stubs, usually not more than one or two in a corallite section. Septal edges are plane in general, some showing only the faintest crenulations. Tabulae, always irregular and variable in any appreciable section of a colony, vary from transverse to those with edges slightly downturned; others with similar downturned edges are slightly depressed centrally. Some are arched upward slightly; forms with such arching and rather long major septa approach the condition of the genus *Cyathophylloides.*

At present the most useful purpose can be served by discussing individually several occurrences and several morphological variations included under this species.

1. FORM FROM MADISON, INDIANA

Pl. 38, fig. 12, 13

Of this form only a small piece of a colony was available. It shows subparallel corallites that range in diameter up to 5 mm across, a slightly larger range than most others, which average 4.0-4.5 mm. Cross-sections commonly show 12 major septa, which extend about halfway to the center; septal tips are always free. Minor septa are only short stubs between major septa when present; commonly only one or two are present in a corallite; some sections show corallites with none.

Tabulae range from simple and transverse to those with downturned edges; some show centers that are faintly and broadly depressed, but relief is slight. Eccentric sections show tabulae pulled forward slightly where they intersect septa. Commonly four tabulae occupy 5 mm, but there is one crowded zone, only 6 mm long, in which 9 occur in that length. The spaces between tabulae vary from 0.5 mm to 1.5 mm, but most average 1.0 mm. NMBM No. 743, from the Saluda beds, Madison, Indiana.

2. FORMS FROM THE CUTTER OF TANK CANYON, NEW MEXICO

Pl. 38, fig. 1-8, 10, 11

Corallites are commonly 5 mm across, showing in section commonly 12 rather short septa, extending little more than halfway to the center. Minor septa are rare and very short when one or two are present in a corallite. Major septa vary in number and length, showing in some sections tips that extend quite close to the center, but tips are never joined even in small groups. Septa up to 14 in number are not uncommon, and one individual shows 17. Tabulae are irregular in spacing, but there are no regular zones of crowded tabulae. Tabulae average 6 in 5 mm, somewhat closer than in the greater part of the preceding form. Tabulae may be transverse and may have downturned edges, and some may have centers depressed as well as the edges. Relief is slight; downturned edges are broader than those of the preceding form.

We have a number of colonies of this form, which are silicified and have been removed from the matrix by etching. Such colonies include a number that were relatively young, and these show rapid, almost conical expansion of the initial calyces, which range slightly larger than those of later, more typical parts of corallites. The etched specimens show major septa clearly, and minor septa as only faint lineations on the inside of the corallite walls. Surfaces show septal striations and fainter transverse, irregular rugose markings. Interestingly, tabulae are not evident in the etched specimens; they do not retain their relief on etched surfaces. However, a longitudinal section was made (pl. 38, fig. 6) that shows them quite clearly.

This form is quite abundant in the coral beds of the Cutter formation in Tank Canyon. A small fragment was found in the "blue limestone" of the Cutter in the Mud Springs Mountains, but the form has not been observed at other localities.

Figured specimens are NMBM No. 695-698; several small individuals are included under the last number.

3. SPECIMENS FROM THE SALUDA OF MADISON, INDIANA

Pl. 39, fig. 4-8

The American Museum of Natural History, in a part of the collection purchased from James Hall, has eight pieces from Madison, Indiana. It is not impossible that this was part of the material upon which the description of *Favistella stellata* was based, but if so, no record exists, and of the original illustrations two are diagrams of the surface of colonies, such illustrations as one could scarcely hope to identify. A third figure is a side view of a broken piece of a colony; in shape, this cannot be matched from our material.

Sections were made from two pieces; they show variation in corallite size and septal length, giving rise to wonder as to whether, as was at first supposed, all the pieces came from one single large colony. One piece (pl. 39, fig. 4-5), is figured unsectioned and in natural size. A comparable piece, quite probably from a relatively early portion of a colony, yielded the sections shown on Plate 39, figures 6 and 8. Figure 8 shows corallites with short, regular major septa, like those of our No. 1 described above, but corallites range from 4.0 mm to, rarely, 4.5 mm in diameter. A longitudinal section from the same piece (pl. 39, fig. 5) shows tabulae commonly 4-5 in 5 mm, but showing great variability in form and spacing, some being strongly curved down, other curved up, some transverse with downturned edges, and other sinuate, depressed at the edges and again at the centers.

Sections from a piece representing the top surface, evidently of a very large colony (the piece is 170 mm across), show corallites ranging as a maximum from 3.5 mm to, rarely, 4.0 mm across (pl. 39, fig. 7). Major septa are consistently long; their tips are joined in irregular groups of twos, threes, and fours close to the center, but perfect fusion is not attained. Minor septa are short, but regularly present between each two adjacent major septa; walls are somewhat crenulate. In longitudinal section tabulae are 4-9 in 5 mm, ranging in form again from transverse to those with downturned edges, and to others with the centers slightly depressed in addition to the edges, but there are a few that are gently arched upward.

The colony, or parts of colonies, is AMNH No. 1168/1, from Madison, Indiana. The coral is somewhat silicified.

4. SPECIMENS FROM THE LIBERTY, NEAR BARDSTOWN, KENTUCKY

Pl. 39, fig. 1-3, 9, 10; pl. 40, fig. 7-9

Three colonies from the Bardstown coral reef differ slightly, but in general show rather small corallites, rather long major septa, and a general development of minor septa. Tabulae vary, the limits of variation being much like those of the Saluda forms, but there is a more general trend toward faint arching upward.

One colony, NMBM No. 744 (pl. 39, fig. 9-10), differs from the others from the Bardstown reefs and agrees with our first specimen from the Saluda at Madison in the rather large size of the corallites, which commonly attain a diameter of 5 mm and may be slightly larger in one direction. Septa extend more than halfway to the center, their tips commonly irregularly joined in twos and threes. Commonly, but not uniformly, there will be one septum conspicuously longer than the others, with those on either side of it a little shorter than the others, thus emphasizing the contrast, but all corallites do not show this condition. Major septa commonly 12-14 in number, corallites with 13 or 14 septa quite common. Minor septa generally present, but only as short stubs, their length less than the thickness of the sclerenchyme from which they extend. Tabulae fairly uniform in spacing, 5-6 in 5 mm, the distance between them commonly 0.9 mm to 1.4 mm, without definite crowded zones. Tabulae show slight relief, varying from transverse to those with downturned edges; tabulae may be arched, transverse, or depressed centrally.

Another colony, NMBM No. 778 (pl. 39, fig. 1-3), shows corallites commonly 4 mm and, less commonly, as much as 4.5 mm across. Major septa commonly range 10-12 in large corallites, but 13 have been seen; their tips lie closer to the center than in the preceding form, joining in irregular groups of twos and threes; a single exceptionally long septum is only most rarely evident. Minor septa commonly present, length less than the thickness of the sclerenchyme, walls slightly crenulated. Longitudinal sections show tabulae commonly 4-5 in 5 mm, generally rather widely and fairly uniformly spaced, but with local zones of crowding, which are not uniform laterally throughout any considerable series of corallites. Tabulae generally transverse, with slight downcurved margins, narrow when developed; centers transverse or with a median depression, which may, in this form, become quite marked. To the left of the lower center in Plate 39, figure 1, are some conspicuously downturned tabulae; indeed, one bends down from the sides, joining the preceding tabula.

Another colony from the same locality, NMBM No. 779, shows corallites ranging commonly up to 4.5 mm across, ranging slightly larger than in the preceding form. Major septa 12-14, rarely fewer in large individuals. Septa join irregularly at their tips, but range a little shorter than in the preceding form; the presence of one long septum is apparent in perhaps half of the corallites in our several sections. Minor septa generally developed, but short, vestigial thickenings of convexities in the crenulate walls in many cases. Tabulae vary from 4 to 8 in 5 mm and are generally transverse, but downturned narrow edges are not uncommon, nor are broad, shallow central depressions, but the relief shown is much less than in the preceding colony.

Present observations are regarded as not sufficiently extensive, but it is of interest that the Liberty forms show in general rather small corallites with rather long major septa, whereas the Saluda forms show variation in two directions, one toward slightly larger corallites with consistently shorter major septa and more irregular tabulae, the other to smaller corallites, down to 3.5 mm, with the major septa long. In both, minor septa are highly variable, but in the larger form they are more generally absent than present; it is this larger form that our single Montoya species from the Cutter formation resembles most closely. One could also suggest that our Aleman species, which is closer stratigraphically to the Liberty occurrence than any other, is not distantly related; it is placed in *Cyathophylloides*, but septa are only a little longer than in the Bardstown coral reef forms, though the tabulae are arched upward consistently more definitely and uniformly.

Favistina magister (Bassler)

Pl. 40, fig. 1-6

Favistella magister Bassler, 1950, Geol. Soc. Am. Mem. 44, p. 273, pl. 16, fig. 5, 6; pl. 18, fig. 19, 20; pl. 19, fig. 11

This species has typically large corallites as much as 10 mm across, in nodular colonies 5 cm high and 10 cm across. Walls are undulate or crenulate; 12 major septa extend close to the center, but their tips do not join; minor septa are quite long, more than half the length of the major septa; both tend to be undulate. Tabulae are simple and horizontal, unusually regular for the genus, occurring 4-7 in 5 mm. The typical material is from the Arnheim beds of Tennessee.

A specimen from the Saluda of Indiana is here figured and described. The colony is small, 45 mm high and 70 mm across; corallites large, ranging up to 9 mm across, rarely more, but one attains 11 mm, though only in one direction. Major septa commonly 14 in number, their length more uniform than the corallite diameter; they extend no more than halfway to the center in the larger corallites, but meet, joining in small irregular groups in the smaller corallites. Minor septa generally developed, but shorter than in the typical material, less than half the length of the major septa.

Tabulae are spaced 3-6 in 5 mm, the distance between them varying from 0.8 mm to 2.0 mm, but spacing is irregular and without definite crowded zones of tabulae. Tabulae are transverse, some with edges and centers downturned, but relief is slight, and variation in both form and spacing of tabulae is much less than is general within the genus. Septal edges are uniform, without serrations; corallite walls are essentially straight, lacking crenulations.

Discussion. This colony agrees with the type of *F. magister* in the very large corallites and the relatively regular and transverse tabulae. It differs in some points; namely, walls are not strongly crenulate, major septa are slightly more numerous, and minor septa are shorter, but these are variations well within limits noted in individuals of other species. The form is of interest in extending the range of *F. magister* from the Arnheim of Tennessee to the Saluda of southeastern Indiana. *Favistella cerioides* Hill (1942), from the Chudleigh limestone of Tasmania, is rather similar to *F. magister*, but corallites range smaller, not exceeding 7 mm across; major septa are commonly 18, more numerous than in the American species; tabulae are closer, 10 in 5 mm.

Our American forms with large corallites that are most similar to the forms discussed above are *F. calicina* (which has more numerous and more strongly undulate major septa but much shorter minor septa, and tabulae that are much more sinuous and more closely spaced) and the Lowville *F. paleophylloides* (in which corallites range smaller, tabulae are more irregular, minor septa are relatively shorter, and major septa are 14 in number). These two forms are not dissimilar in aspect. Both of these forms develop free, rounded corallites, unknown in *magister*.

Figured specimen. AMNH No. 1168/2; this is from the James Hall collection and was formerly regarded as *stellata* or as *alveolata*.

Occurrence. From Madison, Indiana, in the Cincinnatian. Lithology, strong silicification, and experience indicate that it is quite certainly from the coral beds of the Saluda.

Favistina crenulata Flower, n. sp.

Pl. 41, fig. 3, 5-9

This form has corallites commonly 5-6 mm across, rarely 7 mm, being intermediate in size between *F. stellata* and *F. magister*. Corallite walls are strongly crenulate; 12-14 major septa in the larger corallites, rarely as many as 17; they are relatively long and straight, tips generally free, but occasionally joined in groups of twos and threes. Minor septa as broad as the major septa basally, very short, scarcely ever longer than the width of the sclerenchyme from which they extend. Tabulae variable, commonly 4 in 5 mm, but as many as 7 in that length locally; zones of crowding are poorly defined and nonuniform laterally. Our two sections (pl. 40, fig. 3 and 9) show wide contrast in spacing and form of tabulae. In general, the downturned edges, when contrasting with a central median or depressed region, are relatively broad, but some are arched upward, others downward (pl. 40, fig. 3). The type colony is small, with corallites 40 mm long and 60 mm across.

Discussion. In size, corallites are intermediate between those included in *stellata* and those of the larger *magister*. In spacing, considerable relief, and irregularity of tabulae, this form is closer to *stellata,* but is distinctive in the strongly crenulate walls and persistent minor septa with conspicuous bases; interestingly, the larger forms of that species tend to have major septa relatively short.

Type and occurrence. The single holotype, NMBM No. 736, is from the Whitewater beds of the Richmond, from Weisburg, Indiana.

Favistina discreta (Foerste)

Columnaria alveolata-discreta Foerste, 1914, Cincinnati Soc. Nat. Hist., Jour., v. 21, p. 124.

Columnaria discreta Okulitch, 1938, Royal Soc. Canada, Trans., ser. 3, v. 32, sec. 4, p. 106, pl. 1, fig. 1-2.

Favistella alveolata discreta Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 272.

Foerste described this form only very briefly, as follows: "*Columnaria* of the *alveolata* type makes its first appearance in the upper part of the Black River limestone, at Ottawa and also on Cloche Island, in Ontario, Canada. In these Black River forms the corallites are very large, often reaching a diameter of 7 mm., and have a tendency to be discrete, with rounded corallites." No type is designated, and only by inference could a topotype from Ottawa be considered more valid than specimens from Cloche Island.

Okulitch figured under this name, giving the form specific rank, a specimen from the Paquette Rapids beds of the Ottawa River. This is a portion of a colony showing phaceloid corallites, some touching each other and evidently more closely connected at the base, but corallites here attain only 5 mm in diameter.

Curiously, material that comes closer to Foerste's very general description is at hand. Whereas Okulitch's specimen is from the Paquette Rapids beds, which Cooper and the writer, as well as Foerste, consider highest Black River rather than lowest Trenton, this other form is from beds of Lowville age; neither are topotypes, and our specimens are certainly older than Foerste's material, which he specifically states is of late Black River age. Until a type locality can be agreed on and a type selected from topotype material, the species simply cannot be recognized, and it seems far wiser to describe the Lowville form under a new name, designating a proper type and illustrating it, than to increase the concept of the diversity of forms included under Foerste's trivial name.

Favistina paleophylloides Flower, n. sp.

Pl. 42

This form develops rather consistently small, slightly depressed nodular colonies, our figured form being typical, 50 mm across and 30 mm high. In early stages the colony is quite perfectly cerioid and develops corallites 5-6 mm across, but in the distal part of the colony, never for a length greater than 5 mm, and commonly less, corallites become rounded and free, and show a marked reduction in diameter, ranging from 4 to 5 mm across, the edges becoming slightly but conspicuously scalloped in conformation with the septal insertions. Major septa commonly number 14-15 in larger individuals, in many cases extending two-thirds the distance from the sclerenchyme to the center; the distal third of the major septa is commonly bent or undulate. In smaller individuals septa commonly extend close to the centers, their tips irregularly joined in small groups. Minor septa generally present, their length commonly less than the sclerenchyme thickness. Tabulae are quite irregular, tending to anastomose in places, but lacking well-defined zones of crowding; they recall those of the younger *calicina,* but show less extreme relief.

Discussion. The development of corallites that are cerioid for about 30 mm of their length and then the occurrence of a short free interval of 5 mm or less in which corallite diameter is rather abruptly reduced, are characteristic of the association and of the species. Comparison with typical *discreta* is impossible until that species can be reestablished, but as conceived by Okulitch, it has slightly smaller corallites, and the phaceloid region is developed over a longer corallite length.

F. calicina forms much larger colonies in the Richmond; corallites are larger and fail to show marked size reduction when they become free; major septa are more numerous, more strongly undulate, minor septa longer; differences in the variable tabulae are necessarily slight and general, but those of *calicina* show slightly more relief and a more general tendency to anastomose.

It is of interest that this may be considered a *Favistella* that is becoming a *Paleophyllum* by proponents of the biogenetic law, and as a *Paleophyllum* that is becoming a *Favistina* by advocates of proterogenesis. Actually, although there is reason to believe that the cerioid corals are primitive in general, and although the former interpretation seems the more logical of the two, this is not only the oldest species showing any features of *Paleophyllum,* but is also the oldest *Favistina* of which I have been able to discover any indication.

Types. Holotype, NMBM No. 735; figured paratype, No. 794.

Occurrence. From the Lowville beds of Fourth Chute, near Eganville, Ontario.

Favistina calicina (Nicholson)

Pl. 40, fig. 1-6

Favistella (Columnaria) calicina Nicholson, 1874, British Assoc. Adv. Sci., Rept. 44th Meeting, notes and abstracts, p. 89.

Favistella calicina Nicholson, 1875, Rept. Province Ontario, pt. 2, p. 24, fig. 9.

Columnaria calicina Bassler, 1915, U.S. Nat. Mus. Bull. 92, v. 1, p. 259. (Contains intermediate references.)

Favistella alveolata calcina Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 272.

The following description is based on a colony from Streetsville, Ontario:

Colony massive, large, the present specimen 130 mm across and 70 mm high, the top somewhat flattened; corallites show a maximum length of 85 mm, those at the surface free and rounded for only a short anterior distance, those at the sides tending to become free and rounded at the outer third of their length.

Corallites large, the largest observed being 7.5 mm in one direction, 9 mm in the other; the early part of the colony is imperfectly cerioid, there being large patches filled with matrix, but free corallites rounded in section are general only in the outer part. The larger corallites show commonly 16-17, rarely 18, major septa, commonly slightly undulate. Septal length is less variable than corallite size; in smaller individuals septa may join in irregular groups near the corallite centers; in larger individuals septa are free and extend rarely more than halfway from the sclerenchyme to the center. Minor septa are generally present, their length about twice the thickness of the sclerenchyme, but less than half the length of the major septa; as long in small as in large individuals; walls commonly but not universally crenulate in cerioid portions, generally but slightly crenulate in phaceloid stages.

Tabulae vary in distance from 0.5 mm to 2.0 mm, 7-9 occurring in 5 mm; spacing generally irregular, but without definite crowded zones; adjacent anastomosing tabulae are not uncommon. Sections attaining the corallite centers show tabulae generally sinuous, having broadly downturned edges, and generally but not universally downcurved centers, a pattern suggestive of the sutures of *Gonioceras*.

Discussion. Though the description is based upon topotype material that we have every reason to consider typical, there must be some reservation in assignment until the type is studied from sections. Our knowledge of this form from previous descriptions is rather general, being based primarily upon the general aspect of the colony. Bassler (1950) cites the form not only from the Richmond of Ontario and Cape Smythe, Lake Huron, but also from the Cincinnati arch. That the available Cincinnati material has contained nothing that seems typical of this species is hardly conclusive.

Figured specimen. NMBM No. 792, from the Richmond of Streetsville, Ontario.

CYATHOPHYLLOIDES Dybowski

Genotype: *Cyathophylloides kassariensis* Dybowski

Cyathophylloides Dybowski, 1873, Archiv Naturkunde Liv-, Est-, und Kurlands, ser. 1, v. 5, pt. 3, p. 334, 379.
——— Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 274.
——— Duncan, 1956, U.S. Geol. Surv. Bull. 102-F, expl. of pl. 24, fig. 6.

Cerioid corals with 12 or more, commonly 14 or more, major septa meeting at the corallite center, commonly twisting slightly, tabulae arched upward. As at present understood, this genus is similar to *Favistina* in general aspect, differing primarily in the long major septa fused at their tips and the uparching of the tabulae. In *Favistina,* major septa are commonly shorter, and at the most they may join irregularly in groups of twos, threes, and fours at their tips. Tabulae are highly variable, being transverse with slightly downturned edges, centers may be transverse or downturned, but uparching is not a consistent or general feature. The genera are unquestionably related, and it may be, as noted under *Favistina,* that future work will indicate that they are better united, but in regarding them as distinct, previous usage is being followed here, for although the species approach one another, there is not clear intergradation. *Favistina* as it is now known ranges from lower Mohawkian to the top of the Ordovician; *Cyathophylloides* appears later in the Ordovician, but passes up into the Silurian, where, indeed, species differ widely in aspect from *Favistina,* having more numerous major septa and tabulae that are strongly sinuous, well arched, and commonly anastomosing.

The genotype is from the island of Kassar, from which its specific name is derived, near Dago Island, Esthonia, from zone 5 in the Ordovician. The present species, *C. burksae,* is from the coral zone of the Aleman, probably of Waynesville age; another fragment, figured but unnamed, is from the Cutter beds of late Richmond age. These are the only forms in North America so far described certainly assignable to *Cyathophylloides.* Bassler's *C. ulrichi* proves to have the amplexoid septa and crenulate, downturned tabular margins of typical *Crenulites.* Part of *Columnaria alveolata interventa* Foerste is possibly *Cyathophylloides,* as already noted, but other specimens of the syntypes figured include a probable *Crenulites* and a *Saffordophyllum.* (See Foerste, 1914, pl. 4, fig. 1e.)

Cyathophylloides burksae Flower, n. sp.

Pl. 43; pl. 44, fig. 1-5

Colony cerioid, with corallites ranging as a maximum from 3.5 mm to 5.0 mm. The type colony shows corallites commonly ranging from 3.5 mm to 4.0 mm, less commonly up to 4.5 mm, and rare individuals (No. 680) measuring 5.0 mm in one direction, but there is variation, in another colony corallites range from 4.0 mm to 5.0 mm. Major septa range from 10 to 12 in number, 11 septa being most commonly found. They reach the center and in the holotype are regularly joined; in forms with larger corallites, the fusion is less perfect, septa joining in irregular groups, but generally the groups touch one another. Minor septa quite generally present, varying from short stubs to those nearly half the length of the major septa.

Tabulae are generally arched upward; commonly the arching is general, but the form of the tabulae remains highly variable, and some are shown tranverse centrally and downturned at the edges very much as in *Favistina.* The arched tabulae are, however, the more common of the two types, which, of course, show some intergradation. Tabulae show rhythmically repeated zones of crowding. The holotype shows a zone of distant tabulae, averaging 5 in a length of 5 mm over a 7-mm interval, a short crowded zone with 8-9 tabulae in the same length, extending for 6 mm, a second zone of distant tabulae 6 mm long, a second crowded zone of 4 mm, and a final, incomplete zone of widely spaced tabulae. The zonation seems uniform in the species.

