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LOPHOPHYLLID CORALS FROM LOWER PENNSYLVANIAN ROCKS OF KANSAS AND OKLAHOMA

By

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CONTENTS

PAGE

ABSTRACT 187
INTRODUCTION 187
Previous studies 187
Scope of the present paper 189
Material studied 189
Methods of study 190
TERMINOLOGY OF LOPHOPHYLLID STRUCTURES 192
RELATIONSHIPS OF LOPHOPHYLLID CORALS 201
Lophophyllum, *Koninckophyllum*, and *Lophophyllidium* 201
Lophocarinophyllum 208
Sinophyllum 209
Rylstonia and other genera 210
Taxonomic status of lophophyllid corals 211
SYSTEMATIC DESCRIPTIONS 211
Genus *Lophophyllidium* Grabau 211
Lophophyllidium proliferum (McChesney) 213
L. profundum (Edwards and Haime)? 219
L. confertum, n. sp. 221
L. mundulum, n. sp. 223
L. compressum, n. sp. 224
L. complexum, n. sp. 227
L. murale, n. sp. 228
L. expansum, n. sp. 229
L. girtyi, n. sp. 232
L. elongatum, n. sp. 234
L. radiatum, n. sp. 236
L. magnificum, n. sp. 238
L. newelli, n. sp. 242
L. distinctum, n. sp. 243
L. minutum, n. sp. 246
L. sp. A 247
L. sp. B 250
STRATIGRAPHIC SUMMARY 251
ACKNOWLEDGMENTS 253
REFERENCES 255

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Illustrations

PLATE PAGE

1. *Lophophyllidium proliferum* (McChesney), *L. profundum* (Edwards and Haime), and *L. confertum*, n. sp. 217
2. *Lophophyllidium mundulum*, n. sp., *L. compressum*, n. sp., and *L. murale*, n. sp. 225
3. *Lophophyllidium complexum*, n. sp., and *L. expansum*, n. sp. 231
4. *Lophophyllidium elongatum*, n. sp. 235
5. *Lophophyllidium radiatum*, n. sp., and *L.* sp. B. 239
6. *Lophophyllidium magnificum*, n. sp. and *L. newelli*, n. sp. 241
7. *Lophophyllidium girtyi*, n. sp., *L. distinctum*, n. sp., *L. minutum*, n. sp., and *L.* sp. A 245
8. Exterior of *Lophophyllidium compressum*, *L. girtyi*, *L. proliferum*, *L. profundum?*, *L. magnificum*, *L. murale*, and *L. radiatum* 249

FIGURE PAGE

1. Diagrammatic sketches of the septal groove pattern of rugose corals. 197
2. Sections of *Caninia* sp. showing tabulae and dissepiments in transverse and longitudinal section. 199

Abstract

The late Paleozoic column-bearing corals that generally have been designated as *Lophophyllum* are here assigned to *Lophophyllidium* Grabau. A neotype of *Cyathaxonia prolifera* McChesney, the genotype of *Lophophyllidium*, is described, and a revised generic diagnosis based on this material is given. *Sinophyllum* Grabau does not seem to have characters distinct from those of *Lophophyllidium* and accordingly these genera are considered to be synonymous.

Taxonomic problems encountered in a study of lophophyllid corals are discussed, and the nature of closely related lophophyllid genera is reviewed. Fifteen species are assigned to *Lophophyllidium*, of which thirteen are new. Descriptions are given of one new species from Morrow strata of Oklahoma, of two from beds of Lampasas age in southern Oklahoma, eight from the Des Moines series in Oklahoma, Kansas, and Missouri, and two from the Missouri series in Oklahoma and