Corallite walls show a dark axial plate with fibrous sclerenchyme on either side. Under replacement by silica (pl. 44, fig. 4, 5) the texture of the sclerenchyme is altered, but the axial plate commonly retains its identity. In calcitic portions (pl. 40, fig. 1-3) the axial plate varies in appearance, being apparently broken up into short, discrete vertical planes in some places, but continuous in others. Here the fibrous nature of the sclerenchyme is indicated, though imperfectly, and in some places (pl. 40, fig. 3) it appears locally broken up into trabecular units; this is believed to be the result of recrystallization, as all of the material is somewhat altered, the original limestone showing general dolomitization, though sometimes slight where silicification has not first occurred.

Discussion. Duncan (1956) has indicated the presence of corals with long, centrally joined septa and arched tabulae in western Ordovician faunas, but so far no such species have been described. None is known in eastern Ordovician faunas. It is perhaps of interest that this species occurs not in Red River faunas, but only in the Aleman, in a horizon probably of Waynesville age. Curiously, there is some slight parallel between the occurrence of this *Cyathophylloides* in the Aleman and true *Favistina,* resembling closely a form found in the Saluda, in the Cutter. Although the form in the Liberty beds of Kentucky is not a true *Cyathophylloides,* it shows in general longer septa and tabulae with more relief, and though somewhat similar forms continue into the Saluda, the Saluda remains the only source of forms with consistently short major septa and tabulae of less relief and variability in form.

At the extremity of one colony, No. 681 (pl. 43, fig. 5), are found some corallites that have become free and rounded, but the condition has not been observed elsewhere and is not generally evident in specimens of this species.

The species is named for Mrs. Garnett R. Burks, for many years secretary of the New Mexico Bureau of Mines and Mineral Resources.

Types. Holotype, NMBM No. 680; paratypes, No. 671-684.

Occurrence. From the coral zone of the Aleman formation of the Montoya group. The types are from the northern Franklin Mountains, but the species has been found also at the southern end of the mountains at El Paso.

Cyathophylloides(?) sp.

Pl. 38, fig. 9

Under this designation is figured a small silicified part of a colony, a bit of a surface with a maximum length of only 22 mm. The corallites on the surface show a maximum diameter of 4 mm, considerably smaller than those of the associated *Favistina stellata.* The 14 major septa meet or nearly meet in the center, as in *Cyathophylloides;* secondary septa are present, but uniformly short, one-fifth to one-sixth the length of the primary septa. A lateral view shows the corallites to be subparallel; it is not, however, evident whether they are the distal part of a rather large colony, or whether they are short corallites, subparallel in growth, as appears to be true of most of the *Cyathophylloides* of the underlying Aleman beds. There is only a suggestion of one tabula seen in the fragment; this appears to be arched gently, uniformly, and rather broadly upward from the sides to the center.

Discussion. The corallites of this form range very slightly smaller than those of the Aleman *Cyathophylloides burksae,* but it may well be that species. The one specimen from the Cutter is really insufficient to show limits of variation in its colony or to give a very good idea of form and spacing of the tabulae, but is here noted as the only indication of *Cyathophylloides* in this horizon.

Figured specimen. NMBM No. 795.

Occurrence. From the coral bed of the Cutter, Tank Canyon, about 12 miles northeast of Hillsboro, New Mexico.

CRENULITES Flower, n. gen.

Genotype: *Crenulites duncanae* Flower, n. sp.

This is a colonial cerioid coral with thin, solid axial plates and thick fibrous sclerenchyme of the "rugosan" type. It is essentially an amplexoid edition of *Favistina,* with the added feature of tabulae downturned at the edges and scalloped, being turned down most strongly between the septa. Major septa commonly 10-12, alternating minor septa very short. There is wide variation in the rapidity with which the major septa contract when traced forward from a septal surface; in *C. duncanae* and most other species the septa shorten rapidly and are not apparent at the anterior end of a space between tabulae, but in *C. rigidus* (Billings) the major and minor septa are narrowly continuous, though the former are mere vestiges and the latter only the faintest stumps.

Discussion. Though the genus grades into *Favistina* through *C. rigidus* on the basis of the amplexoid condition of the septa, there is no corresponding gradation in the character of the tabulae.

The genus is at present known from *C. duncanae* and *C. magnus* from the Second Value formation of the Montoya group, from *C. ulrichi* (Bassler) of the Maquoketa shale of Iowa, from *C. rigidus* (Billings) and *C. blainvilli* (Billings) from the "Richmond" of Snake Island, Lake St. John, Quebec, and from *C. akpatokense,* a form very similar to *C. magnus* of the Second Value formation, from the lowest horizon with an associated fauna of Red River aspect on Akpatok Island. Sections of favistinid corals from the Richmond of the Cincinnati Arch and from southern Ontario, which, together with some of the above forms, have long been grouped as *"Favistella alveolata,"* are true *Favistina,* and no truly amplexoid forms have been found in those associations.

Cross-sections of *Crenulites* present a weird variation, depending on the position of the section in relation to the tabulae, with their crenulate, downturned edges, and in relation to the septa, for the major septa may extend almost to the corallite center as faint ridges on the anterior faces of the tabulae, but shorten rapidly as they are traced forward and commonly disappear before the level of the next tabula is attained. Anyone not prepared to encounter such a thing in Ordovician faunas may well wonder, as I did, whether he is losing his eyesight, his mind, or both. Longitudinal sections show variation in the downturned edges of the septa, depending on the position of the section in relation to the edges of the septa; near or at septa the downward inclination may be only slight, but between them it is most pronounced. Also, a centrally located section may show no septa whatsoever, but as sections approach closer to the corallite walls, the septa are seen increasing in length, and close to the wall they apparently double in number, for the section encounters the secondary septa, which are usually extremely short.

Foerste (1914) included among the figured syntypes of *Columnaria alveolata interventa* what appear to be representatives of three distinct genera. One (his pl. 4, fig. 1a, b, c, d, g, and possibly also h and i) shows indication of amplexoid septa between which tabular edges are downturned and scalloped; the features are typical of *Crenulites,* though confirmation from study by sections is desirable. Other forms include a *Saffordophyllum* and a form with long septa, apparently a *Cyathophylloides,* noted in the discussions of those genera.

Crenulites duncanae Flower, n. sp.

Pl. 16, fig. 1 (pars); pl. 19; pl. 20, fig. 1-5

Cerioid, colonies often large; length observed 120 mm, and over 180 mm across. Corallites polygonal, commonly irregular, typically 3 mm across, rarely as much as 4 mm, though with a scattering of smaller, obviously young corallites. The amplexoid septa and the crenulate downturned edges of the tabulae combine to produce widely varying aspects among the individuals as seen in any cross-section. Major septa vary in number from 8 to 12, and extend almost to the center in sections close to the anterior faces of tabulae, where the maximum length of the septa is developed. Minor septa cannot be seen at all in most cross-sections, but their position is marked quite commonly by a division in the crenulation of the tabulae.

Tabulae very irregular in spacing, but commonly more crowded near the anterior ends of the colonies, with 8-10 tabulae in 5 mm basally, 10-14 distally. Centrally the tabulae are transverse, but are downturned at the edges, being most strongly turned down between the septa. In a longitudinal section that passes obliquely from the corallite center toward an edge, the central, transverse part of the tabula is marked by short prolongations (the amplexoid septa) on its anterior surface, and in more eccentric sections the tabulae, become zigzag as the marginal, crenulate portion is approached, with the convexities prolonged as amplexoid septa; except, however, where the most extreme crowding occurs, the septa remain discrete and are not continuous from one tabula to the next.

In high magnification the sections have presented a somewhat puzzling aspect, which is largely due to the peculiarities of preservation, which often leave the thin common walls prominent, but the sclerenchyme may be obscure and differentiated from calcite in the corallite only with difficulty. In rare cases the thin, dark, common wall appears to be double (pl. 19, fig. 2). The septa are typically extensions of the sclerenchyme (pl. 19, fig. 5) but some sections may show the septa as dark bands, apparently extensions of the common walls, as in Plate 19, figure 6.

Discussion. This is a common form in the Second Value in the southern Franklin Mountains; indeed, in the vicinity of El Paso it appears to be the commonest of the cerioid corals in that horizon. Megascopically, it is rather difficult to distinguish it from *Trabeculites keithae,* which resembles it rather closely in corallite size, and the slightly smaller *Saffordophyllum newcombae* can be confused with it also. Preservation is such that, particularly where the calcite is somewhat weathered, the long amplexoid septa may not be visible megascopically, though they can be seen clearly in the best preserved material. When corallites are filled with white, rather opaque calcite, it may be necessary to resort to thin-sections for the distinction of this form. *C. magnus* is a related form, but one readily distinguished by the much larger corallites and the general tendency toward irregular growth.

Sections show a bewildering variation of aspects. If transverse sections are taken through a region where tabulae are distant, as at the base of Plate 19, fig. 12, it is possible to obtain sections that fail to show the downturned edges of the tabulae at all, and the septa may be vestigial or wanting in sections taken well anterior in the space between two tabulae.

Types. Holotype, NMBM No. 671; paratypes, No. 672 and 673. All are from the upper, impure part of the Second Value formation, above the calcarenite, from near the crest of the Scenic Drive, El Paso, Texas.

Occurrence. This species has been observed as yet only in the Second Value formation of the Franklin Mountains. The types, as noted above, are from El Paso.

Crenulites magnus Flower, n. sp.

Pl. 33, fig. 1-5; pl. 45, fig. 13

This *Crenulites* has large corallites, commonly 5 mm across; individuals 6 mm across, at least in one direction, are not uncommon. Major septa are amplexoid, reaching nearly to the center, but not quite as far as in *duncanae;* they are, as is usual, difficult to estimate as to number from sections, but there appear to be commonly 12 to 14 in the larger corallites. Minor septa are apparent, which, where the major septa are long, are half as long, extending more than one-third the distance from the edge to the center of the corallite. Major septa are commonly somewhat longer extensions vertically on the anterior faces of the tabulae than in *C. duncanae;* they are long, occupying more than half the distance between tabulae at the margins, but are clearly not continuous, for in some cross-sections the septa cannot be seen at all.

Tabulae are transverse centrally, strongly downturned at the edges, scalloped, and most strongly downturned between the septa. Tabulae occur 6 or 7 in a length of 5 mm, the number in that interval increasing to 8 in zones where the tabulae are crowded.

Our four colonies are all incomplete. Corallites 55 mm long have been observed, but they probably grew considerably longer. Rather loose, irregular growth of the colony is not uncommon. It is quite characteristic of this form that corallites are commonly curved, apparently diverging rapidly in young stages and then becoming subparallel. Although curvature in the corallites is common, the tabulae remain relatively parallel, straight and uniform in position throughout, being apparently oriented by gravity, rather than being normal to the corallite axes. Commonly sections will show some lateral crushing of the corallites, with others elongated normal to the apparent direction of pressure. This is probably the effect of compaction of sediments upon colonies with large thin-walled corallites and short amplexoid septa, which probably gave relatively little support to the strength of the skeleton.

Discussion. This species is readily differentiated from *C. duncanae* by the considerably larger corallites; additional differences are the prominence of minor septa and the subparallel tabulae regardless of erratic curvature of the corallites in growth. The form here described as *C. akpatokensis* is closely similar to *magnus* in proportions of the corallites, but in the former tabulae are commonly normal to the walls of the corallites and are conspicuously more widely spaced, and their edges are not as strongly downturned; indeed, longitudinal sections that cut the sides of the corallites close to the major septa may not be downturned at all; both forms show a susceptibility to crushing, which enhances their general resemblance.

Curiously, in the present material the fibrous nature of septa and their identity in composition with a sclerenchyme, so difficult to see in the associated *C. duncanae,* is quite evident (pl. 45, fig. 13).

Types. Holotype, NMBM No. 787; paratypes, No. 788, 789, and 790.

Occurrence. All specimens are from the Second Value formation of the Montoya group, from near the crest of the Scenic Drive, at El Paso, Texas.

Crenulites rigidus (Billings)

Pl. 29

Columnaria rigida Billings, 1858, Canadian Naturalist and Geologist, v. 3, p. 421.

———— Billings, 1858, Canada Geol. Surv., Rept. Prog. for 1857, p. 167.

Columnaria alveolata, C. rigida, C. alveolata rigida Foerste, 1924, Canada Geol. Surv., Mem. 138, p. 67-68, pl. 5, fig. 1.

Favistella alveolata rigida Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 273.

Description. This species forms large cerioid colonies, with corallites attaining diameters up to 4.0, 4.5, and rarely 5.0 mm. Tabulae downturned at the edges, scalloped, curved strongly downward between the major septa, spaced rather far apart over most of the length, but with rare erratic zones of crowding; where distant, there are 3 tabulae in 5 mm, 6-7 in 10 mm; where crowded, which is commonly in intervals of 5 mm or less, there are 5-6 tabulae in 5 mm, 9-10 in 10 mm. Primary septa long on the anterior faces of tabulae, 11-12 in number, shortening rapidly forward, but commonly continuous, though vestigial, being 0.4 mm in length or less, and only tiny projections on the inside of the corallite. Minor septa always extremely short, continuous, and apparently uniform in length from one tabula to the other, so short that anterior views of the tabulae that show the major septa commonly do not show the minor septa at all. In lateral view the corallite walls appear longitudinally striated, the striae marking the insertions of the major and minor septa.

The two specimens on which the present description is based, both numbered 81976 in the collections of the U.S. National Museum, show a general uniformity. One, which was sectioned when it came into my hands, shows in the sections corallites commonly ranging from 4.0 mm to 4.5 mm across, and tabulae that are rather closely spaced. In contrast, the second colony shows in its sections slightly larger corallites, ranging not uncommonly up to 5 mm across, and one corallite, elongate and probably on the verge of division, has a length in one direction of 7.0 mm. The longitudinal sections from this colony show a more consistent development of widely spaced tabulae. Inspection of the entire colonies shows that these differences in proportion are not uniform.

Discussion. This species is quite distinctive in corallite diameter and the rather generally consistent wide spacing of the tabulae, which are always well arched, with major septa that shorten rapidly when traced forward from the tabular surface, but are continuous, though very short, up to the next tabula. Minor septa are likewise continuous, but always very short, and uniform in length, or nearly so, from one tabula to the next. The continuity of the septa at the corallite margin makes this form transitional to some extent between *Favistina* and *Crenulites,* but the well-arched tabulae, strongly scalloped at their downturned edges, are without a parallel in any known *Favistina.*

Some reservations must be made as to the identity of this species, in that the types have never been studied from sections. Billings' descriptions are extremely brief and general; there are no accompanying illustrations, and from the descriptions alone it would hardly be possible to recognize the species at all. Foerste, however, presented a figure of the form, a specimen from the type locality, and a somewhat more detailed description. He indicated that corallites range from 4 mm to 5 mm across, but his following statement, "the septa from 7 to 8 in a length of 10 mm., and, as a rule, short but some reaching the center," is apparently a clerical error, and the first part of this quotation clearly must refer to the spacing of the tabulae. The wide variation in the length of the septa is, of course, the result of a section's cutting the amplexoid septa at varying distances anterior to the tabular face. Foerste discussed this form under the heading of *Columnaria alveolata* (Goldfuss), citing it in the text as *Columnaria rigida,* and in the explanation of the plate as *Columnaria alveolata rigida.* It is plain from his discussion of the range that, although discussing the two species that Billings named from Lake St. John, he considered these only as synonyms of *Columnaria alveolata.* At the present time it is necessary to admit that *Columnaria alveolata* is a species so broadly defined as to be meaningless, its exact morphology is not known, and this condition can be corrected only by restudy of the type from sections. However, most of what was formerly included in that species is now placed in the genus *Favistina,* and the forms from the Richmond of the Cincinnati arch and from southern Ontario, with which Foerste grouped *C. rigida* and *C. blainvilli,* are true *Favistina,* and no *Crenulites* has been recognized in either of these associations.

Types. Billings' type or types, on which I have been unable to get any information, are presumably in the collections of the Geological Survey of Canada. In the same collection, the specimen figured by Foerste is listed as No. 8438, but it is not evident whether this is a part of Billings' original material. The hypotypes on which the present description and illustrations are based are two specimens numbered 81976 in the collection of the U.S. National Museum.

Occurrence. From Snake Island, Lake St. John, Quebec, in beds generally regarded as Richmond in age, a matter that should be reviewed in view of the pre-Richmond age of the Red River faunas, and the conclusion of Sinclair (1956) that the English Head beds of Anticosti are pre-Richmond.

Crenulites blainvilli (Billings)

Columnaria Blainvilli Billings, 1858, Canadian Naturalist and Geologist, v. 3, p. 421.

——— Billings, 1858, Canada Geol. Surv., Rept. Prog. for 1857, p. 166.

Columnaria alveolata Bassler, 1915, U.S. Nat. Mus., Bull. 92, v. 1, p. 259.

Columnaria alveolata, C. blainvilli, C. alveolata blainvilli Foreste, 1924, Canada Geol. Surv., Mem. 138, p. 67-68, pl. 5, fig. 2.

This form, described by Billings as a species, was considered a synonym of *Columnaria alveolata* Goldfuss by both Bassler and Foerste. Foerste presents a brief description, noting that corallites average 3 mm in diameter and that septa are conspicuous, almost or quite reaching the center, with 6-8 tabulae in a length of 10 mm. The form is from Snake Island, Lake St. John, Quebec, and is differentiated from *C. rigidus* by the smaller corallites and the closer tabulae. Foerste's illustration of the forms shows unmistakable crenulate edges to the tabulae and traces of the septa which, being amplexoid, show wide variation in aspect and apparent length on a broken transverse section through the colony. Although there is some reservation to be noted concerning the identity of the species, for it is not clear that Foerste consulted the types of Billings, there can be little doubt that this form at Lake St. John, differentiated from *C. rigida* by small corallites and close tabulae, is, like that species, a valid species and one assignable not to *Favistina* but to *Crenulites.*

The types, if extant, are in the collection of the Geological Survey of Canada, which contains Foerste's figured specimen. The species is known only from the "Richmond" of Lake St. John, Quebec.

Crenulites akpatokensis Flower, n. sp.

Pl. 30

This species has corallites commonly attaining widths of 4-6 mm, commonly elongate in cross-section; septa amplexoid, primary septa long on anterior tabular face, 12-14, secondary septa very short. Adoral extent of septa variable; commonly septa disappear adorally, but some have been observed continuous from one tabula to the next, though only as very short stumps. Tabulae normal to corallite axis, transverse centrally, scarcely downturned at radii of major septa, but downturned and deeply scalloped between septa; spacing rhythmically variable, ranging from 3 to 6 tabulae in 5 mm; distance between tabulae ranges from 0.8 mm to 2.0 mm.

Colonies of this form observed are only fragments; the largest shows corallites subparallel and 100 mm in length, evidently not including the basal part of the colony, and the piece is 100 mm wide (SMC No. A50679). Another piece, from near the base of the colony, shows corallites radiating; a number of pieces show corallite growth irregular, with some spaces in the normally cerioid colony. Apparently the corals were thin walled and, with amplexoid septa which are generally short, were apparently quite fragile, for, strangely, nearly every colony shows evidence of some distortion, and some show extensive lateral crushing of the corallites (notably SMC No. A50675 and A50679).

Corallites are commonly elongate in cross-section; USNM No. 92079 shows corallites commonly 4 mm across in one direction, 6 mm in the other. Of this form, only two sections were available, and a somewhat oblique cross-section could produce this effect. However, additional material shows the same general elongation in sections that are definitely transverse to the corallite axes. Interestingly, the elongation of the corallites in one specimen (pl. 30, fig. 8-9) is normal to the direction of crushing, and thus may be the result of distortion; the most regular corallites are shown in Plate 30, figure 5. Major septa are amplexoid, never showing completely around the circumference of a corallite; so their number is necessarily an estimate, but appears to be 12-14. In the larger corallites they do not extend more than halfway from the wall to the center, though the extent is slightly greater in the small corallite shown at the right of Plate 30, figure 5, which is an immature specimen; here the septa merge in a central dark region, which is a transverse section through a tabula. Minor septa are consistently very short. Cross-sections show that the edges of the tabulae are strongly scalloped between both major and minor septa. The length of the septa varies. Plate 30, figure 4, is an oblique section showing septa which, from their discontinuity, are strongly amplexoid. Plate 30, figure 9, shows, on the other hand, some places where the plane of the section is markedly eccentric, and, as in the lower center of that figure, one may see here septa that are continuous through several tabulae; furthermore, not only are the tabulae zigzag, owing to crenulations between the septa, but they are displaced slightly as traced through the septa.

Longitudinal sections show tabulae in highly variable aspects, depending on the position of the section in relation to the center, and also in relation to the septal insertion. A tabula cut centrally, and showing at the sides parts close to the septa, may show no downturning of the edges; indeed, in such a section it is impossible to say which end is anterior and which is posterior. Where this condition does not occur, a central section will show tabulae transverse over most of their width, but downturned near the edges. Eccentric sections will show the tabulae zigzag, with projections on the upward pointing angles, representing the amplexoid septa; conditions showing septa long and continuous through several tabulae are present, as already noted, but are not common. The contrast between central and eccentric sections through tabulae is well shown in Plate 30, figure 7.

Tabulae are normal to the corallite axis, even where direction of growth is highly irregular (pl. 30, fig. 63). In spacing, tabulae are highly variable, being at the most 2 mm apart and at the least 0.8 mm apart, so that in a length of 5 mm there may be from 3 to 6 tabulae.

Discussion. This species is based upon a series of five specimens from the collection of the Sedgewick Museum of Cambridge, and two thinsections, No. 92079 in the U.S. National Museum.

In corallite size and general aspect this form is very close to C. *magnus;* so much so that I considered regarding it as only a subspecies. C. *magnus,* however, shows irregularity of growth, but, strangely, with tabulae subparallel through a series of oblique and diverging corallites; its amplexoid septa are shorter; the tabulae are more strongly downturned at their edges; and nowhere in the species are there such widely spaced tabulae as are exhibited by *akpatokensis.* The discovery of two such similar forms in New Mexico and western Texas on the one hand, and on Akpatok Island on the other, with no similar forms between, is remarkable. It is interesting, but at present futile, to speculate on whether similar forms will be found when the corals of intervening regions are studied more closely.

The large corallites and the amplexoid septa in both this form and C. *magnus* must have resulted in unusually fragile corallites, for commonly large parts of the colonies of both species are crushed laterally, a feature not shared by associated species with stronger and more continuous septa. Because of crushing and attendant vicissitudes, no one specimen is outstanding in the series of specimens on which this species is based; it has seemed best, therefore, to regard them as equivalent syntypes.

Types. Syntypes, SMC No. A50674, A50675, A50678-A50680, and USNM No. 92079.

Occurrence. All specimens are from the Ordovician of Akpatok Island. Two of the five syntypes of the Sedgewick Museum (No. A50675 and A50679) are from sea level. For the remaining three there are no accurate horizon data. Cox (*fide litt.*) suggests that these were probably specimens brought into camp by various members of the party who failed to note the horizon. Faunas from sea level to a 300-foot elevation suggest Red River age. The two sections in the U.S. National Museum almost certainly came from the material sent by Cox, and from these colonies. Preservation suggests that the cross and longitudinal sections came from different colonies.

PHACELOID CORALS

Phaceloid corals of the Ordovician develop in the syringoporids and in the favistinids. Only one genus representing the latter group, characterized by prominent development of the septa, was found in the Montoya corals. Three species from the Second Value and one from the Aleman formation belong to the genus *Paleophyllum,* described below.

Possibly two other genera may be found with further search. *Eofletcheria* has rather distant small tubes with thick fibrous walls, tabulae, and no septa, but a thin external holotheca. It is characteristic of faunas older than those dealt with here, faunas of Chazy or Whiterock age (Duncan, 1956), but some representatives have been reported in faunas of Red River aspect; so it may ultimately be found in the Second Value faunas. I have, as a matter of fact, collected a colony of the aspect of this genus in the Red River of Ash Canyon, but the specimen appears to be lost and has not been duplicated with further collecting. *Reuschia,* recognized by

Hill (1959) in the Second Value outlier in Arizona, has not yet been found in collections from the typical Montoya. Like *Eofletcheria,* the corallites are thick walled, but rows of septal spines develop, and tabulae are absent or obscure. The Arizona specimens figured by Hill range from 2 mm to 3 mm across and are, in general, larger than *Eofletcheria,* a superficial observation, but one that may aid in the recognition of this form in future material.

PALEOPHYLLUM Billings

Genotype: *Paleophyllum rugosum* Billings

Paleophyllum Billings, 1858, Canada Geol. Surv., Rept. Prog. for 1857, p. 168.
Columnaria (Paleophyllum) Bassler, 1915, U.S. Nat. Mus. Bull. 92, v. 1, p. 258. (Summary of earlier references.)
Paleophyllum Bassler, 1950, Geol. Soc. Amer., Mem. 44, p. 274.
————Duncan, 1956, U.S. Geol. Surv., Bull. 1021-F, p. 255, expl. of pl. 25.
———— Hill, 1959, N. Mex. Inst. Min. and Technology, State Bur. Mines and Mineral Res. Bull. 64, p. 4.

Diagnosis. Phaceloid corals, with thin outer wall (epitheca), fibrous lining, with obscure radial units, obscurely trabecular; septa variable in number, but with major septa extending near to center, thick basally, thin at their tips, sometimes joining irregularly in pairs, sometimes anastomosing irregularly; shorter secondary septa variable in development, wanting in some species; tabulae variously arched, downturned in genotype at edges and centers; in other species they may be strongly sinuate and high arched, with or without a central depression.

Discussion. Dorothy Hill (1959) has recently redefined this genus and has published figures of the genotype, both transverse and longitudinal sections. Previous to this work, it was believed that *P. rugosum* had septa that did not attain the center of the corallite, and transverse tabulae. As such, it appeared that the genotype showed much the internal features of *Favistina,* whereas the species of the Montoya, having long septa, the tips of which joined, and arched tabulae, corresponded to phaceloid editions of *Cyathophylloides,* a similarity noted by Duncan (1956). There can be no question that *Paleophyllum* is related to the *Favistina-Cyathopylloides* lineage; enough so that questions have been raised as to the best taxonomic treatment of these forms. Can *Paleophyllum* be merely species derived from the dominantly cerioid lineage independently, and not closely related to one another? It is even suitable to inquire whether perhaps such variation can occur in a species. The last question can be answered with certainty in the negative. Abundant representatives of three species in the Second Value are known, and one in the Aleman. Close search has failed to yield cerioid forms in the same associations agreeing at all closely with these species in tabular and septal features, nor are there phaceloid counterparts of the two *Crenulites* of the Second Value, nor of the *Cyathophylloides* of the Aleman, nor of the *Favistina* in the Cutter. This is suggestive, but perhaps not conclusive, for it may be argued that different stocks may respond differently to the same environments, but that the environments in which these forms lived were too uniform to result in variation of this sort. However, in extending this investigation to a wider stratigraphic scope, still no counterparts of any of these species are known differing only in growth habit. Further, *Paleophyllum* exhibits among the species specializations in the fibers of the septa, and no really comparable specializations have been found in any of the cerioid types involved. This has been discussed in the section dealing with morphology, and is shown in Text Figure 5. *Favistina* and *Cyathophylloides* show, at the most, fibers arranged along axes extending as median planes in the septa, but they change direction gradually upon approaching the corallite wall and merge gradually into the radial oblique fibers there. It is only in *Paleophyllum* that the bases of the planar axes in the septa become removed from the epitheca, fibers are arranged radially around the edges of the planes, and thus fibers finally come to assume a pattern showing septa as distinct entities, the fibers of which meet the wall fibers at such sharp angles as to suggest two totally distinct structures.

In *Paleophyllum thomi,* in the Aleman, variation has been noted between colonies with relatively small, rather closely spaced corallites and others with slightly larger corallites separated by appreciably wider spaces. One is tempted to suggest that polyps more widely spaced had larger feeding areas and were thus larger, but the explanation seems at fault, for it cannot be applied to cerioid colonies in the same association, and comparable variation in corallite size was noted in *Cyathophylloides burksae.*

The genotype and the oldest known species of *Paleophyllum* in the North American Ordovician is *Paleophyllum rugosum* Billings, from Little Discharge, in the Ordovician outlier of Lake St. John, Quebec. Confusion long surrounded the morphology of this species, as the only available figures were rather diagrammatic drawings. Hill (1959) has figured sections of this species, showing that it has numerous (22-24) long major septa and very short minor septa. Tabulae are strongly curved. Hill has interpreted the species as having tabulae strongly arched down from the margins to the center, and this interpretation is supported by the divergence of corallites in the upper part of her figure. Similar divergence, however, can be found in the reverse direction, owing to the erratic curvature of the free corallites, in Montoya species; further confirmation of this matter seems desirable, particularly since other known species show tabulae arching in the opposite direction.

The species is from the Simard limestone of Lake St. John, which Sinclair (1953) has shown to lie at the bottom of the section. It is here that the faunas contain a peculiar mixture of Lowville, Chaumont, and Rockland types, together with a sprinkling of types not elsewhere known in the Middle Ordovician, the canteniform species long assigned to *Halysites* or *Catenipora,* but now recognized as a distinct genus. *Quepora,* as well as *Paleophyllum, Streptelasma,* and a few other anomalous types, seems the source of a general conviction on the part of those who have never seen the section that it is obviously Richmond, which is absurd. However, upper Ordovician beds with a fauna of Richmond aspect are, or were prior to building of a dam and the raising of the lake level, exposed on Snake Island. In the light of Sinclair's (1956) correlation of the English Head of Anticosti with the Maysville, and faunal similarities of the Lake St. John material with the English Head of Anticosti, the matter is perhaps one well deserving of critical review.

Paleophyllum is absent from the section for a considerable interval, but reappears in Red River faunas and continues sparingly in the western Richmond. Many citations of *Paleophyllum stokesi* Edwards and Haime occur in faunal lists, indicating phaceloid corals ranging widely from the Red River of southern Manitoba north to Greenland, south into the Bighorn region, and east to Timiskaming. The species was described as *Lithostrotion stokesi* by Edwards and Haime from the region of Lake Winnipeg. It has been assumed to be *Paleophyllum* and been regarded generally as derived from the Red River. However, their illustration shows a phaceloid colony with frequent processes connecting the corallites. Such processes are suggestive of the Silurian coral *Eridophyllum*[18] and cause one to wonder whether this could not belong to that genus, and whether it could have been derived from some part of the Interlake group, which outcrops not far west of Lake Winnipeg. Obviously, restudy of the type is required before the species can be identified with certainty.

With only faunal lists, one can only assume that citations of *Paleophyllum stokesi* indicate the presence of a phaceloid coral that probably belongs to that genus.

In the Cape Calhoun formation Troedsson (1929) figured and described material of the genus. His *Columnaria halysitoides* is a *Paleophyllum* with large corallites forming imperfect chains, about 20 major and as many minor septa, tabulae 10-14 in 10 mm, arched upward, downturned at the sides, and essentially transverse over much of the central region. Corallities range from 3 mm to 6 mm across. He figured as *Columnaria (Paleophyllum) stokesi* a form with about 60 septa corallites slightly larger, and septa irregularly joining at corallite centers. Poulsen (1941) identifies with Troedsson's specimen a colony from Cape Madison. He says of Troedsson's form: "After having studied Troedsson's specimen from Cape Calhoun, the writer is convinced that it was not found *in situ*, and that it does not belong to the Cape Calhoun fauna; the limestone between the corallites is quite different from that of the Cape Calhoun beds, whereas it is of exactly the same petrographical character as the limestone of the Offley Island formation at Cape Madison and Cape Jefferson." Poulsen describes his form as a new species, *Columnaria (Paleophyllum) troedssoni*. He notes maximum corallite diameters of 8 mm, notes 48 rather than 60 septa, shows a section in which tabulae are curved laterally like the sutures of a *Gonioceras*, but transverse, though somewhat irregular, in a broad central portion. His conclusion as to age is somewhat puzzling, as the species is a good *Paleophyllum*, and that genus is not otherwise known in beds of Silurian age.

P. vaurealense Twenhofel 1929 is a species of the English Head and Ellis Bay formations of Anticosti. The rather brief illustration and the one inadequate figure hardly permit specific comparison. Corallites range from 2.5 mm to 3.0 mm in diameter; tabulae are thin, interpreted as bending down in the middle and again at the margins; 16 major septa, reaching the center and unite there, and there are as many minor septa.

Stearn (1956) has described *Paleophyllum pasense* and *P. panense parvum* from the Stonewall formation of Manitoba. The former has corallites 3-4.5 mm across, tabulae flat, 15 in 10 mm. Major septa, 15, reach the center but do not join; minor septa only faint ridges. The latter has corallites up to 2.0 mm, 10 major septa, vestigial minor septa, tabulae 20 in 10 m, uparched in the centers.

Wilson (1926) has described some phaceloid corals from the Beaverfoot formation. Though they were assigned with question to *Diphyphyllum*, and preservation and illustrations leave something to be desired, they are worth noting as resembling *Paleophyllum;* perhaps restudy would show them to belong to the genus. The *Diphyphyllum halysitoides* has corallites forming short imperfect chains; corallites up to 5 mm, with about 20 major and as many minor septa; tabulae are not preserved and remain unknown. *D.(?) primum* has corallites up to 6 mm, with about 20 major and as many minor septa. The condition of the tabulae is not known.

Columnaria thomi Hall 1857, described in the report on the Mexican boundary survey, is of uncertain origin, but was believed to have come from the Montoya in the vicinity of El Paso. Fortunately, direct comparison of our present material with the type was possible, and it is this species that is abundantly developed in the coral zone of the Aleman at the southern end of the Franklin Mountains.

Paleophyllum gracile Flower, n. sp.

Pl. 46; pl. 47, fig. 1-8

Diagnosis. Corallites hold largely to a diameter of 3.0 mm; rare individuals attain 3.5 mm. Major septa commonly 12-14, rarely as high as 17 in number, their tips joined in groups of twos and threes, but with a small central region free of septa; minor septa wanting or vestigial. Tabulae 3-4 in a length equal to the corallite width, 7-8 in 5 mm, gently arched upward, height of arching rarely equal to corallite width; displaced slightly at sides by intersecting septa.

Description. The holotype colony is incomplete, but shows corallites 50 mm long, and is 80 mm across. Corallites small, individuals over 3.0 mm across are rare; outlines rounded in cross-section, never scalloped as in distal phaceloid parts of *Favistina*, with thin epithecae. Within, the fibrous wall is uniform in thickness, fibers simple, radial in cross-section. Septa with bases broad for a distance about equal to twice the width of the fibrous wall. Axial planes in septa poorly developed, complicated in all observed material by recrystallization, wanting in some sections; where present, axes reach the epitheca and fibers change direction gradually to join those of the wall, as in Figure 5B.

Major septa are short only in sections cutting calyces; in Plate 47, figure 5, they are only short stubs in one corallite seen in the upper center. In the lower right of Plate 47, figure 1, major septa are only slightly smaller than usual, but tips are not joined; the section is presumably just above the base of a calyx. Other sections (pl. 46, fig. 2, 5; pl. 47, fig. 3, 4, 6, 7, and 8) show the highly variable tendency of septal tips to join in small groups, leaving a central cavity somewhat variable in size. Minor septa commonly are completely wanting; when present at all they are very short, and a section showing more than four in one corallite is most exceptional. Their length is commonly less than the thickness of the wall.

Tabulae are arched upward, the extent of arching being variable; nearly flat in the upper right of Plate 46, figure 3, well arched in the upper center of the same figure, whereas the lower left of Plate 46, figure 4 shows the center broad and slightly depressed, but this condition is not common. The illustrations suggest some apparent zonation in spacing of tabulae, but this is false; corallites are not perfectly straight for any distance, and apparent close spacing of tabulae is found where corallites curve normal to the plane of the section. Tabular spacing in mature individuals is commonly 3-4 in a length equal to corallite width, but spacing is uniform

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[18] I am indebted to Miss Helen Duncan for this suggestion. Sinclair's (1959) observations on the confusion of the mottled limestone of the Stony Mountain with the Selkirk limestone raises doubt as to the identity of *P. stokesi* with the *Paleophyllum* of the Red River beds.

in small and large individuals, and a safer generalization is 7-8 tabulae in a length of 5 mm and 13-16 in 10 mm. Longitudinal sections that are well off center augment the apparent variation in the form of tabulae; such sections are recognizable from the intersections with septa, and slight displacement of tabulae occurs where they intersect septa, as shown in various sections on Plate 46.

Corallites grow by lateral budding, and cross-sections show common examples of small corallites still in contact with their parents. Budding individuals are always broadly attached, and few are smaller than 2.0 mm; they commonly show 12 major septa. One example of axial increase (pl. 47, fig. 5) was noted, where 1 corallite evidently divided into 3, of which the largest shows 8 septa, another 7, and the smallest only 4.

Discussion. This species is readily distinguished by the relatively tiny size of the corallites. In rarity of minor septa it agrees with *P. thomi*, which has larger corallites and more undulate tabulae. The associated *P. margaretae* is larger, with tabular zones prominent in every cross-section by virtue of the angular bending of the tabulae; minor septa are always developed and are quite long, extending to the tabular zone. In *P. cateniforme* corallites are still larger, major septa are more numerous and longer, minor septa are generally developed but short, and tabulae are strongly sinuate, curved down at the margins and again in the centers.

Holotype. NMBM No. 689.

Occurrence. From the Second Value formation, from near the crest of the Scenic Drive, El Paso, Texas. The type came from a boulder clearly derived from the basal 10 feet of the formation. A second, rather poor specimen was collected in Hembrillo Canyon in the San Andres Mountains, also in the lower part of the Second Value formation. The species is apparently not common.

Paleophyllum margaretae Flower, n. sp.

Pl. 47, fig. 10-11; pl. 48

Diagnosis. This is the medium-sized of the three species of *Paleophyllum* in the Second Value formation. Corallites range commonly from 4.0 mm to 4.5 mm and rarely to 5.0 mm across. Major septa, 20-24 in number, extend close to the center, leaving a clear central cavity one-fourth to one-sixth (rarely one-seventh) the corallite diameter across; their tips join in groups of twos and threes. Minor septa always present, long, one-third the length of the major septa, reaching to the tabular zone. Tabulae 16-19 in 10 mm, the outer portion directly transverse, then becoming vertical or nearly so; tabulae commonly fused in this region and transverse in the central half.

Description. Colonies may be large; a height of 20 mm and a width of 40 mm have been observed. Corallites are largely free, rarely more than 3 mm apart; individuals joined in short chains are common. Such joined individuals are commonly elongated (pl. 48, fig. 5, 7). Major septa are long and uniform in length, their tips commonly joined in pairs, though free septa and others joined in groups of three or four occur. No radial differentiation compatible with recognition of cardinal or counter septa is evident. Cross-sections are always characterized by a tabular zone, in which the vertical parts of tabulae are intersected; the tabulae appear as two closely spaced rings, rarely one or three. Minor septa extend commonly to the tabular zone. General absence of the axial plane in sections is believed to be a preservation phenomenon.

Major septa are clearly fibrous basally, but distally they are not only thinner but darker in color and granular in texture. Small spheres of poikiloplasm are involved in their tips, and some sections show such spheres also clustered on the sides of the fibrous portions. Other spheres develop on distal faces of tabulae and may appear as free bodies in cross-sections. One large body of this sort is shown in the lower corallite in Plate 48, figure 7, and several smaller ones are seen in figure 3 on the same plate. Plate 48, figure 5, shows tiny spherical bodies on the sides of some of the septa. Septa thicken gradually toward the point of contact with the wall. Fibers in the septa are not readily apparent, and there is commonly no trace of an axial plane. However, fibrous basal parts of septa are light yellow in section, lighter than and quite distinct from the material of the wall; sections commonly show the septal material, broad where the septum joins the wall, narrowing toward the epitheca, giving the appearance of septa inserted in a wall of different material. This is shown in the upper part of Plate 48, figure 7. The epitheca is thin and dark, not obviously distinct from the matrix in most sections, but clearly evident where adjacent corallites are joined.

In vertical section the tabulae show a sharply angular pattern that is most characteristic, best shown in Plate 48, figure 8. Irregular growth results in longitudinal sections in which individuals are cut at all angles (pl. 47, fig. 11), but diagnostic central portions are readily evident. Eccentric sections commonly cut numerous septa, along which tabulae are commonly slightly displaced. Tabulae, spaced 16-19 in a length of 10 mm, fail to show clear alternation of widely spaced and crowded tabulae.

Discussion. Gross proportions will separate this from associated species in the Upham limestone. In size and gross aspect this species is very similar to *Paleophyllum thomi* of the Aleman coral zone, but in that species sections present very different aspects, and in corallite characters the two forms are not even closely similar. In *P. thomi* minor septa are largely wanting, major septa fail to show regularity at their ends, and the central cavity beyond their tips is less prominent; tabulae are sinuate instead of angular, and no definite tabular zone is evident in cross-sections; indeed, the regularity and prominence of this zone is perhaps the most constant and distinctive feature of *P. margaretae*. *P. gracile* has much smaller corallites, with minor septa suppressed and gently arched tabulae; *P. cateniforme*, which is much larger, has long major septa, which are more numerous, and their tips are more complexly fused; minor septa, though generally present, are relatively short; cross-sections fail to show a strikingly distinct tabular zone, and tabulae are broadly sinuate in longitudinal section, with centers commonly strongly depressed.

Occurrence. This is the common species of the Second Value formation, well developed in the southern Franklin Mountains, but collected also in the Sacramento and San Andres Mountains. The poorly preserved specimen figured by Hill (1959, p. 9) from the Mud Springs Mountains belongs to this species, as does her *Paleophyllum thomi*? (1959, p. 6, pl. 1, fig. 3) from the outlier near Morenci, Arizona. I have noted the species at Lone Mountain, but have not observed it in sections in the Black Range, Cooks Range, Florida Mountains, or Big Hatchet Mountains. The species is named for my wife, who joined in collecting it at El Paso.

Types. Holotype, NMBM No. 688; paratypes, not designated, though numerous other colonies were studied and sectioned.

Paleophyllum cateniforme Flower, n. sp.

Pl. 49; pl. 50

Diagnosis. Corallites large, commonly 6 mm across, but with frequent cateniform chains in which elongation parallel to the chain may increase corallites to as much as 9 mm. Major septa 22-26, their tips fused, commonly in groups of more than two, generally four; fusion irregular, and close enough to the center that no median fossula is clearly evident. Minor septa always present, short, one-sixth the length of major septa and commonly no thicker than the fibrous wall; tabulae 12-15 in 10 mm, strongly sinuate, edges and centers depressed, with rounded elevations between; central depression variable in width and depth; very rarely transverse, sometimes descending as low as the margins.

Description. This is the largest *Paleophyllum* observed, both in corallite and colony size. The type colony is incomplete, but shows a height of 14 cm and a width of 22 cm. The colony appears phaceloid, but cross-sections show corallites grouped in irregular chains commoner than free individuals; corallites are commonly, though irregularly and not at all universally, elongated somewhat along the axis of the chain. The major septa, commonly 22-26, most commonly 24-26 in larger individuals, have their tips irregularly joined in irregular groups, involving more commonly 4 than 2 or 3 septa in a group, but highly variable and irregular. Septa join close to the center, and no central fossula such as characterized *P. margaretae* is clearly evident. Minor septa always present, but short, scarcely longer than the width of the fibrous wall, sometimes shorter, and commonly one-sixth the length of the major septa. Tips of major septa are commonly thin and dark, but appear commonly fibrous; septa broaden gradually toward their bases and are clearly fibrous, with axial planes commonly clear in the basal portion. The axes terminate before attaining the epitheca, and fibers continue around their ends, as in Text Figure 5C; as a result, both major and minor septa appear as distinct entities, their bases, broadest where they join the wall and narrowing toward the epitheca, apparently embedded in a fibrous sclerenchyme slightly different in color and texture, and showing markedly discordant fiber orientations. Axial planes in septa common, but apparently absent in some forms; evidently preservation is variable, and probably recrystallization is commonly involved. (See pl. 50, fig. 1, 2, 4.)

Mature corallites are, when free and round, most commonly 6 mm across, more rarely 5 mm, but when corallites form chains, they are irregular in cross-section, some showing definite elongation, others with a broad flattened contact, or one corallite may be concave, curving around the surface of its neighbor. Joined corallites commonly show the thin dark epitheca, which commonly is not distinguishable externally in the illustration from the dark matrix in the photographs, though in examining sections the distinction is commonly clearer from slight color variation. Tabulae show some variation in spacing, but no zones are developed in which they are crowded for any appreciable length; every section, however, shows individuals curving normal to the plane of the section, which may produce a false impression of such crowded zones. Eccentric sections show tabulae significantly displaced as they intersect the septa; central sections show tabulae sinuate, the centers rarely flat, commonly downcurved, and in some the median depression may be as deep as the marginal portion, though the latter is more commonly somewhat deeper. Edges of tabulae joining walls may point slightly down, horizontally, or may be reflexed slightly upward. Because of the sinuate rather than angular course of the tabulae, this species lacks the prominent rings formed by intersections of cross-sections with the tabulae, which are so characteristic of *P. margaretae;* cross-sections show such intersections, but never in such restricted and well-defined zones; many cross-sections show slight displacement of the tabulae where they intersect septa.

In Plate 49, figure 5, a somewhat eccentric section shows the depth of a calyx and the length of septa, which are developed materially anterior to the last of the tabulae. Plate 49, figure 3 shows a portion of a chain in which an exceptionally small laterally budding individual is developed; its wall is complete, but within apparent septa form a triangular pattern, most unlike what would be expected there.

Discussion. The large corallite size makes this species distinctive among the Montoya members of the genus; more significant distinctions are found in the corallite features, the long numerous septa irregularly joined at their tips, the very short minor septa, and the strongly sinuate condition of the tabulae in longitudinal sections.

P. halysitoides (Troedsson) is similar in growth habit, but major septa are fewer and reach closer to the center; tabulae are less sinuate, and their centers are not as strongly depressed. *P. troedssoni* Poulsen has somewhat larger corallites, lacks the tendency to cateniform growth, and has more numerous major septa, which tend to join in larger and more irregular groups in the corallite centers. Poulsen's figures show tabulae curving forward from the margins to rounded salients separated by a median depression generally broader and flatter than that in the present species, though with more sections of *troedssoni* this distinction may prove gradational.

Holotype. NMBM No. 687.

Occurrence. From the Second Value formation. The type is from the lower massive member of this unit at the southern end of the Franklin Mountains, near the Scenic Drive at El Paso. Another less perfectly preserved colony was found 15 feet above the base of the Upham member in Hembrillo Canyon, in the San Andres Mountains. Though internal preservation is poor, two of the three specimens described by Hill (1959, p. 7, 8) are similar and quite probably conspecific. One, No. 564, shows corallites agreeing closely with the type of *cateniforme* in size and count of the septa; two others, with slightly larger corallites, appear to have about the same number of septa and are quite probably conspecific.

Paleophyllum thomi (Hall)

Pl. 47, fig. 9; pl. 51; pl. 52

Columnaria thomi Hall, *in* Emory, 1857, Rept. U.S. Mexican Boundary Surv., pl. 20, figs. 1a-d.

Cyathophylloides thomi Walcott, 1903, Pal. Univ., ser. 1, fasc. 2, pl. 29.

Columnaria (Paleophyllum) thomi Bassler, 1915, U.S. Nat. Mus., Bull. 92, v. 1, p. 261.

Paleophyllum thomi Bassler, 1950, Geol. Soc. Amer., Mem. 44, pl. 18, fig. 12-14; pl. 19, fig. 12.

——— Hill, 1959, N. Mex. Inst. Min. and Technology, State Bur. Mines and Minerals Res. Bull. 64, p. 4, pl. 1, fig. 1, 2.

Diagnosis. Mature corallites 4, 5, and rarely 6 mm across; major septa 20-22, rarely up to 24, meeting in twos and threes, at or very close to center; secondary septa wanting, very rarely one or two in a section. Tabulae 7 in a length of 5 mm, arching variable, but transverse laterally, rising to round crests and concave in the center.

Description. Colonies of this form may be quite large, 20 mm high and 40 mm across. Corallites vary slightly in size and in spacing from one colony to another, but accompanying differences in septal or tabular number and arrangement have not been found. One colony (pl. 51, fig. 1, 2) is rather loose in growth, corallites being commonly 5 mm across, whereas another (pl. 51, fig. 4), has the corallites much closer together, and most of them do not exceed 4 mm in diameter.

Cross-sections show the septa varying widely in their approach to the corallite center; commonly they extend quite close with no central cavity evident, but where such a cavity is developed it never shows as prominently as in *P. margaretae.* Tips of septa are relatively straight, lacking the general irregularities in direction notable in *P. cateniforme* and *P. margaretae.* Septa show a general gentle thickening from their tips to their bases; prominent thickening confined to the basal portions is occasionally seen (pl. 52, fig. 3) but is not typical; more general is the condition shown in Plate 47, figure 9, and Plate 52, figures 4-6. Alteration of materials is relatively common in representatives of this species, but in spite of such changes the axial planes are commonly evident in the septa. Septa broaden most where they join the wall, and insertion of the septal fibers in the wall is uniformly broad and shallow; such fibers suggest that septa are developed on the inside of the wall, inserted only in the shallowest excavations, instead of penetrating in narrow acute-angled extensions attaining or nearly attaining the epitheca. Minor septa are poorly developed; rarely from 1-4 short stubs can be seen in a section of a single corallite.

Though tabulae show considerable variation in form even in median sections, their general pattern is strongly sinuate and more like that found in *P. cateniforme* than in *P. margaretae* or *P. gracile.* The median depression varies markedly in individual corallites (pl. 52, fig. 7) from shallow and broad to deeply depressed, and such areas may be quite narrow. In some cases marked variation is found in adjacent tabulae, and in the left of Plate 52, figure 7, a tabula that is essentially flat across the center is succeeded by one with a prominent median depression, so deep that the two tabulae are joined. The upward curving lateral flanges are not uncommonly asymmetric. Plate 52, figure 1, shows a condition in which the tabulae are lowest in the central region. Lateral portions of the tabulae commonly point obliquely down and out where they join the wall, but are here concave anteriorly, and extreme margins may be transverse or even pointed slightly upward. Eccentric portions of longitudinal sections commonly show little or no displacement of tabulae where they intersect septa.

Colonies show some variation in corallite size and in spacing of corallites; these variations are shown by the several specimens on Plate 51. As already noted, it appears in general that colonies with slightly more widely spaced corallites show corallites of slightly larger diameter. The differences are slight, and there was enough material at hand to show that no constant separation of specimens on this basis was possible, nor were these differences supported by any consistent differences in septa or tabulae.

Hill (1959, pl. 1, fig. 1, 2) figured as *P. thomi* a portion of a most fragmentary colony; though corallites are rather small and show 18 primary septa, this specimen, though a little anomalous, seems properly included in the present species.

For many years there was some confusion as to the identity, origin, and characters of this species, stemming from the very general description and illustration. Bassler (1915) considered it possibly identical with *P. stokesi.* Although restudy of the type is necessary before we can be certain that *stokesi* is even a proper *Paleophyllum,* fortunately the type of *P. thomi* has been sectioned, and figures of these sections have been presented by Bassler (1950) and Hill (1959). Comparison of abundant material indicates the presence of one slightly variable *Paleophyllum* in the coral zone of the Aleman, and comparison of the type with materials found in place leaves no question as to the identity of the species.

In gross aspect, corallites of this form resemble those of *P. margaretae* in general size range, and colonies of the two species are quite similar in aspect. However, there are wide differences, and in sections the two species do not resemble each other at all closely. In the few major septa, relatively straight at their tips, and the general suppression of minor septa, *P. thomi* is more similar to the much smaller *P. gracile* of the Upham. In the strongly sinuate tabulae with median depressions, *P. cateniforme,* readily distinguished by the much larger corallites, is more similar. Cross-sections may be distinguished from *P. margaretae* most easily by the absence of a clearly defined central cavity, the absence of long minor septa, and the failure of sections or weathered surfaces to show intersections of the plane of the surface with the tabulae as a narrow, strongly demarcated zone.

Occurrence. Paleophyllum thomi seems to be confined to the coral zone of the Aleman. It is, surprisingly, known in abundance in two widely separated regions, the Franklin Mountains and Lone Mountain. Pray (1958) has presented a section, and shows this zone 123 feet above the base of the Aleman, and 5 feet thick. At Lone Mountain *P. thomi* occurs in a 1-foot layer 84 feet above the base of the Aleman. Here colonies are abundant, but badly broken; numerous fragments fill the interstices of the colonies, suggestive of extensive breakage by wave action prior to burial; colonies are in dolomite and are universally strongly silicified. The material in the Franklin Mountains is in a matrix that is less dolomitized; specimens are commonly partially silicified, but alteration is less advanced, and this region has yielded the best material for study of the morphology of the species. As noted under the generic discussion, though records of the origin of Hall's type leave doubt even as to the locality, there can be little doubt from the present study that it came from the vicinity of El Paso, and none whatsoever as to its origin in the narrow coral zone within the Aleman.

Types. Holotype, USNM No. 9851; hypotypes, here described and figured, NMBM No. 690-693, from the coral zone of the Franklin Mountains, and No. 694, from the same horizon at Lone Mountain, south of Silver City, New Mexico.

Summary of the Montoya Corals

The demands of modern paleontology require detailed descriptions, for properly a new species should be shown to be distinct from those previously described; in particular, from from other species of the same genus. Likewise, discussion of the genus is necessarily extensive, requiring variously critical investigation of the structure and review, and on occasion reassignment of some species. To omit these matters would leave unstated some most significant facts and conclusions needed by those studying other coral associations. After all, descriptions and illustrations should be sufficient for others to recognize the species without requiring recourse to the types.

On the local level, this amount of material is rather bewildering and unnecessary for anyone whose sole interest is the identification of corals within the Montoya group. For such work the following summary is appended, in which obvious rather than fundamental features are stressed, with a view toward facilitating ready identification. In an association in which a proper study has been made, identification by such methods is possible, and insofar as could be done, characters are stressed that can be recognized without the preparation of thinsections. For some species field identification should be possible. In one respect the summary is fallible: it will of course not include any additional species that may be found with subsequent work. Indeed, were there not reason to believe that most of the representative forms have been included, it would be rather like giving a person three lessons in German, who would then be able to talk only to others who have had the same three lessons. However, diminishing returns in later collecting suggest that additional forms should not be numerous as to species nor abundant.

I. CATENIFORM

Colonies chainlike, ranks enclosing lacunae

A. Corallites rectangular and thin walled in single ranks; common walls may show crenulation; double ranks and agglomerative patches common; in them corallites are polygonal. *MANIPORA* (Second Value)

M. magna. Three to three and one-half corallites in a length of 5 mm; walls thin, single ranks dominant, in which common walls are normal to the course of the rank; both outer walls equally and slightly convex. Corallites swell, normal to rank, from 1.0 mm to 1.8 mm or from 1.5 mm to 2.0 mm. Tabulae mainly transverse, rarely 5, commonly 7-8, in 5 mm, but with short, poorly defined crowded zones, with 9-11 in that length.

M. amicarum. Corallite sizes much as in the preceding, walls thicker, crenulations more prominent; common walls as often oblique as normal to outer walls; double ranks and agglutinative patches commoner than single ranks. Tabulae 6-7 in 5 mm.

M. trapezoidalis. Corallites 2.5 mm to 3.0 mm in length of 5 mm; width increases from 1.8 mm to 2.0 mm. In single ranks common walls oblique, alternating in direction; corallites trapezoidal, with narrow base flat, longer base slightly convex; double ranks and agglutinative patches common. Tabulae 4-5 in 5 mm.

AA. Corallites oval-elongate with thick fibrous walls; cross-sections commonly show indication of real or apparent septal spines. *CATENIPORA*

C. workmanae. Commonly 3 corallites in a length of 5 mm in length of rank; broad common walls with balken; corallites increase normal to rank from 1.8 mm to 1.2 mm. Tabulae 6-7 in 5 mm. (Second Value)

C. cf. *workmanae.* Corallites scarcely broaden from common wall, from 1.0 mm to 1.2 mm and rarely 1.3 mm. Length parallel to rank 1.5 mm to 2.0 mm. Corallites more slender, septal spines more distant. (Second Value)

C. sp. (1) Corallites strongly convex in cross-section, common wall unusually narrow, without apparent balken. Corallites 1.5 mm to 2.0 mm long; corallites expand narrowest to broadest parts as 3:4. (Second Value)

C. sp. (2) Corallites large, 3 in a length of 7 mm; width increases from 1.5 mm to 1.9 mm and from 1.6 mm to 2.0 mm. Corallite cavity quadrate rather than elliptical; common walls wide, balken present. Tabulae 5-6 in 5 mm. Short zones of crowded tabulae 4 mm long with 6 tabulae. (Aleman?)

II. RAMOSE

PRAGNELLIA

Pragnellia(?) delicatula. Slender branches from 2 mm across, and round, to flattened and as much as 6 mm across; surfaces show small round corallites 0.8 mm to 1.4 mm across, edges raised, pustulose to finely denticulated, but with septal spines vestigial. Corallites scattered in a pustulose coenenchyme, the distance between them less than their diameters. Only fragments are observed, failing to show thus far nodes dividing branches into short segments. (Aleman coral zone)

III. CERIOID

1. ENCRUSTING; TEXTURE FINE

A. Surfaces and cross-sections show small stellate corallites, common walls broadened, septa extending from them joining a columella, leaving 12 conspicuous interseptal spaces traversed by tabulae. In sections, material of walls, septa, and columella may appear homogeneous. *PROTROCHISCOLITHUS*

P. hembrilloensis. Corallites 1.5 mm to 1.6 mm across; septa broader than interspaces; interspaces essentially linear; columella solid, bacular, one-third the corallite diameter. (Second Value)

P. *alemanensis*. Corallites 1.8 mm to 2.0 mm across; septa narrow beyond short broad bases; interspaces wider than septa; columella vesicular, one-half corallite width. (Aleman)

AA. Colony a crust of vertical fibers, baculi; the one species shows no differentiation between baculi of septa, wall, and columella; septa widened so as to touch; colonies suggest Bryozoa or Stromatoporida rather than corals. *COCCOSERIS*

Only one species observed, C. *astomata*. (Second Value)

2. LARGE TYPICALLY CERIOID FORMS

A. Small thick-walled corallites with 8-16 prominent septal ridges; walls and septa massive in comparison with a corallite diameter. *NYCTOPORA*

N. *mutabilis*. Corallites 1.5 mm to 1.8 mm across; walls highly variable in thickness; septa prominent, extending at least halfway to center; 9-11 tabulae in 5 mm. (Second Value)

N. sp. Corallites 1.0 mm across, wall thick septal ridges short and thick. (Second Value, Arizona; Hill, 1959)

N. *nondescripta*. Corallites 1.0 mm to 1.2 mm across; walls fairly thin; septal ridges commonly short with pointed tips; 13-16 tabulae in 5 mm. (Aleman)

AA. Corallites larger, thin walled, polygonal. Some suggestion of septal ridges.

Saffordophyllum newcombae. Corallites 2.0 mm to 2.5 mm across; walls thin, crenulate; convexities thickened into 12 septal ridges per corallite, but so short as to be commonly obscure; conspicuous rhythmic thickening and thinning of walls in growth. Tabulae basally 7, distally 15-16 in 5 mm, transverse, edges more often turned up than down; may be finely crenulate. Pores present, but obscure. (Second Value)

Trabeculites keithae. Corallites 2.5 mm to 3.0 mm across; tabulae irregular, as above, spaced from 5 to 8-9 in 5 mm; walls in cross-section show instead of crenulations alternate thick and thin regions, about 20-22 thick regions around each corallite. No pores. (Second Value)

AAA. Corallites simple tubes without septal ridges or spines. Pores at corallite angles. *PALEOFAVOSITES*

P. *sparsus*. Corallites 2.5 mm to 3.0 mm; colonies small; cross-sections show wall segments conspicuously curved; longitudinal sections show walls broadly undulate, tabulae variable in form and spacing, conspicuously distant and downcurved in young stages. Colonies small. (Second Value)

P. *prayi*. Large colonies; corallites commonly 2.0 mm or smaller; walls scarcely curved in cross-section; in longitudinal section walls gently undulate, tabulae commonly 9-10 in 5 mm, rare distant zones with 5 in that length. (Aleman)

P. cf. *prayi*. Similar; corallites run slightly smaller; tabular spacing similar. (Cutter)

P. *kuellmeri*. Corallites commonly up to 2.5 mm; walls show closer undulations; tabulae 6 to 7 in normal, 9 to 10 in crowded 5-mm intervals. (Aleman)

P. *mccullochae*. Corallites 2.5 mm to 3.0 mm across; small, round budding individuals; tabulae rarely 4, typically 5 to 6 in 5 mm; in mature part edges of tabulae downturned and faintly crenulate. (Cutter, commonest species)

3. WALLS THICK, POROUS; CORALLITES ROUNDED

CALAPOECIA

C. *coxi*. Walls moderately thin, some corallites obscurely polygonal; corallites 3.0 mm to 3.5 mm across; walls with regular pores in intersecting vertical and horizontal rows; inner surfaces show pores slightly elongated vertically, at interstices of weak horizontal and strong vertical ridges; extended into spines, 19 to 21 in corallite circumference; spines twice as numerous vertically as pores, one at interspace and one opposite a pore. (Cutter)

C. cf. *ungava*. Corallites round, in coenenchyme, 2 mm across; centers at most 3 mm apart. (Aleman)

C. cf. *anticostiensis*. Corallites 2.5 mm to 3.0 mm across widely spaced, centers 3-5 mm apart; round, raised rims. Septai spines obscure on surface; interior of walls shows pores horizontally elongated, interstices in a mesh of prominent horizontal and weaker vertical ridges; spines confined to horizontal bands between pores. (Second Value)

4. SEPTA PROMINENT

A. Septa amplexoid, tabulae with edges scalloped, strongly downturned between septa. *CRENULITES*

C. *duncanae*. Corallites 3 mm to 4 mm across; major septa, 8-12; very short longitudinally; minor speta vestigial. Tabulae 8-10 basally, 10-14 distally in 5 mm. (When poorly preserved may be confused with *Trabeculites keithae*, which has corallites of the same size range; spacing and consistently downturned edges of tabulae are then diagnostic. In extreme cases thinsections will show rugosan wall here, in contrast to trabecular structure of *Trabeculites*.) (Second Value)

C. *magnus*. Corallites up to 6 mm across, commonly irregularly curved in growth, but with tabulae essentially parallel throughout, tabulae 6-7, rarely 8, in 5 mm; up to 14 major septa; minor septa generally longer than fibrous wall. (Second Value)

AA. Septa continuous.

Favistina stellata (Hall). Corallites average 5 mm across; major septa 11-12; straight, not joining or attaining center; minor septa vestigial, rare; tabulae 6 in 5 mm, variable, edges commonly downturned. (Cutter)

Cyathophylloides burksae. Corallites variable in zone, but fairly uniform in each colony, from 3.5 mm to 5.0 mm across. Ten to 12 long major septa, ends irregularly joined at center; minor septa present; tabulae arched upward, 5 in normal zones, 8-9 in crowded zones in 5 mm. (Aleman)

Cyathophylloides sp. Corallites 4 mm across; major septa 14, well fused in center; inadequately known. (Cutter)

IV. PHACELOID

1. PROMINENT SEPTA

PALEOPHYLLUM

P. *gracile.* Corallites up to 3.0 mm across; major septa 12-14, ends relatively straight, tips variably joined in groups of twos and threes, not uncommonly free; minor septa rarely evident, when present only rare short stubs; tabulae simply and gently arched, 13-16 in 10 mm. (Second Value)

P. *margaretae.* Corallites 4.0 mm to 4.5, rarely 5.0 mm; 20-24 major septa with ends commonly joined in twos and threes termination sharp and uniform, leaving central free circular space. Sections show a definite narrow ring formed by vertical parts of tabulae; minor septa long, attaining or nearly attaining this ring; tabulae subquadrate in vertical section, horizontal at margins, then vertical, and horizontal over central half; 16-18 tabulae in 10 mm. (Second Value)

P. *cateniforme.* Corallites up to 6.0 mm across; commonly in short chains and elongated parallel to chains up to 7 to 9 mm; 22 to 26 major septa, ends irregularly joined, somewhat undulate or twisted though never strongly vertical; joined commonly in groups of 4 or more; minor septa developed but very short; tabulae 12-15 in 10 mm; strongly sinuate, edges and centers downturned; never angular as in *margaretae.* (Second Value)

P. *thomi.* Corallites 4-5 mm across, in size close to *margaretae,* but with minor septa suppressed; 20-22 major septa, ends straight, free or joined in groups of twos or rarely threes, as in *gracile;* no clear central cavity defined; no tabulae ring. Tabulae sinuate, very much as in *cateniforme,* but with central depressed region not usually as deep; tabulae 12-16 in 10 mm. (Aleman)

2. NO SEPTA

REUSCHIA

Form in Arizona, not known yet in New Mexico. Only known specimens rather poorly preserved; thick-walled corallites 2.0-3.0 mm across; obscure septal spines; tabulae not clear, possibly suppressed. See Hill, 1959.

Tetradium, omitted from the above, should be found. It is distinctive in small corallites, quadrate in cross-section, and has four short septal ridges, one stemming from the center of each of the four walls, giving corallites in cross-section the aspect of a four-leafed clover. Reported by Paige (1916) from the Silver City region; apparently from the Second Value.

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PART II

ORGANISMS ATTACHED TO MONTOYA CORALS

Abstract

The primary purpose of this study is the description of some 19 different sorts of organic calcareous remains found attached to colonial corals of the Montoya group, mainly on colonies of *Catenipora*. These forms comprise 18 genera and species, all new. They are roughly divisible into (1) solid objects or calcareous capsules with central spaces, (2) coiled tests or shells, (3) straight tubes, and (4) a bivalved shell. The last is quite apparently an orbiculoid brachiopod, but the affinities of the others remain extremely doubtful, though in various cases the several possible interpretations are discussed. All forms are known only from their appearance in thinsections. Attention is also called to *Lichenocrinus*-like bodies in colonies of *Coccoseris*, and some cavities obviously occupied by foreign organisms in colonies of the same genus. The coral sections yielded a characteristic worm burrow in the matrix, which is briefly described but not named.

Introduction

The primary purpose of this study is the description and illustration of some small organic remains found attached to various of the corals described in Part I. These bodies, dominantly calcitic, are like nothing described before, and their affinities are highly uncertain. They were first observed in the examination of the thinsections prepared for the study of the corals, and indeed still remain known only from such sections. They are all small, few exceed 2 mm in their greater dimension, and most are 1 mm or less across. As the same sections and the same photographs that show these bodies also exhibit significant features of the corals to which they are attached, this and the preceding paper are illustrated by a common series of plates, and illustrations of these bodies are primarily concentrated in Plates 9-12, following the illustrations of *Catenipora*, for most individuals were found on colonies of that genus. In order that the description of these remarkable bodies might not be obscured, as might be the case were they described as an appendix to the above coral study, several of my colleagues suggested that this study be kept distinct, with a separate title. For completeness, some observations are added on a *Lichenocrinus*-like body found in colonies of *Coccoseris*, and on some cavities, obviously of organic origin, noted in cerioid colonies of the same genus.

When these bodies were first found, I was at a loss to determine their affinities. The evidence supplied by sections was necessarily limited, but it was obvious that nothing like the majority of these bodies has been observed before, either in natural relief or in sections. It was, then, the more amazing to find, while comparing sections of Montoya corals with those from other regions in the collections of the U.S. National Museum, that bodies similar to some of them, notably *Tholella*, were present in material from the later Ordovician of the Scandinavian region, and later work brought to light similar bodies attached to colonies of *Catenipora* from the Fish Haven dolomite of northern Utah. Thus it is evident that these bodies were of fairly wide geographic distribution in the later Ordovician. Most of them are found attached to colonies of *Catenipora*, but one was observed on *Manipora*, and several were later found on *Paleophyllum*. The restricted lacunae in the ranks of the cateniform corals certainly supplied a protected environment, one in which, quite obviously, these tiny creatures throve, sometimes prolifically, for although some colonies yielded none of these bodies at all, others were practically peppered with these little calcareous excrescences. The phaceloid corals also provided a protected environment. Their corallites are close enough to keep out all but the smallest predators, but the spaces were always open on many sides, and the environment provided was certainly more exposed to wave and current action; this explains perhaps why the population on such colonies is generally relatively sparse in comparison with the cateniform genera, where lacunae are more enclosed and therefore more protected.

The attached bodies may be divided into four groups, those which are solid bodies or tests completely enclosing cavities, those which are coiled tests or shells, those which are relatively straight tubes, and a single bivalved shell. There remain also a few bodies too poorly known from isolated sections for determination of their form; these are figured but not named. The named bodies may be summarized as follows:

A. Apparently complete tests enclosing cavities or solid bodies

1. High-arched tests of numerous thin plates, a large main cavity commonly supplemented by an accessory cavity. *Tholella*

2. Low-arched bodies of few thick plates with vertical fibrous structure, generally with a central cavity open externally through a passage low in the low (anterior?) end. *Moundia*

3. High-arched bodies, like *Tholella*, but with walls apparently of a single piece, yellowish, suggesting chitinous rather than calcareous material, the base always very thick. *Ivesella*

4. Solid bodies of finely granular calcite, broadly sessile, the free surface rounded, lacking a central cavity. *Mooreopsis*

5. A round, evidently spherical body of few, very thick plates, and a small central cavity, the whole attached by a short, thick stalk. *Eliasites*

6. Calcitic granular bodies with dark borders, spherical or with obscure flattenings, facetings, on the surface, the whole enclosed in an irregular mass of coarse calcite, by which it is broadly attached to the coral. The calcite is explicable only as replacement of an originally tough, possibly gelatinous organic substance. *Niccumites*

7. A broadly sessile body, the free surface low arched, covered with a moderately thick plate; within is calcitic material showing fibrous lines converging from the broad base to the top. *Cheneyella*

8. A round body with a covering of numerous thin plates, elevated on a short neck from a broad base of attachment; within are round, thick-walled calcitic bodies with small carbonaceous centers. *Cystosphaera*

9. A body with a broad base of attachment rising into a linear extension bifurcated at its tip, resembling an echinoderm pedicillaria; the basal material is built of calcareous spheres, the distal part of longitudinal fibers. *Pedicillaria*

10. Bodies subquadrate in cross-section, sides and base complete, top flat, with evident numerous slits or pores. *Slocomia*

11. A vase-shaped body, rounded below, with a long neck above and a solid, granular calcitic body in the center; the wall is thick, with many short, rodlike dark inclusions, rounded at their ends. *Harjesia*

12. Small wart-like elevations composed of a number of small spherical calcitic bodies. *Kruschevia*

B. Tube builders

14. Short, free, vase-shaped tubes. *Ampulites*

15. Small colonies of short, parallel-sided tubes. *Ancestrulites*

16. Long, slender tubes widening gently distally, the young budding from near the bases of the parents. *Wellerites*

C. Coiled shells or tests

17. Low-spired, widely umbilicate shells, attached by the surface of the spire, outer margins tending to be slightly keeled. *Warthinites*

18. Tiny planispiral shells, attached by the broad flat side, presumably the top of the flat spire; whorl cavity rounded, wall thin and round below, thicker above, slightly carinate at the outer edge. *Goldringella*

19. Small planispiral shells or tests, calcitic, fine structure lost, outer margin rough, irregular, the cavity within relatively small and greatly reduced or completely closed in the inner whorls. *Fentonites*

D. Bivalved shells

20. Here alone is a reference possible to a described genus or major group; these bodies are tentatively assigned to *Orbiculoidea.*

Investigation of the affinities of these bodies has been most unrewarding. The bodies appearing either as solid or as capsules enclosing a central space seem most logically interpreted as some sort of quiescent stage, enclosing eggs, cysts, or spores. It is difficult to see how the apparently solid bodies can be thus interpreted, but any alternate suggestions have been lacking. For those bodies with central cavities, it is again extremely difficult to say whether those enclosing hollow cavities were tests of some metabolically active animal. Tests of such animals should show regular apertures, but recognition of such apertures is made difficult by the materials, which have been observed only in sections. Every apparent opening involves the question as to whether it is an accidental break, a natural opening developed when spores, cyst, eggs, or young were ready to be voided into the water, or a natural opening of the alimentary canal or of a possible respiratory system. Openings in the outer test of *Cystosphaera* are obviously either accidental, or breaks preparatory to the voiding of the thick-walled, round calcitic bodies enclosed by the outer covering. *Tholella* contains no such bodies, and some apparent breaks appear to be accidental. Only in *Moundia* do there appear to be regular apertures permitting a communication between the internal cavity and the external environment.

That most of these bodies have been observed only in sections is, of course, a real handicap to their interpretation. In a number of instances, the bodies have been observed in sections that were made in series. Some are sections made by smoothing and grinding two surfaces on opposite sides of a single cut; such surfaces are probably not less than 3 mm and not more than 5 mm apart. In some other cases, serial sections were cut across the same part of a colony, and the surfaces thus shown in sections are from 5 mm to 8 mm or, rarely, 10 mm apart. Enough such sections were available to show that none of these bodies extended for any appreciable vertical distance along the corallites. It is thus evident that these bodies, as seen in section, are not cross-sections of elongate wormlike bodies growing the length of the corallites for appreciable distances. Further, those bodies that are represented by several sections show some central sections and other sections that are obviously off center, as shown by comparing the two sections of *Cystosphaera* (pl. 11, fig. 2 and 3). Among the sections of *Moundia* are some that are central and asymmetric, showing a low elongate end which is possibly anterior (pl. 10, fig. 9, 11; pl. 12, fig. 12), whereas others are symmetrical and are quite probably transverse rather than longitudinal sections. Attempts to observe these bodies in relief were unsuccessful. Most of the bodies were found on corals in the Second Value formation. Preservation is such that the corals cannot be separated cleanly from the matrix so as to show surfaces with any such possible bodies upon them.

The presence of some of the bodies on *Paleophyllum* of the Aleman, where the corals are commonly silicified and can be separated from the matrix by etching, led to the hope that etched surfaces might show some of the bodies. However, no bodies were observed on etched material. The *Paleophyllum* of the coral zone of the Aleman of the Franklin Mountains are well preserved as far as sectioned material is concerned, but the silicification is incomplete, and etching revealed corallites from which the epitheca and parts of the sclerenchyme that were not replaced by silica had been removed; thus even the surface to which these bodies were attached could not be observed. Material from Lone Mountain, where silicification is commonly extreme, was examined, but this material showed such coarse replacement of the surfaces that it was not evident whether various irregularities represented some of these foreign organisms, too coarsely replaced for recognition, or whether they were merely nodules of excess inorganic silica. Thus this method of examination for the attached bodies proved completely unrewarding.

In the two years during which this study was in progress, opinions of other paleontologists were widely solicited on the possible nature of the attached bodies. First, the opinions of coral specialists were sought in the hope that some of them might have observed similar organic remains. It was at this time that I let it be known that these objects were to be named, and that if no suggestions as to their affinities were forthcoming, I would consider it appropriate to name them for students of corals, those persons who today are "attached" to corals. Even this specious threat of blackmail elicited no good suggestions as to affinities, or any indication that similar bodies had been observed previously. Some of the bodies, the coiled tubes or tests, seemed to be logically interpreted as gastropods, but this suggestion was vigorously opposed by the few gastropod specialists consulted. The straighter and simpler tubes are obviously Bryozoa, but experience should lead one to suspect the obvious. Opinions of specialists on the Bryozoa were unanimous in rejecting these bodies as possible members of the group, and with good reason, for they are from 8 to 20 times as large as the tubes of associated orthodox Bryozoa found in the same sections.

In the process of the investigation the opinions of many specialists have been solicited. Visitors to my office had these sections thrust upon their attention. A number of specialists were consulted by letter, with accompanying photographs of the sections. When I took many of the thinsections to the U.S. National Museum for comparison of the corals, as many specialists as were then available were consulted. For viewing either the actual sections on their photographs and offering opinions and suggestions, I am indebted to Dr. E. R. Cumings, Dr. J. J. Galloway, and Dr. R. S. Bassler, who were unanimous in rejecting the tube-builders as possible Bryozoa; Dr. Ellis Yokelson, who likewise rejected the coiled bodies as gastropods; Dr. K. E. Caster, Dr. Ruth Todd, Dr. James Wilson, Dr. R. S. Boardman, Dr. Frank Neumann, Dr. William Sando, Dr. Jean Berdan, and, among coral specialists, Dr. Frederick Bayer, Miss Helen Duncan, Dr. Harry Ladd, and Dr. J. W. Wells. The accumulated opinions of the specialists resulted in the conclusion that none of these bodies could be referred to any of the major groups commonly represented by fossil material. More remote possibilities were explored, but without any very rewarding results. The possibility of fossil rotifers, tunicates, or acorn barnacles was considered, as were the Cyamoidea and Cycloidea, in themselves no good solution, as their position in the Echinodermata seems highly questionable.

The possibility that some of these objects could be reproductive stages of the corals themselves received consideration. Such an interpretation would have profound implications as to the nature of some of the genera as corals, for it is in the Hydrozoa that somewhat similar sexual organs develop externally, whereas the known Anthozoa have reproductive organs developed internally, on the sides of the mesentaries. The possibility was rejected, for although the majority of the bodies occur on colonies of *Catenipora,* they were also found on *Paleophyllum.* Furthermore, as the investigation continued, the status of *Catenipora* as a coral, and indeed the close interrelationship of the colonial corals of the Ordovician, seemed to be greatly strengthened; moreover, the present conclusions indicate that no clear line can be drawn dividing these corals into Rugosa and Tabulata. The general development of holotheca or epitheca on the coral exterior indicated the attached bodies to be foreign, and not a part of the coral. The possibility that these bodies might be algae was also considered, but although all sorts of odd calcareous things have been attributed to algae, no clear case for such an assignment could be posed for any of the present bodies; those representing possible cases of eggs, spores, or cysts could be attributed to numerous groups, including the algae, all with about an equal degree of probability. None, however, showed close enough similarity to structures known in certain members of any of these groups to permit the erection of a convincing case.

In the end it has seemed best to describe and illustrate these forms, indicating that their taxonomic position is still a puzzle. They are named in terms of genera and species; any other procedure with these 19 highly disparate objects would only have created confusion. Some consolation is attained from the reflection that, after all, there is nothing like giving an object a name, for getting other people worried about where it belongs in the general scheme of organisms.

Some years ago a paper was prepared for an entertainment in the geology department of the University of Cincinnati. This was a study of fossil tracks and trails, fictitiously attributed to Dr. Nevin M. Fenneman. It approached the problem with the following logic: There are some tracks and trails that are sensible; there are others that are simply silly. Surely it is not too much to believe that the sensible ones were made by sensible animals, the silly ones by creatures that were utterly absurd. I may leave to the imagination of our readers the restorations of the animals responsible for some of the odder trails, such as *Arthraria* and *Climactichnites.* It seems not unlikely that when a correct solution of the bodies attached to these Ordovician corals is reached, it will be, seemingly, as absurd and as wild, and certainly as remote from our present knowledge of fossil groups, as was the reconstruction of the creature considered responsible for *Climactichnites* on the above premises; it was, as I recall, an arthropod that converted exuviae into a lawnroller type of arrangement with a chevron pattern on its surface.

Obviously names were required for these 19 disparate organic remains, if only for intelligible discussion. The selection of new genera and species names was thus necessary. Some considerations involved in the selection of the names deserve brief mention. There are a number of individuals who have set themselves up as authorities on matters of taste in the erection of names. Their qualifications in this regard have never been made clear. They seem to differ somewhat in details but agree quite generally that the selection of a name is a matter that should be given profound thought. The recommendations stop barely short of including fasting, prayer, and a night-long vigil, approaching thus rather closely the initiation into medieval knighthood. The authorities certainly agree that one should thumb through dictionaries of Greek and Latin in an effort to find a name indicative of affinities, descriptive as to form, suggesting some resemblance, or indicating occurrence. Once such a name is selected, the author must then ascertain from the literature that it is not preoccupied; if it is, he loses two turns and has to go back and begin over again. The writer has long held the conviction that the selection of a name is a purely secondary matter, and that it is a sad mistake to give to the procedure the time and attention that might far better be devoted to the systematic investigations, one outcome of which is the discovery of the need of new names. The claim that such a course is meritorious is particularly absurd in paleontology, a field in which our descriptive work is as yet barely more than begun. As Needham (1930) pointed out, a name is a name, not a catalog of the characters of an organism. Sinclair (1953) rightly states that, after all, paleontology is the study of fossils and not the study of the names of fossils.

The author has long felt that the selection of names is a proper field for relaxation, and not properly an end in itself. Surely there is no place for regulations governing the erection of names beyond the simple matters of syntax involved in the general rule that, whatever their ultimate origin, genera are Latin or Latinized nouns, and specific names either nouns or adjectives in the same tongue.[19]

Two matters seem to distress the self-appointed authorities beyond all others: First, the combination of roots from the Latin and from the Greek, second, the naming of species and genera for persons. This first matter seems a bit odd in view of two facts: First, the Romans themselves borrowed liberally from the Greek where need arose, and second, it is a bit absurd to bar Greek when we have Latinized words from almost every other language, including not only the main languages of Europe, but also Chinese, Japanese, American Indian, and Eskimo. True, many are involved in place names, but it seems odd to balk at the relatively euphonious *Ovoceras* and swallow *Shamattawaceras* or *Tofangoceras*. Objections to naming genera and species for persons seem to have an equally unsubstantial basis, and in this practice I have taken particular delight.

In the preceding study of corals a number of specific names are descriptive, but where such names did not suggest themselves, or those suggested seemed already sadly overworked, the species have been named for beautiful women, particularly deserving of honor. In the present work the dilemma was worse; a few names are suggestive of form or appearance, but one could hardly draw upon affinities, when affinities remain uncertain, or range, when it was obvious that our present concept of range falls far short of the truth. However, I was not faced here with the necessity of selecting those whose names should necessarily be perpetrated, nor was I dealing with an application of names that was necessarily complimentary. One body, which resembles a fossil wart, I have named for a certain international figure whose activities in Washington made me seriously late in arriving at the U.S. National Museum. As for the others, most are unworthy of mention; to those who recognize their names, I can only say that those also serve who only stand and wait.

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[19] What stand will be taken on this matter by the International Rules of Zoological Nomenclature when they are finally adopted is a matter on which all attempts at prophecy fail. The rules, under revision since 1950, are at present in a state in which there is more rumor than information, but the task of systematists, who have worked for 10 years in the hope of complying with rules to be adopted by a future Zoological Congress, has descended into the depths of futility.

Organic Remains Attached to Colonial Corals

CAPSULES, CLOSED TESTS, AND SOLID BODIES

THOLELLA Flower, n. gen.

Genotype: *Tholella idiotica* Flower, n. sp.

This genus is erected for small bodies attached to corals and observed only in thinsections. They are in general thin walled, high arched, and shaped more or less like a chocolate drop, the top not uncommonly showing a low asymmetric point. The wall enclosing the large main chamber is thin, commonly composed of a series of plates, but may show some secondary thickening, usually near the top of the arch. Secondary accessory bodies may be present, but in the several individuals observed they vary in relative size from some that are relatively minute to others that are nearly half as large as the main cavity. In one case, only the basal part of an accessory body is present, as though the top had broken away naturally, voiding possible cysts, spores, or eggs into the water. Most plates show fine structure of transverse fibers; some are irregular in texture, the condition suggesting alteration, but in one form the walls are largely composed of plates showing fine lamellae vertical to the inner and outer surfaces.

Discussion. Although five bodies attributed to this genus and to the single species recognized within it are known, they show a bewildering variation of detail, though agreeing closely in general appearance. The affinities of the genus are highly uncertain. That it is a body enclosed by a test of numerous small thin plates suggests some sort of sessile echinoderm. However, no attached echinoderms are known that are of such small size at maturity, and from what is known of echinoderms in general (information on extremely early stages of attached forms is meager), such tiny immature stages would be expected to show fewer and thicker plates.

The shape of the body and its structure of apparently relatively few plates are, in general, faintly suggestive of acorn barnacles. Paleozoic fossils attributed to the acorn barnacles have been recently summarized by Fischer (1954). The writer has long regarded the Machaeridia as the true beginning of the Cirripedia, considering the assignment of that group to the Echinodermata as unjustified, the evolution in the group trending from forms enclosed in a long linear series of plates through those in which the basal plates are first reduced in size, and eventually lost, producing the goose barnacles, the neck later reduced producing the acorn barnacles. On this basis, the supposed acorn barnacles of the Paleozoic are most unlikely, and some other interpretation should be sought for them. In any case, the tiny size of the present organism and the presence of small accessory chambers are both inconsistent with its interpretation as a balanid. The small accessory chambers are almost equally difficult to explain when *Tholella* is considered as a possible echinoderm.

Other rare fossil groups have been considered, but without any very profitable results. Such groups include the Cyamoidea and Cycloidea, and the remarkable *Endosacculus* (Voight, 1959), which builds cyst-like bodies on colonies of the alcyonarian coral *Molktia.* This body is not composed of several plates, and is not known from any beds older than the Cretaceous.

More likely affinities proving unconvincing, only some seemingly fantastic possibilities remain. Some Bryozoa have been known to have early stages in which the sessile organic body is covered by two valves. The body is similar enough to *Tholella* in minute size and shape to suggest possible affinities. *Tholella* could have developed from such a stage by division of the original two upper plates into many small plates, but such a suggestion, from the present evidence, is not capable of proof. It is even difficult to say whether *Tholella* was an active animal metabolically or whether the plates enclosed a quiescent stage, egg, cyst, or spores. However, the variation in the size and aspect of the accessory chambers suggests that they may have been involved in reproduction, whereas the main cavity may have been occupied by a metabolically more active creature. If this is true, one would expect the covering of the main chamber to have at least one normal aperture, perhaps more. From our present material no such apertures can be recognized, but this limitation may very well be due to the nature of the material, for *Tholella* is known from a series of sections that happen to cut these several specimens; they fail also to give any clear concept of the number or arrangement of the plates making up the test. Whereas on the one hand it is evident that these bodies are significant, worthy of notice, and requiring recognition and further observation, the evidence is as yet sadly insufficient to permit a real evaluation of their taxonomic position or even any very accurate knowledge of the construction of the test. Quite evidently, this form cannot be assigned convincingly to the Protozoa, for no Protozoa with calcareous tests are recognized in the older Paleozoic; neither are there any close parallels to the tests of *Tholella* in known fossil or living forms. No forms at all comparable with *Tholella* are known in the Coelenterates or Porifera, and there is no indication in *Tholella* that would suggest its assignment to the worm phyla. Bryozoa, Brachiopoda, and Mollusca have been compared without profit; the presence of obvious plates forming a base to the test rules out any comparison with the Polyplacophora. The closest affinities are found with sessile echinoderms and barnacles, but objections are found to either assignment.

The possibilities that remain involve more far-fetched analogies and assumptions not capable of proof. The shape of *Tholella* is vaguely suggestive of an ascidian, but that group is unknown in the fossil record, and such assignment would involve the premise that ancient ascidians had skeletons of calcium carbonate rather than of cellulose. It is possible that *Tholella* contained entirely cysts, eggs, or spores, but this seems unlikely in relation to the primary chamber. It is possible in relation to the accessory chambers, but these could as easily be interpreted as budding individuals, which, being covered by new plates which may have been thin and fragile, were more susceptible to destruction than those of the parent. It is, vexingly, not possible to be very certain even as to how the organism that built this remarkable test lived, other than that it was obviously attached to the coral on which it is found. Other far-fetched analogies, including the tests of rotifers, have been considered and rejected as unlikely from the present evidence. Also the possibility that *Tholella* might have been some specialized organ or appendage of the coral is found to lack support; in every instance the epitheca of the coral wall is found beneath the body, and textural differences alone make this unlikely hypothesis the more untenable.

Occurrence. The one species here described is from colonies from the Second Value formation of southern New Mexico and western Texas. Additional material was observed in sections from the Fish Haven dolomite of northern Utah, and similar bodies were observed in the sections in the collection of the U.S. National Museum from the later Ordovician of the Scandinavian region.

Tholella idiotica Flower, n. sp.

Pl. 12, fig. 1-5, 8; text fig. 6-9

The general features of this species have been discussed under the genus, in which it is the only species recognized at present. The bodies are small, showing a maximum observed height of 1.2 mm, and a width usually subequal to the height, though it may be increased slightly where accessory chambers are relatively large. The several observed sections show some variation in form and texture of the plates, and are best discussed individually.

The holotype (pl. 12, fig. 1, 2; text fig. 6; from slide 666a) measures 1.0 mm wide and 1.2 mm high. The main body cavity is enclosed largely by thin plates; on the left anterior surface, two such plates are very clear and show fine transverse laminations. The wall is greatly thickened on the upper right; here individual plates are not clear, but there has been some recrystallization of materials. There remains, however, a pattern in which transverse laminae dominate, suggesting fine imbricating plates overlapping, although the interpretation of secondary thickening of original plates retaining transverse fibrous structure cannot be ruled out. At the lower right, the wall seems incomplete externally, below an obvious plate which is sloping obliquely outward and downward, but excess calcareous material is present internally, within which no definite structure or textural pattern can be recognized. When traced to the right, this material thins and is apparently continuous with part of the wall, though with a separate plate or series of plates beneath it. Matrix within the main cavity contains a considerable amount of calcitic material on the left, and there is a large calcitic body in the lower right showing some fracture. The interior shows nowhere any concentration of carbon that might reflect original organic material, but is uniform in texture and appearance with matrix on the outside. In the lower right there is a small, round accessory chamber completely enclosed by thin plates, which are distinct from a plate bounding the primary chamber, but continuous with the lower of the two layers comprising the base of the specimen. The lower left shows a very small, slightly dissociated body, possibly a second accessory chamber, though it is somewhat detached from the primary chamber in outline and its association could be adventitious. Although the *Catenipora* to which the specimen is attached shows some slight alteration, there is clear evidence of a dark epitheca between the *Tholella* and the fibrous wall of the coral.

A paratype found on slide 665h is shown in Plate 12, figure 3, and some of its more ambiguous structures are more fully interpreted in Text Figure 7. The body is 1 mm high and 1.2 mm wide. The section shows a principal chamber filled largely with calcite. On the left it is broken, and wall plates are missing, and the calcite of the interior shows an irregular contact with the matrix of the exterior. The top is strongly rounded, almost bluntly pointed; to the left of the apex the wall is straight, sloping downward toward the side and straight to the termination of the wall at the broken portion. To the right of the apex there is a small break in the wall through which some matrix has penetrated the interior. The plate forming the top of the capsule seems slightly displaced to the left; thus the opening is quite possibly adventitious. On the right side is an unusually large accessory chamber, which is filled with a mixture of matrix and calcite. This chamber is broadly rounded below, both sides being convex, thus producing a conspicuous excavation in the margin of the lower part of the main chamber. Anteriorly, the accessory chamber is seemingly produced into a narrow neck, and is closed at the anterior end. The calcite here is obscure and not clearly shown in the photograph. The right margin of the chamber is made up of rather vesicular calcite, with no clear evidence of plate structure. The other side is made up of plates; as the wall is traced down from the top, a short bifurcation is seen, the one limb of which is extremely short, the other continuing as the common wall of the two chambers. The wall is greatly thickened as it approaches the base of the body, and there is evidence here of its being composed of a series of imbricating plates. The basal plates are obscure, largely, it is believed, by reason of the extreme thinness of the section.

A curious feature of the specimen is that it was apparently broken, the left side being lost, after calcite filled the principal chamber.

A second paratype, shown in Plate 12, figure 8, and in Text Figure 8, from slide 665g, is seen in a section that is a little too thick to show details of the body clearly. It is approximately 1 mm in height and width. The top shows a low,

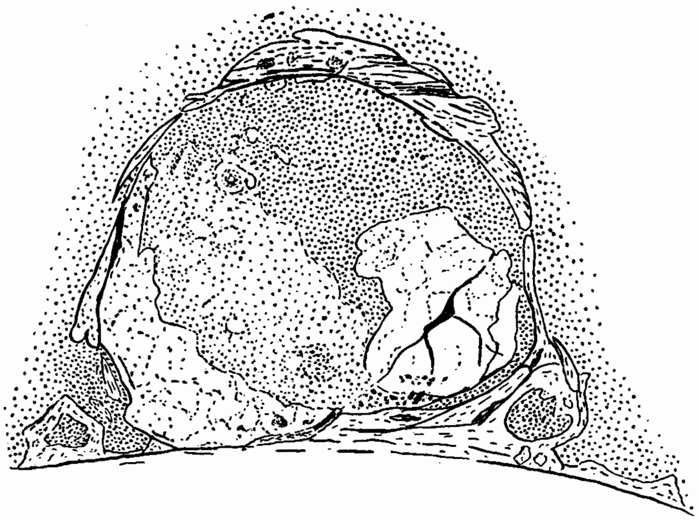

Figure 6

Tholella idiotica. Camera lucida drawing of holotype, ×65, see Pl. 12, figures 1 and 2. The main body cavity is enclosed by numerous thin plates, some showing transverse fibrous structure, others irregular. The wall is greatly thickened on the upper left; whether by imbricating plates or thickening of plates is not certain. A small accessory cavity is present at the lower left, and a smaller cavity, less distinctly joined to the main body, is seen at the lower left. From slide 666a.

blunt, asymmetric point, to the left of which are two flattened areas lying at different angles. The lower right shows the base somewhat extended and underlying a hooklike extension of the body, suggestive of the base of an accessory chamber that is no longer enclosed above. Plates in the wall cannot be made out clearly. The primary chamber is largely filled with calcite, but at the top are two small, round carbonaceous masses. The clearer part of the calcite shows two fine, curved dark lines in the upper left, and another in the lower right, which seem hardly explicable as inorganic, although an attempt to interpret them as parts of the animal which built and inhabited the cavity yields no significant results. If *Tholella* were a cirripede, these bands might be remains of appendages, but absence of joints, evidence of chitinous structure, or definite width to these bands opposes any such interpretation.

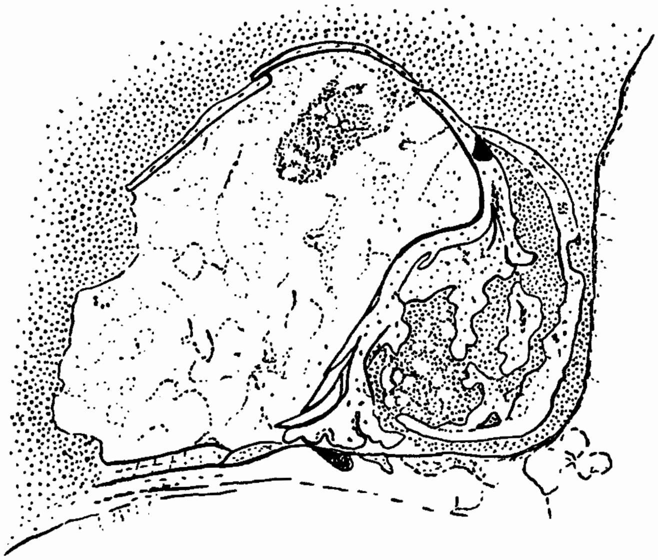

Figure 7

Tholella idiotica. Camera lucida drawing of paratype, ×70, see Pl. 12, figure 3. A large asymmetric cavity is incomplete on the left, but bounded in general by thin plates; its interior is filled with light calcite, with a small amount of matrix penetrating from the opening in the upper right. A relatively large accessory cavity, its wall material somewhat obscure at the top, is filled with a mixture of calcite and matrix. From slide 665h.

A third paratype is shown on Plate 12, figure 4, and in Text Figure 9. This body, from slide 666i, is smaller than the others, which have ranged around 1 mm in width and height; it is 0.5 mm high and 0.6 mm to 0.7 mm in width. Like the others it is a high-arched body, the top somewhat asymmetric. The right side is steep and uniformly curved; the left side is slightly distended below, its wall irregularly thickened, but no accessory chambers are present. Over the top and right side the plates are seen to be composed of fine lamellae normal to the surfaces. A break between plates is clear on the lower right, but elsewhere boundaries of individual plates are not evident. The lower wall of the body is quite thin and indistinct in some places. The interior shows matrix that is finer grained than that of the outside, with several calcitic areas, notably one large calcitic body near the base, a little to the right of the center. The smaller size and the vertical rather than horizontal fibers of the plates, as well as the general indistinctness of plate boundaries, suggest that this may be different from the forms discussed above, but at the present time there is little point in creating a separate name for this solitary specimen. It might also be that these differences represent features shown by a younger individual, an interpretation consistent with the smaller size of this specimen.

A small high-arched body similar in shape to the above was found in a vertical section of a colony of *Manipora magna.* This is shown in Plate 9, figure 6, and is from slide 664-o. The section is a little too thick to show the details of the body.

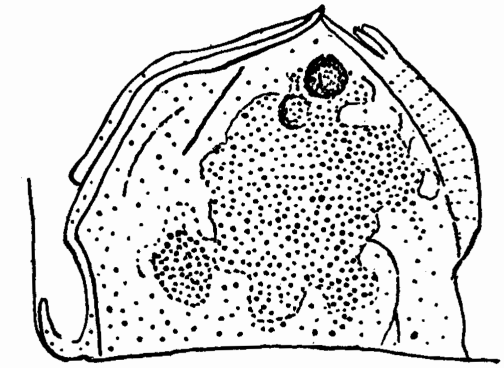

Figure 8

Tholella idiotica. Outline drawing of a paratype, shown in Pl. 12, figure 8, seen in a section rather too thick to show details of this body. Evident is a large main cavity enclosed by a number of plates, largely thin, but on the upper right the wall is thickened and shows fine structure of vertical lamellae. A receptacle, suggestive of an incomplete accessory cavity, is seen at the lower left. From slide 665g, ×60.

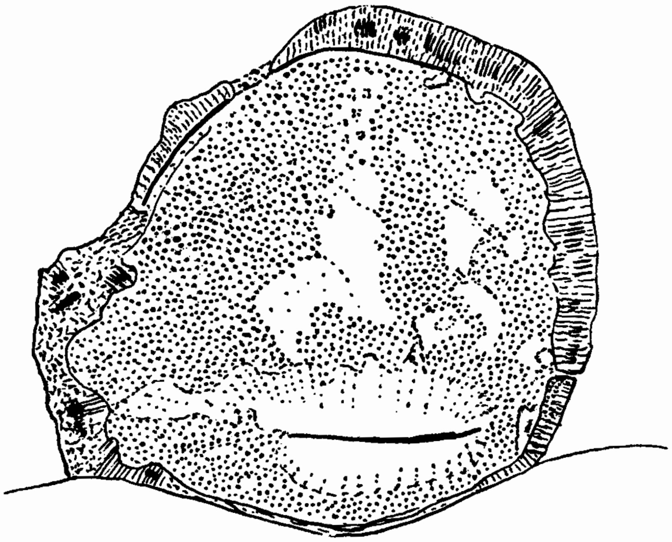

Figure 9

Tholella idiotica. Camera lucida drawing of paratype shown in Pl. 12, figure 8, ×80. This body, slightly smaller than the others, is distinctive in lacking any suggestion of accessory chambers and in showing the wall relatively thick, with individual plates indistinct, but shows in general fine structure of lamellae passing from the inner to the outer surface of the capsule. The interior contains a large calcitic body below; the remainder is occupied with matrix, with some minor calcitic masses.

The height and width are subequal, about 0.7 mm. The base is flat, the body arched and symmetrical, enclosing a cavity that is small and filled with calcite; the wall apparently thickened greatly at the top of the body, which is at the left side of the figure. The plates are not clear, and the tentative identification of the body with *Tholella* rests purely on its general shape and appearance.

Types are noted in detail above, all material is from the Second Value formation of El Paso, Texas, and southern New Mexico.

IVESELLA Flower, n. gen.

Genotype: *Ivesella adnata* Flower, n. sp.

This genus is erected for high-arched, capsulelike bodies, the wall being composed of a single piece, rather than of a series of plates as in *Tholella.* Bases of attachment are greatly thickened. Texture appears homogeneous. A light-yellow color suggests the original material to have been possibly chitinous rather than calcitic.

Only one species is recognized, *I. adnata,* found attached to colonies of *Paleophyllum thomi* in the coral zone of the Aleman. Interpretation of these bodies as egg or spore or cyst capsules is suggested, particularly by the presence of one body in which the distal parts are wanting. Calcite is commonly present within the closed specimens, giving no indication of the contents of the capsule.

Ivesella adnata Flower, n. sp.

Pl. 9, fig. 1-5

Under this name are described some high-arched, thin-walled, hollow bodies found on *Paleophyllum thomi* in the Aleman coral zone of the Franklin Mountains. These bodies are more smoothly rounded than *Tholella,* the walls are thin, and evidence of discrete plates is wanting; perhaps this is not conclusive, for all specimens were found on slides mounted thin enough to show the features of the *Paleophyllum* adequately, but too thick to show the structures of this body clearly. A peculiarity of this form is that the base is broad and thick, and in some cases the slightly yellowish material of the main part of the test is supplemented by additional material, which, whatever its original condition, is now light calcite, having a coarse crystalline structure obviously not pertaining to its original fine structure.

The original of Plate 9, figure 1 (slide 690a), the holotype, is a small body 0.8 mm wide and 0.6 mm high, with a yellowish outer covering, calcite within, and having an apparent opening on the upper right. A second unfigured individual on the same slide shows the top absent and matrix on the interior. Plate 9, figure 2, from slide 691c, shows the same general features, but a slight variation in form. The same slide yielded the original of Plate 9, figure 3, in which the well-rounded cavity is seen on a broad and slightly elevated base. Plate 9, figure 4, from slide 691b, shows again much the same features, the broadened base, the high, rounded test. The same slide yielded Plate 9, figure 5, evidently a larger form, with the base greatly thickened, but only the basal half of the test retained.

Discussion. Although this may be a form very different in nature from the preceding, all observed specimens were found on slides a little too thick to show desired structural details. The presence of one specimen with only the base preserved may be fortuitous, but this whole series of specimens is rather suggestive of some sort of capsule, possibly an early developmental stage of some organism (one is tempted to suggest a spore sac), but the comparison can hardly be carried far. Algae or Protozoa showing such structures would develop them on a much smaller dimension than that of the present specimens.

Types. All types are on colonies of *Paleophyllum thomi,* and are from the southern end of the Franklin Mountains, from the Aleman coral zone. Slides are listed above and in the explanation of plates.

MOUNDIA Flower, n. gen.

Genotype: *Moundia fibrosa* Flower, n. sp.

This name is proposed for a series of remarkable bodies known from a series of tests. They are broadly attached to corals by a flat base; the free side is low arched. They are composed of a series of relatively few thick plates, the plates being composed of finely granular calcite in their present condition, the grains showing a vertical alignment, giving them a fibrous appearance, which is further accentuated by the vertical bands formed where the plates are joined. The bodies are apparently bilaterally symmetrical, longer than wide, the rather small internal cavity commonly communicating with the exterior by an aperture that lies low in one end, which is slightly protracted and is regarded as anterior. Cross-sections show an asymmetrical arrangement of plates on the two sides, suggestive of plates that are polygonal and alternating in position, like those of many echinoderms, rather than in perfectly regular longitudinal rows. A puzzling feature of the genus and its one species is the presence of a number of bodies that are either two individuals growing so close together that they appear as one body with two internal cavities, or a single body in the process of dividing into two. Evidence is not conclusive, but the former explanation seems the more probable of the two.

Discussion. The bodies for which this name is proposed are highly characteristic, although sections far enough off center that the central cavity is avoided may be confused with *Mooreopsis,* and some such sections cannot be determined with absolute certainty. The affinities of *Moundia* are most uncertain. The relatively few large thick plates agree in general with isolated fragments found in the same sections that have been considered as echinoderm fragments. However, the plates of *Moundia* fail in general to show the uniform crystal orientation that is considered characteristic of echinoderm remains. Nevertheless, assignment to the Echinodermata seems to involve fewer objections than assignment to any other known phylum. There are, however, no known echinoderms, fossil or recent, that are at all comparable to the present form. If one is to consider this as an echinoderm, it must be a member of a group hitherto unrecognized. Indeed, to consider it as a possible echinoderm, one must draw upon speculation not capable of proof. If a dipleurula larva were to become attached by its ventral side, and to secrete a series of few relatively thick plates within its tissue, the result would not be unlike the present genus. However, critical examination of this idea shows that there is really very little real evidence in its support and the resemblance to the dipleurula rests mainly upon the elongate shape and the presence of a mouthlike aperture low in the anterior end. If the analogy has any merit, one would expect other openings in the test for the apertures of the coelomic sacs, as well as an anal opening. No such additional apertures have been found, but with the observation at present confined to a half dozen chance-oriented thinsections, the absence of such openings may be more apparent than real. It is, indeed, extremely difficult to say whether some boundaries between plates might represent minute apertures of such a sort as might be expected.

Quite curiously, *Moundia* is vaguely comparable to two genera, *Peridionites* and *Cymbionites,* which Whitehouse (1941) described from the Middle Cambrian of Australia, considering them as archaic echinoderms, and for which the order Cyamoidea was erected. In making such a comparison, however, one is forced into some unproved assumptions. *Moundia* certainly differs from both of these forms in being attached, and in having a well-developed ventral layer. Can it be that the Cyamoidea were also attached originally and had a "dorsal" layer comparable to the "ventral" layer of *Moundia,* but that the flat region of attachment was lost when the dorsal cups of these two genera broke away and became free? Closer examination of these genera reveals some profound differences from *Moundia,* and raises the question whether any real relationship exists among the three genera. On the other hand, if there is no relationship, we are left without any forms that are close relatives of *Moundia.*

Peridionites is an elongate body composed of five thick plates forming a cup. One can see in these plates a general analogy to the dorsal arched part of *Moundia;* indeed, if the arched, distal part of *Moundia* had broken away and were found separated from the matrix, it might be quite similar in general appearance. How close the similarity would be cannot be determined with certainty. Present evidence suggests that the dorsal part of *Moundia* was quite possibly composed of a greater number of plates than those comprising *Peridionites.* The plates of *Peridionites* show in thinsection a texture that is not at all similar to that of *Moundia.*

Cymbionites is a thick-walled, cup-shaped body, round, and composed of five plates. In its circular form it is more remote from *Moundia* than is the elongate *Peridionites.* The plates of *Cymbionites* show, in thinsection, a fibrous structure more akin to that of *Moundia* than are those of *Peridionites,* but *Cymbionites* shows a finer texture, and there are significant transverse as well as radial or longitudinal elements involved, for which no counterparts can be found in *Moundia.*

On the one hand, these two genera assigned to the Cyamoidea seem to be the only fossil bodies that are at all similar to *Moundia,* that have been described previously. On the other hand, there are such differences in form and texture of the plates that one can question whether either is really related to *Moundia,* or whether the two, *Cymbionites* and *Peridionites,* are necessarily related to each other. It is quite curious that the writer and Whitehouse independently (I had overlooked Whitehouse's paper earlier) concluded that these three peculiar types of fossil remains were more logically assigned to the echinoderms, and in doing so both students invoked the development of skeletal plates in the wall of a dipleurula-like animal.

Although it seems that all three of these genera are questionable as echinoderms, and some objections, based mainly on the texture of the plates, can be offered in opposition to such an interpretation, no other affinities have yet been suggested. *Moundia,* in possessing a series of basal plates, cannot be interpreted as a tiny fossil polyplacophoran, which the low-arched form and presence of relatively few plates in a series of linear rows might suggest. The Polyplacophora, to be sure, have a single longitudinal series of plates, but one could visualize such plates as having folded edges, which could possibly produce some aspect similar to that shown in the sections of the dorsal part of *Moundia.*

The facts of which we can be certain from the present material are not very conclusive as to the position of *Moundia.* It was clearly an elongate, bilaterally symmetrical body; there is every reason to believe that the plates were arranged regularly, although the present material does not permit a clear analysis of their number or arrangement. The aperture low in the anterior(?) end suggests an animal that was active metabolically; the possibility suggested for some associated forms, that they might be capsules for eggs, spores, or cysts, seems here most unconvincing. It is not possible to say with certainty whether the plates of *Moundia* were secreted in tissue, or upon a specialized secreting surface, although the former explanation seems the more convincing. It is clearly an animal, and an animal above the coelenterates. As one in which possibly plates were developed in the wall, the phylum Echinodermata is suggested. In spite of objections to such an assignment, it seems to be the only one which is even remotely possible from the known invertebrate phyla. Analogy with *Peridionites* and *Cymbionites* is perhaps more interesting than real, and is no good evidence of position, for the assignment of these forms to the Echinodermata seems equally questionable.

The presence of some bodies that are either two individuals fused so that their outlines are indistinct, or a dividing individual, injects another complication in the problem of relationship. The former interpretation seems the more probable, as, from the above considerations, it seems probable that this organism belongs among the higher invertebrate phyla, where such growth is not commonly developed. Indeed, budding or dividing individuals are very largely confined to the Porifera, Coelenterata and Protozoa, and there is little support in the known features for assigning *Moundia* to one of these groups.

Moundia fibrosa Flower, n. sp.

Pl. 10, fig. 9-11; pl. 12, fig. 11, 12; pl. 9, fig. 21-22 (pars); pl. 5, fig. 6 (pars); text fig. 10

These bodies have essentially the characters of the genus, low-arched bodies attached to *Catenipora* (the genus of coral is not necessarily diagnostic, but thus far specimens have been found only on that genus), with thick walls of plates showing fine vertical fibrous structure, a central cavity open to the exterior through an aperture in one (anterior?) end, which is slightly more prolonged than the other (posterior?) extremity. The observed individuals are never more than 1 mm high, and are 1.5 mm wide and 2.0 mm long. The clearest longitudinal section, from slide 665i, is shown to the right in Plate 10, figure 11, and in more detail in Plate 12, figure 12; also to the right in Text Figure 10A. Walls are fairly uniform in thickness, showing a decided contrast between the flat base and the gently arched top. Low in the left side, actually below and behind the anterior angulation separating the base and the top, is a clear aperture connecting the central cavity with the interior. The walls consist of vertically aligned granules, and show further rather obscure division into a series of plates. The dark band projecting from the central cavity to the upper right is somewhat difficult of interpretation, but it appears to be a contact between two plates rather than a canal-like opening through the test, although such an interpretation is not strictly impossible. Light calcite lining the central cavity is irregular and does not suggest an organic structure, but there is a possibility that it may involve a very thin original lining of calcite, lighter than that composing the main part of the test and lacking the granular structure that characterizes the thick plates.

Plate 12, figure 11, shows two sections that are symmetrical, and therefore seem to be transverse rather than longitudinal sections. Both show a division into plates and suggest, allowance being made for some replacement or recrystallization, that the plates were arranged symmetrically. It is not, however, possible to come to a certain conclusion as to the number of plates across the top, and the arrangement on the two sides is not identical. Such a condition may indicate a dorsal series of plates and a more complex lateral series of polygonal plates, which would appear thus in sections that were not perfectly transverse. The smaller body to the left suggests three plates across the top, and on the sloping sides two upper small lateral plates and a larger one extending to the angle between the top and the base. Division of plates across the base is obscure. The larger body on the right shows a contrast between the two sides, making interpretation of plates difficult, but there is a broad region at the top, of one or more plates, to the left of which are two or three small dorsolateral plates. The corners formed by junction of the arched top and the flat base seem on both sides to be of individual plates that do not reach to the central cavity. The base, which thins centrally, is apparently of more than one plate, but again precise determination is not possible. The body shown in the upper left of Plate 10, figure 11, is one of the longest observed. A slight emargination near the left end is possibly the edge of a normal aperture. The central cavity appears reduced to a few dissociated dark irregular areas. The thick walls show typical granules, but the usual radial alignment is poorly developed, and boundaries between individual plates are not apparent. The body in the same figure at the extreme left is slightly asymmetric, but is an essentially transverse section, showing vertical alignment of fibers in the plates and obscure plate boundaries. In this section the base is thickened centrally instead of being greatly reduced in thickness as was seen in Plate 12, figure 11.

In Text Figure 10 are shown three successive sections from the same portion of a colony. Unfortunately, the relationship of the section shown in 10B to the others is not evident, but 10A and 10C are from two sides of a single cut. Obviously, the single individual shown in 10C, which is an oblique section, but nearly longitudinal, cannot be the same individual as that at the left of 10A, which is essentially a transverse section. Text Figure 10A shows two individuals not present in 10C. Text Figure 10B shows a very different situation. At the left are two bodies so grown together that their outlines are not distinct; they are superimposed upon a bryozoan growing on the *Catenipora*. To the right is a third body, more distinctly separated. Certainly none of the same individuals is present in 10C, and it is very doubtful whether either of the individuals to the left of 10A is properly identical.

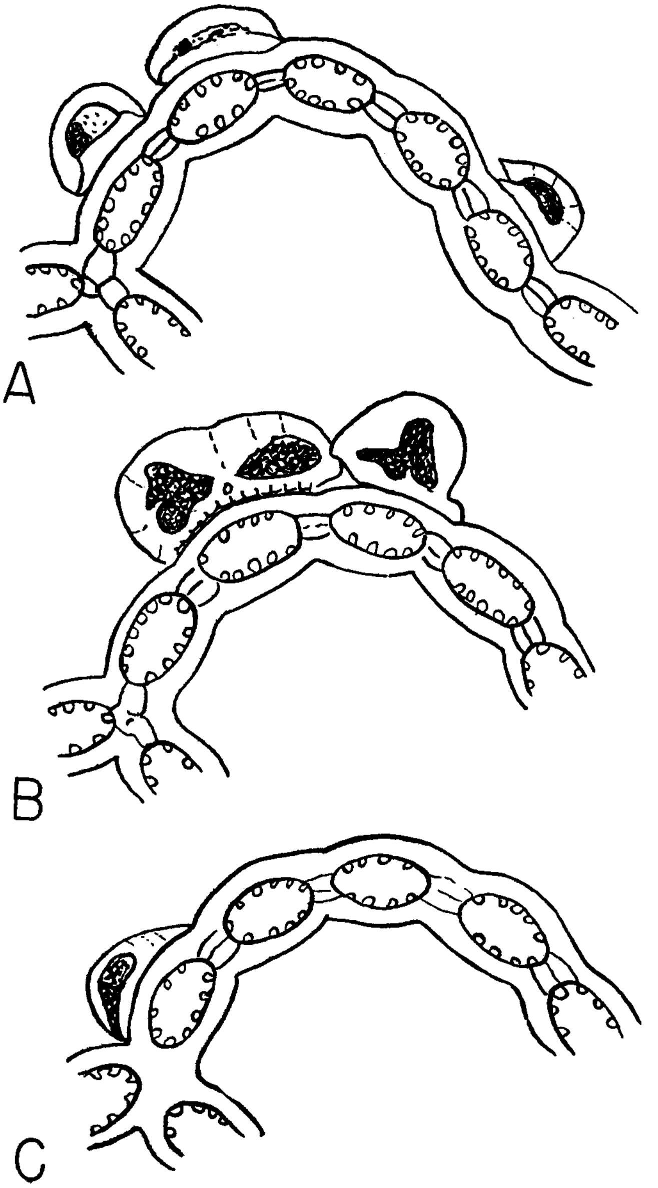

Figure 10

Three adjacent sections, 5 mm apart or less, through the same portion of a colony of *Catenipora workmanae*, showing attached *Moundia fibrosa*. The actual sequence of the three sections is, unfortunately, unknown, but together they show that these bodies are of relatively slight vertical extent on the colony. All ×10.

A. From slide 665i, shown in Plate 10, figure 11; shows three distinct bodies.

B. From slide 665n, shown in Plate 10, figure 10; shows at the upper left either two closely fused bodies or a single body with a double cavity, overgrowing a bryozoan attached to the *Catenipora;* contiguous, but more distinct in outline, is a third body at the right.

C. From slide 665k; shows a single body, which by its position is distinct from any of those shown in the previous sections.

The same sections show, in another region, the association of bodies shown in Plate 9, figures 21 and 22. These two sections are mirror images, from opposite sides of the same cut, but in addition to reversal, figure 22 is revolved 90 degrees to the right in reference to figure 21. In figure 21 the curved rank of *Catenipora* to the right shows two bodies suggestive of *Moundia*, one incompletely closed, the other containing two cavities. The mirror image of this part of the section is seen at the top of figure 22, where two closely appressed bodies, each with its own cavity, are distinct texturally, their contact being a sharp boundary. The extreme left side of figure 22 shows, a little below the center, a section through a body that appears solid here, but consists of several distinct plates and is regarded as a section through a *Moundia* so eccentric that the cavity of the interior is not shown. In the lower part of figure 21 are two bodies suggestive of *Moundia,* but believed not to pertain to this organism at all; they are far too large and irregular in structure. To the left is a large body with an irregular central cavity, thickened where it is attached, below, to the *Catenipora.* A smaller body, with two cavities, is attached to its side. Counterparts of these bodies in figure 22 are more suggestive of chance-oriented sections close to the beaks of brachiopods than of anything else, but in both sections it is evident that the texture and the absence of well-defined plates distinguish these bodies from *Moundia.*

The body shown in Plate 10, figure 9, and in Text Figure 10C is unusual in that the internal cavity is centered a little to left of the center, and it is on this side that the greatest height is attained. There is a suggestion of an aperture on the base close to this end, as in Plate 12, figure 12. The rather unusual symmetry may be explained as a section that is subcentral to the left but eccentric to the right.

Discussion. There seems little doubt as to the specific identity of the bodies here figured in Plates 10 and 12, although the identity of the bodies in Plate 9, figures 21 and 22, remains somewhat doubtful. The *Catenipor*a colony shown in Plate 5, figure 6, shows reversed the three bodies of Plate 10, figure 11, at the top, and almost directly below, in the bottom third of the picture, are the two bodies shown in Plate 12, figure 11.

Syntypes. All observed specimens are from a single colony of *Catenipora workmanae,* No. 665, shown on slides 665i, k, and n. It is from the Second Value formation of the southern Franklin Mountains, near the crest of the Scenic Drive, El Paso, Texas.

SLOCOMIA Flower, n. gen.

Genotype: *Slocomia quadrata* Flower, n. sp.

These bodies are subquadrate in cross-section, the free sides tending to be irregularly rounded, particularly at the corners. The attached portion has a thick continuous wall, the free surface extensively and apparently irregularly porous; the inner surface of the wall is extended in short processes into the internal cavity.

Slocomia quadrata Flower, n. sp.

Pl. 12, fig. 10.

Only the best example of this form is figured, the holotype, from slide 666f. It is attached at the corner of two joined branches of *Catenipora;* both attached surfaces broad, flat, conforming to the surface of the corallites. It is 2 mm long, 1 mm high, and subquadrate. The upper surface appears as a series of discontinuous, irregular bits of calcite, indicating a surface that was extensively pierced by tiny pores. Irregular processes of calcite extend from the solid walls into the cavity, but differentiation of organic and inorganic structures here is not certain.

Discussion. This is evidently an elongate, broadly attached test, the upper surface of which is extensively perforate. Its affinities remain highly uncertain.

Type. From slide 666f, from a colony of *Catenipora* from the Second Value formation of the Cooks Range.

HARJESIA Flower, n. gen.

Genotype: *Harjesia anomala* Flower, n. sp.

These are tiny bodies, vasiform or flask shaped, irregularly rounded, and slightly elongate, the free end extended into a short neck. The wall is thick and calcitic, with embedded dark bodies, mainly in the form of very short rods with bluntly rounded ends. The central cavity is occupied by a single, solid calcitic body, margined with dark material.

Harjesia anomala Flower, n. sp.

Pl. 11, fig. 7.

The figured type is the only specimen observed; 1.4 mm long, 1.2 mm wide; outline quite irregularly undulate, not quite symmetrical; surface entirely of light calcite, apparently recrystallized, and showing only calcitic structure; similar material forms interstices of the dark-brown rods within the wall, at first suggestive of a calcitic structure with a meshwork of pores, but the material seems distinct from the matrix. The central cavity shows a single calcitic body with a dark boundary.

Only one specimen has been observed, and it seems quite possible that the section, if central, should show the central cavity opening through the neck.

Affinities of this peculiar form are most uncertain. Nothing else in these sections has been found showing similar structure. The possibility that the brown bodies could be pores or cavities seems opposed not only by their texture, but by their failure to penetrate the light calcite that forms the surface. Similar saclike bodies with necklike extensions are found in the statoblasts of sponges, but largely in siliceous fresh water forms. None is known to be sessile, as is this object, and their walls are composed of fused spicules coarsely arranged, but no such interpretation is possible from the present specimen. No other possible affinities have suggested themselves; the form could be accepted as a possible protozoan, but nothing closely similar is known. As such ancient Protozoa are scarcely known, except for Radiolaria, it is impossible to determine what their limits of form in the Ordovician should be.

Holotype. Slide 666f, from a colony of *Catenipora* from the Second Value formation of the Cooks Range, New Mexico.

KRUSCHEVIA Flower, n. gen.

Genotype: *Kruschevia verruca* Flower, n. sp.

These are small fibrous narrowly elevated bodies, the tip narrowly rounded, rarely bifurcate.

Kruschevia verruca Flower, n. sp.

Pl. 10, fig. 3, 4; pl. 11, fig. 12 (pars)

Of these bodies, only two are figured, although they are not uncommon. They are all very small, ranging in height and width from only 0.2 mm to 0.3 mm. The holotype, Plate 10, figure 3, from slide 666f, shows an outer continuous layer and a central layer, both showing transverse lamellae faintly upcurved at their edges. The coral holotheca, though faint, seems to continue beneath.

A second figured body of similar form, Plate 10, figure 4, shows three parallel small, arched, light bodies across the base, above a distinct epitheca, but the top portion contains one central light body surrounded by a thick margin of darker fibrous material.

A similar pointed body is shown on the right of Plate 11, figure 12 (from the same slide), but here light calcite is present, and the structure is obviously altered.

Affinities of this form remain dubious.

Holotype. From slide 666f. Paratypes, slide 665k, from *Catenipora* colonies of the Second Value formation, 665 is from El Paso, Texas, 666 from the Cooks Range, New Mexico.

MOOREOPSIS Flower, n. gen.

Genotype: *Mooreopsis rotundus* Flower, n. sp.

This genus is erected for broadly sessile bodies of calcitic material, finely granular in texture, with rare faint radial alignment of granules, lacking central cavities.

Mooreopsis rotundus Flower, n. sp.

Pl. 10, fig. 1, 2, 6 (pars), 7, 8; pl. 9, fig. 21 and 22 (pars)

This species, represented by a number of specimens shown in various sections of *Catenipora,* appears as small round bodies, broadly attached on one side and apparently hemispherical in form, in longitudinal section. Occasional free bodies have been observed which appear round; orientation is, of course, uncertain without definite evidence, which is lacking, but these may well be transverse sections parallel to the base of attachment. The several representatives of this form, regarded as syntypes, are described separately.

Plate 10, figure 1, shows a section through a body (from slide 665k) round above, attached at the concave interspace of two corallites, showing a free, somewhat irregularly rounded surface, with granules faintly aligned in a radial pattern. The oblique light band passing from the center to the upper light appears to be a phenomenon of recrystallization. The body is 1 mm across.

Plate 10, figure 2, shows a relatively tiny mass, with a central well-rounded lobe and two smaller lobes, one on either side. Very faint dark lines separate the middle lobe from those on its two sides. Texture is granular, without any suggestion of radial alignment. The total width of the body across its base is 1 mm. Without a clear indication of the nature of this body, it is impossible to say whether it represents three individuals in juxtaposition, or whether the two small bodies on the sides have grown from the larger central individual. The specimen is from slide 665i.

Plate 10, figure 6, shows a typical representative of this form in the upper left. In attachment and outline this specimen, from slide 665k, resembles the one shown in figure 1, but the texture is granular, with no trace of radial alignment of granules. A black spot is seen in the center, irregularly enclosed in a thin dark-brown line. In the lower left of the same figure is a body similar in shape and size, but composed only of clear calcite; it may well be a similar body, but one in which the fine structure has been lost. The body in the upper right is a different form, *Eliasites pedunculatus.*

Plate 10, figure 7, from slide 665i, shows attached to *Catenipora* two joined round bodies, the larger one on the left showing a narrow, dark, sharply defined ring at the center. Above is a free body, round and faintly elongated in the plane of the section, which agrees perfectly in texture and is regarded as a horizontal section through an individual that has been broken free.

Plate 10, figure 8, is a perfectly semicircular body, homogeneous in texture, from slide 665k.

Some similar bodies are shown in Plate 9, figures 21 and 22, which are sections from opposing surfaces of a single cut through a *Catenipora* colony. In the lower part of figure 21, just to the right of the center, a similar body is seen attached on what appears to be a bryozoan colony. In figure 22, a similar body is seen in the extreme upper left. Intersected by the left margin, just below the center, is a single, rather larger body, which resembles *Mooreopsis* in lacking any apparent central cavity, but there is a suggestion of division into three plates, which suggests instead a *Moundia fibrosa* cut transversely probably near the posterior end, for no cavity is shown.

The series of specimens figured in Plate 10 are regarded as syntypes. All are found on colonies of *Catenipora workmanae* in the Second Value formation, and are from a colony from the southern end of the Franklin Mountains, near the crest of the Scenic Drive, El Paso, Texas.

The affinities of these bodies remain uncertain. In texture they agree not only with occasional free, round, solid bodies, but with round bodies with central cavities, which would ordinarily be interpreted as sections of segments of echinoderm stems. It is, however, admittedly difficult to visualize these calcitic bodies as organic, but this condition is shown amply by their uniformity in form and texture, and their general development as bodies adhering to colonies of *Catenipora.*

ELIASITES Flower, n. gen.

Eliasites pedunculatus Flower, n. sp.

This is a round, evidently spherical body with a thick fibrous wall composed apparently of relatively few plates, and with a central cavity half the diameter of the whole; it is attached to a *Catenipora* colony by a short neck or stalk, broadened at the point of attachment.

Eliasites pedunculatus Flower, n. sp.

Pl. 10, fig. 6 (pars)

The holotype is the only body of this sort observed; it measures 0.8 mm high and 0.9 mm across. The wall is thick, the cavity within about half the exterior surface in diameter. The wall shows fine radial fibers and coarser regional dark bands suggestive of the margins of a series of plates. The inner cavity is roughly rounded, but the wall extends inward, forming several narrow, short, pointed processes. On the lower surface the round exterior is slightly retraced where it meets the very short peduncle, which is hollow internally at the base.

Affinities of the form are uncertain. The apparent several thick plates suggests an echinoderm, but such an interpretation is obviously faced by the objection that no even remotely similar echinoderms are known, although interpretation as an extremely early stage of a cystid seems not impossible. The apparent development of several plates opposes interpretation as a foraminiferan, and other test-bearing Protozoa seem unlikely from size and texture.

Holotype. From slide 665k, from a colony of *Catenipora,* from the Second Value formation of the southern Franklin Mountains, from near the crest of the Scenic Drive, El Paso, Texas.

CHENEYELLA Flower, n. gen.

Genotype: *Cheneyella clausa* Flower, n. sp.

This is a tiny low-arched body, the surface covered with a rather thick plate; within are dark fibrous lines converging from the broad base to the more restricted top.

Cheneyella clausa Flower, n. sp.

Pl. 11, fig. 10

The species has essentially the characters of the genus. The one observed specimen is small, 0.7 mm long and only 0.2 mm high. As seen in the figure, the plate forming its top is thick and well developed from the left margin to slightly beyond the center, but is not apparent on the right, where apparently inorganic calcite is encountered. The dark lines, converging upward, found within, give the interior a curious fibrous aspect, but one completely unlike the fine fibrous walls of *Moundia* or *Mooreites.* Instead, the general aspect is highly suggestive of small bryozoan tubes, but how such tubes could be found enclosed in such a covering can hardly be explained. The analogy is, however, the only one suggested by the proportions and texture of other materials in the same sections.

Type. The type is from slide 666a, from a colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

NICCUMITES Flower, n. gen.

Genotype: *Niccumites oculatus* Flower, n. sp.

This genus is erected for small round bodies of fine-grained, seemingly granular calcitic material, apparently spheroidal or with poorly developed flat surfaces, some sections being obscurely polygonal. These bodies, never flattened basally, are attached to colonies of *Catenipora* by irregular masses of what is now clear calcite, though with occasional foreign inclusions. Most of the bodies show fine granular texture and prominently dark surfaces. One, however, shows a conspicuous small dark center. It is believed that this represents a relatively central section, and that other sections, showing bodies of smaller diameter and lacking any central structure, represent eccentric sections.

The appearance of these remarkable bodies suggests a thick-walled calcitic resting stage, possibly originally attached to the colonies of *Catenipora* by a relatively resistant gelatinous substance in which, upon occasion, foreign bodies may have been included; several individuals show one or two large sand grains involved in the calcite. Such material was apparently resistant enough to retain much of its substance in the face of deposition of surrounding matrix, but later disappeared, leaving a cavity to be filled with coarsely crystalline calcite.

Niccumites oculatus Flower

Pl. 11, fig. 1, 8, 9

The holotype, from slide 666j, Plate 11, figure 1, shows a round body of fine-grained calcite, seemingly granular in texture, with a small dark center and a conspicuously dark margin, partially embedded in a mass of irregular coarsely crystalline calcite, which does not quite surround this body but is broadly in contact with the exterior of a rank of *Catenipora.*

A second specimen from the same slide, Plate 11, figure 8, shows a smaller granular calcitic body lacking a dark center, but showing a dark margin which, instead of being evenly rounded, exhibits obscurely flattened faces. The coarse calcite by which it is attached to the rank of *Catenipora* completely encloses the central granular body, but contains at the top, just to the left of the center as seen in the section, a clear body that represents a sand grain. The enclosing calcite shows a surface largely composed of slightly concave intersecting arcs. A third specimen, a paratype, from slide 666*l*, shows the central body somewhat elongated and narrowed basally, the whole enclosed in a very thin calcitic covering, which extends for some distance as a process away from the main body on the lower left.

Discussion. Several more of these bodies have been seen in sections that are not figured, as they fail to show any further variations in structure and aspect. One of these agrees with Plate 11, figure 8, in showing more sand grains included in the calcitic covering. These bodies are so nondescript in nature that the organic relationship of the round, granular central body and enclosing coarse calcite would not have been accepted had it not been shown consistently in a number of individuals, all of which are broadly attached to ranks of *Catenipora.* The interpretation noted under the generic discussion seems the only logical one possible, but unfortunately gives no real indication as to the taxonomic position of this form. It should be noted that for either an egg, spore capsule, or cyst, it appears that the thickness of the wall of this body is out of all reasonable proportion to the extremely small center.

Types. From slides 666j, holotype and one paratype, and 666*l*, a second paratype, all from a colony of *Catenipora* from the Second Value formation of the Cooks Range, New Mexico. Apparently the colony came from the basal layers of the Upham limestone, for it is only in this horizon that scattered grains of quartz sand are common.

CYSTOSPHAERA Flower, n. gen.

Genotype: *Cystosphaera rotunda* Flower, n. sp.

This genus is erected for a spherical body covered by small thin plates, attached by a broad neck that expands to a broader area of attachment. The thin walls enclose a series of round, thick-walled calcitic bodies, the wall more than two-thirds the radius, with dark centers.

Discussion. This is one of the most striking of the organic remains found attached to colonies of *Catenipora.* As a thin-walled round body containing thick-walled smaller round bodies, it suggests numerous structures connected with encystment or development of resting stages, or even of spores, found in various invertebrate groups, but the parallel seems unconvincing, as all these structures seem to be formed in relatively soft tissue. Its general similarity to the sexual organs of some Hydrozoa raised the question as to whether this could be a reproductive stage of the *Catenipora.* This seems most unlikely, as the continuation of the epitheca below the body shows that it grew on the coral, but there is no evidence of any connection of its cavity with the cavity in the corralite. Indeed, such an interpretation would be most remarkable, and consideration of the hypothesis gave rise to another question; namely, whether *Catenipora* could be a Hydrozoan rather than a true coral. Close examination of the structure of the genus reveals numerous points in common with other corals. The fibrous walls, the holotheca, the septal spines, and the development of poikiloplasm all confirm the affinities of *Catenipora* and the Halysitidae with the fibrous-walled cerioid corals *Lichenaria* and *Saffordophyllum*. As all known Anthozoa show reproductive bodies not on the outer surface, but attached to mesentaries in the body cavity, no such interpretation is tenable.

Resting stages of various organisms have been considered in searching for the affinities of this form. The large size of the object, many times that of the spore-forming stages of various of the Protozoa, makes any analogy with members of that group unconvincing. The same applies to the simpler of the algae, although it seems that among the more specialized and larger forms, some parallel might be found. The writer has not been able to find a record of strikingly similar forms, but such a search requires a remarkably complete library, which was not available. In the Animal Kingdom various comparisons have been considered, including sponge statocysts, an unlikely interpretation in view of the broad attachment and short broad neck. Indeed, it is the neck, and the continuity of the internal cavity into the neck, that opposes any interpretation involving some egg or egglike object attached to the coral colony; rather, all that is known of this body suggests that it grew from something smaller, and was not something attached by any possible parent. A striking, if incredible, parallel is found in the resemblance of this body to cyst stages of some of the Cestoda of the Platyhelminthes.

From the viewpoint of general appearance and texture, the material most similar to that comprising *Cystosphaera* is found in various small colonies of Bryozoa, largely Trepostomata, in the same sections. However, this parallel seems as fruitless as those suggested previously; resolution of this body as a bryozoan colony proved impossible.

Although close affinities with no major fossil group can be demonstrated, one necessarily returns to the suggestion that this was a thin-walled capsule containing cysts, thick-walled spores, or some analogous reproductive stage of some organism; it developed from some smaller beginning in place upon the exterior of the coral, and apparently, when mature, the wall broke away, freeing the thick-walled bodies. This is a process that occurs in a variety of lower organisms, both plant and animal. The present condition of the body is calcitic, and from the detailed retention of fine structure it seems unlikely, though one could hardly say that it was impossible, that it might be a histometebatic replacement of some other substance. If the writer can offer no certain interpretation for this remarkable body, some cold comfort is derived from the reflection that no one who has seen the sections or the photographs has been able to do any better. The form remains one of particular interest, as nothing of this sort has been previously recognized in the fossil record.

Cystosphaera rotunda Flower, n. sp.

Pl. 11, fig. 2, 3

The species has essentially the characters of the genus. The bodies are at the most 1 mm across and 1.1 mm high. The holotype, slide 666a, Plate 11, figure 2, show a broad base of attachment, beneath which the holotheca of the corallite extends as a thin dark band. The area of attachment contracts abruptly to a short broad neck, which enlarges distally, merging in the round main body. The surface is seen well on the right side, where it is composed of numerous very thin small plates, which can be traced from the distal end well down into the neck; in the neck they are covered by homogeneous granular material on the outside. At the top the wall is broken, and matrix has penetrated the cavity slightly; to the left of the break a plate is clearly seen, but most of the left side below this, and continuing down into the neck, is without plates, but the irregular surface suggests some slight damage. Calcite within the body shows clearly four oval thick-walled masses. The two on the left, which are cut nearly, if not completely, through the center, show dark centers, less evident in the two on the right. The remaining calcite is marked by lines that in appearance suggest that the section has cut other similar bodies well off center. In the lower part of the cavity similar bodies possibly continue, but the structure there is less clear.

A paratype, slide 666f, shown in Plate 11, figure 3, shows a section through a similar body, but the plane of the section is well off center, and though the distal round portion is intersected, the neck is not retained. Here again the body contains four rounded masses; the one on the right has had the distal part removed. The wall is indicated on the left side, though somewhat less clearly than in the holotype, and individual plates cannot be made out. The body here is 0.7 mm across.

Types. Sections 666a and 666f, both from the paratype colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

PEDICILLARIA Flower, n. gen.

Genotype: *Pedicillaria bifurcata* Flower, n. sp.

This is an astonishing body; a stalk narrows from a broad base of attachment, terminating in a bifurcated tip. Distally, stricture is longitudinal and fibrous; basally, the material is composed of small rounded masses.

Pedicillaria bifurcata Flower, n. sp.

Pl. 11, fig. 4, 5

This perplexing beast is only 1 mm in length. The base is broadly attached to the colony of *Catenipora,* showing fibers at the lower part, sloping parallel to the two sides. Above this region, and occupying the whole of the length of the basal part, the material is composed of round calcareous bodies closely packed. These are shown in Plate 11, figure 5, with somewhat more clarity than appears to the eye, by photographing for extreme contrast. Above the lower portion is a short region in which calcite is darker; the contrast used in obtaining figure 5 causes this region to resemble the matrix, a condition that is obviously untrue. Actually there is here a small semicircular body, the flat side lying on the base. Above is longitudinally fibrous material bifurcated at the tip. The dark band separating the lower prong of the tip is exaggerated by the contrast shown in Plate 11, figure 5, and is a brown discoloration leading to a tiny black body lodged at the base of the bifurcation, but not, seemingly, a part of the original structure.

Discussion. This odd body is vaguely suggestive of some of the pedicillariae of echinoderms, a resemblance that is certainly adventitious. It is clearly not a part of the coral, for the epitheca continues below it.

Holotype. On slide 666a, on a paratype colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

TUBE BUILDERS

Few organic remains may be more nondescript, or less informative of the nature of the animals that made them, than simple tubes, solitary or branching. Tubes attached basally and free distally occur in a wide assortment of fossil groups; they occur in the Protozoa and Hydrozoa; some sponges may take this form; they may be produced by the Annelida or various lesser groups of coelemate "worms." They appear in the Bryozoa and in the graptolites, now recognized as Chordata; and such structure seems foreign only to the Mollusca, Arthropoda, and Echinodermata.

In relation to the fossil record, there are no forms recognized as forming calcareous tubes attached only at the proximal end among the Protozoa. Such forms would be expected in the Hydrozoa, but only ten genera tentatively assigned to that group in the Paleozoic are known in which tubes form long branching or pinnate colonies. Our present forms do not resemble the previously described forms at all closely. Tubes produced by annelids vary widely in form and composition, but in general they tend to be irregular in form, and are more often attached along their entire length than only at the base. The simpler Bryozoa develop loose and irregular colonies, and comparison within that group has seemed more rewarding. Objections exist, however, and although one might expect that forms similar to some of those described below should have existed in the Early Paleozoic, as yet no forms have been described that seem really closely similar to the ones described here.

The types, described in more detail below, may be summarized as follows:

Ampulites. Small, short, free, vase-shaped tubes.

Ancestrulites. Small colonies of few short, parallel-sided tubes, suggesting early stages of Bryozoa, but anomalous in their large size.

Wellerites. Long, slender tubes, attached basally, one budding from at or close to the base of the parent. In spite of obvious objections, this form alone seems logically interpreted as one of the simpler Bryozoa.

AMPULITES Flower, n. gen.

Genotype: *Ampulites vasiformis* Flower, n. sp.

These are small, simple, single tubes, circular in section, broad basally, contracting to a neck, and expanding slightly beyond; basal area prior to constriction longer than anterior necklike part.

Again affinities are doubtful, for the kinds of organisms capable of building such small short tubes could belong to the Protozoa and various of the worm phyla, including the rotifers, which are not known as fossils at all. The vaselike shape suggests a minute sponge, but the thin calcitic wall lacking pores opposes any such interpretation. They are, again, too large for any known Bryozoa.

Ampulites vasiformis Flower, n. sp.

Pl. 9, fig. 16

The most complete of these bodies, shown on the left of Plate 9, figure 16, is a vase-shaped tube with a body contracting over the lower two-thirds of its length, then flaring; rather like an Erlenmeyer flask with an expanded neck. The tube is 1 mm long, the wall thin, calcitic; composed of irregular calcite crystals; plainly, all original structure is lost by alteration. The small round body beside it could easily be a similar body seen in cross-section.

Type. The holotype, on slide no. 666i is from a colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

ANCESTRULITES Flower, n. gen.

Genotype: *Ancestrulites tubiformis* Flower, n. sp.

These are short, calcitic, tubular thick-walled tubes, forming small colonies, individuals budding from near the base of attachment.

Discussion. These forms in section appear almost as textbook diagrams for the early stages of some Bryozoa, but their walls show none of the textural features possessed by members of that group, and these tubes are 8-12 times as large as those of any associated Bryozoa. Affinities are uncertain; from what can be learned of these forms they are equally convincingly considered as large and peculiar Foraminifera, or as tubes built by some kinds of annelids, although admittedly neither interpretation is very satisfactory.

Ancestrulites tubiformis Flower, n. sp.

Pl. 9, fig. 18, 20

Individual tubes are cylindrical and slightly irregular, the interior thickened at the base; maximum length 1 mm, width about 0.5 mm. The holotype, at the left of Plate 9, fig. 20, shows one long complete tube in the plane of the section, and two others cut obliquely by the plane. On the right is a second specimen, in which all tubes intersect the plane of the section. Both are from slide 666c. Two similar tubes, more widely separated basally and much the same in dimensions, are shown in Plate 9, figure 18, from slide 666f.

Types. Holotype, on slide 666c; paratypes, slides 666f and 666c. All are found in a colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

WELLERITES Flower, n. gen.

Genotype: *Wellerites gracilis* Flower, n. sp.

These are small (about 1 mm long and 0.3 mm wide), slender calcareous tubes; walls calcareous, homogeneous, forming small attached colonies; tubes branch, separation always at the bases, never from the distal ends.

The genus is named for Dr. J. M. Weller in recognition of his discovery of the impingement of genetics on paleontology.

Wellerites gracilis Flower, n. sp.

Pl. 10, fig. 5

One section (slide 665k) shows growing on the side of a colony of *Catenipora* a series of long, very slender calcareous tubes, loosely and rather irregularly arranged, but apparently growing by the budding of one individual from near or at the base of the parent. Traces of 12 individuals are seen in a small area; the longest shows a length of 1 mm and a maximum width of 0.3 mm. All appear widest distally and narrow basally; internal cavities are, however, seen only in the distal portions; both of these phenomena may well be the natural effect of a series of tubes, the axes of which intersect the plane of the section at varying angles. Walls fail to show any original organic structures.

Discussion. This form is known only from a single thinsection; although the information thus supplied is inadequate in some respects, which would seemingly leave open a wide choice of forms with which it might be compared, the affinities remain again highly uncertain. The general aspect shown by the colonial tubes suggests some of the simpler Bryozoa belonging to the Ctenostomata or Cyclostomata. These tubes, however, are extremely large in comparison with those belonging to known Trepostomata and Cyclostomata in the same sections, and fail to show the usual textural features of Bryozoa. Photographs were submitted to our two most experienced students of Bryozoa, Dr. E. R. Cumings and Dr. R. S. Bassler. Both expressed disbelief that this colony was a bryozoan. However, there seem to be no other groups that contain representatives which are at all comparable. In the Protozoa only the Foraminifera have calcareous tubes; none is known anywhere that is comparable to the present form. No Foraminifera with calcareous shells are recognized prior to the Mississippian. Members of other groups to which one may look for possible affinities have tubes that are much smaller, and none of them is calcareous. Hydrozoa are not known to build similar calcareous tubes. The small size does not completely rule out the consideration of annelid worms, but the only point favoring such an interpretation is that worms could produce tubes of almost any size or substance. Rotifers sometimes build tubes, but not of calcitic material alone; again, these forms would be extremely large as rotifers. No affinities can be suggested with any of the Arthropoda or Mollusca. No calcareous graptolites are known, and no textural details suggest assignment to the Hemichordata.

In spite of objections, interpretation of these forms as Bryozoa seems to encounter fewer objections than any other suggested assignment. There are a number of the Ctenostomata and Cyclostomata that have relatively large tubes, but those of the Ordovician are stolonlike masses, creeping and encrusting, and such forms, commonly found on surfaces of shells, have apparently never been studied from sections. As far as the writer could ascertain, no sections of such forms have been published, and no actual sections could be located. Probably none exists, because these forms, having little substance and being found on shell surfaces, do not lend themselves well to this method of study.

Unfortunately it is not certain whether these tubes bud actually one from the base of another, or whether they extend from a common stolon. The upper two tubes shown in the right side of Plate 10, figure 5, could be interpreted as both diverging from a short common stolon, but no others show this appearance; stolons, moreover, are commonly long and not subject to frequent angular bends, which we must accept if the interpretation of the short connecting calcareous bit is accepted as a stolon. However, stolons are characteristic of the Ctenostomata, and no described genus of that group is particularly similar to our present form.

Among the Cyclostomata there are known genera that approach the present colony in aspect. One would, however, expect that similar types might be known from the Early Paleozoic, but surprisingly, this does not seem to be true. The early Paleozoic forms that resemble this colony at all are few; they are encrusting forms, with the apertures on the upper side of long reclined tubes, not at the tips, and new individuals bud from the distal rather than the proximal parts of the parents. Morphologically, the Cyclostomata closest to the present form have a distribution that makes any suggested affinities embarrassing; they are largely Recent and Cenozoic genera, with a few species known for some of them from the Cretaceous. In general, the Crisiidae are comparable; for example, *Tubulipora,* in which tubes are similar in aspect and seem to be connected by a mass of generalized calcareous material. *Leptopora* again is comparable, but builds more massive colonies. *Reptaria, Hederella,* and *Hernodia* seem the most comparable forms known in the Paleozoic, but the first two are always flatlying and tend to grow in rather long branches, and in *Hernodia* new individuals bud from the middle rather than the base of the parent, and the tubes tend to lie in contact one with another for most of their lengths.

Type. Slide no. 666k, from a colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

COILED SHELLS OR TESTS

Three types of coiled shells are found attached to colonies of *Catenipora,* and thus far have been observed only in sections. The range in size rarely above 1 mm, and never above 1.4 mm in either height or width. One suggests a trochoid gastropod, with a slightly convex low spire, the edge extended as a slight carina, whorl rounded below, with a steep umbilical shoulder and a wide umbilicus. Plate 9, figures 7, 8, 11, and 12, shows these forms in cross-sections; figures 9 and 10 probably are sections of the same form, so eccentric as to cut only part of the outer whorl.

A quite different form, a planispiral shell, is shown in Plate 9, figures 13 and 14. Still different is a planispiral form showing rather roughly rounded whorls, thick-walled, with the internal vacuity small and irregular.

The affinities of these forms seem questionable, although the evidence seems to support recognizing the first two as gastropods. This view was rejected by Dr. Ellis Yokelson (*fide litt.*), to whom I sent photographs of these forms, on the basis of their tiny size, but their size range seems slightly larger than that of the abundant tiny gastropods of the Cincinnatian long known as *Cyclora minuta,* which Knight (1941) restudied, concluding that they were probably young stages of the common Cincinnatian genus *Cyclonema.*

The third form, from its thick and irregular walls and surface, seems quite foreign to these other two. Although no Foraminifera with calcareous shells are recognized in the Ordovician, no other assignment has been found that seems at all consistent with the observed features of this form. All the bodies have walls of light calcite, coarsely crystalline, and evidently considerably altered from its original condition, a feature characteristic of the main shell parts of most associated gastropods and of mollusca in general in these beds. Affinities with the flat-spired, encrusting *Spirorbis* were considered, but although such affinities might be suggested for the two low-spired forms, close comparison is inhibited by the lack of any information on the appearance of this genus in sections. The forms are named, in order to have something to call them, and described below.

WARTHINITES Flower, n. gen.

Genotype: *Warthinites adhaerens* Flower, n. sp.

These are low-spired, widely umbilicate shells, spire slightly convex, outer margin of whorl tending to be slightly keeled, top of outer whorls slightly convex, inner whorls slightly elevated above them. These forms are found always attached by part of the spire. Whorl cavities are rounded, slightly wider than high, the inner or umbilical wall vertical externally.

Warthinites adhaerens Flower, n. sp.

Pl. 9, fig. 7-12; pl. 11, fig. 11

The description of the genus will essentially define this species, though future work may show that it is rather too broadly drawn. The holotype, Plate 9, figure 7, on slide 666f, shows a section of a shell 1 mm across and 0.6 mm high. The attached top of the two parts of the outer whorl would together define a gentle curve, above which the spire of the earlier whorl is slightly elevated. Outer edges of the surface of the spire are slightly thickened. The whorls are gently rounded, vertical externally, and strongly rounded below, with the umbilical wall reduced in curvature and nearly vertical on the outer whorl, and slightly inclined inward in the earlier half whorl. The section is slightly off center, so that the earlier whorls are indistinct. A paratype, Plate 9, figure 8, from the same slide, appears as a form with a significantly higher spire, an effect that may, however, be the result of the plane of the section. This form is attached by only one side of the spire; whorl cavities and suggestion of a marginal carina agree with the preceding form. This shell is 1 mm across and 0.8 mm high. The same slide yields the section shown in Plate 9, figure 9, regarded as a section through only the outer whorl of one of these forms. Plate 9, figure 11, shows another form, from slide 666*l*, in which the spire is low, gently curved, and ridged faintly at the edges, the outer whorl cavity oblique, sloping inward below. The same slide yields the section shown in figure 12, only 0.6 mm wide and 0.3 mm high, showing only a portion of an outer whorl more regularly rounded in section. In Plate 11, figure 11, is shown the smallest individual observed, a section of possibly a distinct form, to judge from its evenly rounded surface. This form, from slide 666h, is only 6 mm across. It is shown attached to a rank of *Catenipora* at the intercorallite region. Replacement obscures the balken, a feature rather general in this section, but attention should be called to the curious abnormal reentrant in the coral wall to the right of the foreign body, the only indication suggesting damage or abnormality of growth found in connection with any of these forms.

Types. On slides 666f, h and *l*. All from a single colony of *Catenipora workmanae,* from the Second Value formation, Cooks Range, New Mexico. In addition, six other forms were observed on the same colony, but are not described or figured, as they add nothing to the knowledge of this form.

GOLDRINGELLA Flower, n. gen.

Genotype: *Goldringella plana* Flower, n. sp.

These tiny thin-walled planispiral shells are attached by the broad flat side, presumably the top of the spire; the opposite side shallowly concave; whorl cavity rounded; wall thin and round below, flat and faintly carinate at the edge above.

Goldringella plana Flower, n. sp.

Pl. 9, fig. 13, 14

This form is known from two sections. The first, the holotype, on slide 666g, is a coiled shell shown in the section, 1.2 mm across and 0.6 mm high. The section cuts an outer whorl, but passes tangentially through the previous whorl, showing no cavity there. The attached side is flat, showing a definite carinate edge at the lower left below the section of the whorl cavity, which is inclined slightly outward above, toward the supposed real base, and is slightly narrowed there. The carina at the edge of the flat spire is less evident on the opposite side, but there also the whorl slopes outward.

A second specimen, on slide 666i, is of about the same height, but shorter, and represents a section through the same general type of organism. The larger end with a cavity within is smaller, represting a different growth stage, and the cavity slopes in toward the umbilicate free side.

Types. Slides 666g and i, from the paratype colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

FENTONITES Flower, n. gen.

Genotype: *Fentonites irregularis* Flower, n. sp.

These are small planispiral shells or tests, calcitic, and thick-walled, with surfaces irregular, the cavity within relatively small.

Discussion. These are small, irregular planispiral tests found attached to Ordovician corals, and specifically observed on colonies of *Catenipora.* Irregularity of form, and thickness of the test suggest possible assignment to the Foraminifera, even though comparable calcitic forms are as yet unrecognized in the Ordovician. The genus is named for Dr. W. N. Fenton, in order that he may be remembered in paleontological circles by something more prepossessing than the legislation that he engendered governing the collection of fossils in New York.

Fentonites irregularis Flower, n. sp.

Pl. 9, fig. 17, fig. 18 (pars), fig. 19

These are low, broad objects, observed only in section, obviously irregular, thick-walled, coiled shells. The holotype, shown in the left of Plate 9, figure 19, is 1 mm across, the top slightly concave, the sides rounded, slightly convex below. The paratype, shown in the lower right of the same figure, is comparable, but is attached to the coral by the concave rather than the convex side. A third specimen, Plate 9, figure 17, resembles the holotype in the concave free surface, shows the internal cavity markedly reduced in size in the earlier half whorl, and exhibits a stronger angulation on the outer, upper angle of the whorl than does the holotype. Probably none of the sections is quite central, but this one is clearly eccentric.

Types. Holotype and one paratype, slide 668h; paratype, slide 668f. All are from a colony of *Catenipora workmanae,* from the Second Value formation of the Cooks Range, New Mexico.

BIVALVED SHELLS

Orbiculoidea(?) sp.

Pl. 12, fig. 6-7

Two bodies attached to colonies of *Catenipora* appear in section as being composed of a lower, flat plate, closely cemented, and an upper, gently arched plate. The larger, on slide 666i, is 2.0 mm long, not quite complete at one end, and 0.6 mm high. It appears as purely calcitic material, with some extraneous calcite between the two shells. The smaller, on slide 666f, is 1 mm long and 0.2 mm high. The upper shell here shows a fine light-yellow color and some appreciable thickness, but fine structure is not retained.

Figured specimens. Slides 666f and 666i, from a colony of *Catenipora,* from the Second Value formation of the Cooks Range, New Mexico.

UNNAMED BODIES

Pl. 8, fig. 8; pl. 9, fig. 15; pl. 12, fig. 9

Two of the bodies attached to the ranks of *Catenipora* are obviously distinct from the others, but supply so little evidence of the form of the organism as a whole that they are not named. Plate 9, figure 15, suggests a capsulelike body that opened at the distal end, twisting irregularly and freeing whatever bodies were originally contained within it. A very different body is shown in Plate 12, figure 9; for the most part this suggests a section of a broadly attached coiled shell, well off center, but one not strictly like any of the others observed in sections. At the left, however, a process apart from the apparent whorls extends first laterally and then obliquely upward. A chance section through a coiled shell or test, the adoral part of which was broken, would produce this effect, but with no comparable specimens, the interpretation must remain uncertain.

Some additional bodies are shown in pl. 8, fig. 8, adequately noted in the explanation of the plate.

Other Traces of Foreign Organisms

Lichenocrinus(?) minutus Flower, n. sp.

Pl. 16, fig. 3, 4; pl. 17, fig. 1-3; pl. 18, fig. 1, 2, 4.

In the discussion of *Coccoseris astomata* attention is called to the presence of tiny, raised, ringlike bodies found on the surface of the colony, a surface resulting from natural weathering. These bodies have the essential shape of what has been called *Lichenocrinus* in the Cincinnatian, although they are anomalous in their consistently tiny size when compared to other bodies that have been referred to that genus. They are also anomalous in that they are not obviously composed of a number of distinct plates. Weathered surfaces with such bodies are shown in Plate 16, figure 3, 4, and Plate 18, figure 5. One section (pl. 17, fig. 2) is figured showing the bodies on the surface of the colony. They are shown in cross-section in Plate 18, figures 1, 2, and 4. Such sections reveal them as coarsely crystalline calcite, not very revealing as to the original fine structure. Bodies of this sort have been regarded as the bases of attachment of crinoid stems. Such an interpretation seems untenable in the present case, for if this interpretation were correct, the bodies would be incomplete above, showing a break where the stem should have joined the basal body. There are, however, a number of sections, one of which is shown in Plate 17, figures 1 and 3, that reveal these bodies as complete and rounded at the top. Although assignment to *Lichenocrinus* is almost certainly incorrect, there seems little point in erecting a new genus for these bodies at the present time.

Occurrence. From the holotype colony of *Coccoseris astomata,* from the Second Value formation, from the southern end of the Franklin Mountains, near the crest of the Scenic Drive, El Paso, Texas.

CAVITIES IN COLONIES OF COCCOSERIS

Pl. 17, fig. 3, 4.

Sections of *Coccoseris astomata* show a number of cavities, which, from the disruption of baculi intersected, appear to be borings made in the calcareous colony by some foreign organism. The two sections illustrated are typical in showing elongate oval cavities. In spite of numerous sections, it appears that these cavities were not commonly open to the exterior, indicating that the organism that made them was short-lived, and that after its death the coral continued to grow, completely submerging the spaces thus formed. Elongate oval forms are consistent, enough as to indicate that they are not the result of intersection of the planes of the sections with oblique tubular cavities. Further, examination of the surface of the *Coccoseris* colony has revealed no obvious opens for such cavities, as one might expect to find there.

ANNELID BURROWS

Pl. 11, fig. 6.

Worm burrows in the matrix of the colonies of *Catenipora* show an interesting structure. The walls are dark, suggesting some organic carbonaceous material, possibly secreted as a mucus, in which are entrapped numerous small fragments, all oriented parallel to the circumference of the tube and normal to its axis. Centers vary from those with undifferentiated matrix to others showing varying amounts of calcite, generally irregular, as though replacing some organic object that decayed after it inhibited the spread of sediment. The figured specimen, from slide 667d, is 2.2 mm across; it shows below the wall for some distance in the plane of the section, in the lower part of the figure, but above the tube turns so that an almost perfect cross-section is seen.

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NOTES ON THE ECOLOGY OF THE ZOANTHARIA

THE NEMATOCYST

The coral is a polyp
A polyp is a thing
That sits and sits awaiting
For something it can sting.

PHYSIOGRAPHY

An atol has a top that's flat
And featurless, extremely;
Corals and algae make a mat
Where mountains are not seemly.

BUDDING

The coral leads a sorry life;
He knows no love, he knows no strife;
But look not on him with derision,
He multiplies by long division

His lovelife could not be much worse
He reproduces by divource
But yet he leaves on 'Kini's rim
The only thing that's really him.

THE MISSING MESODERM

The corals and their softer kin
Solve for us nature's riddle:
They show we can find centers in
Creatures that lack a middle.

WHY FEW CORAL GROW TEN FEET HIGH

The planula that settles down
Becomes a polyp with a crown
Of tentacles, with which he eats
His fellows find their little seats
  Too soft, too low
  And so they grow
Secreting lime beneath their feet;
On this they rise until they meet
Perhaps the tidal zone or shore
Then find that they can grow no more.

S. L. S. & S. P. C. (C. P. N. & R. H. F.)

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Numbers in **boldface** indicate main references.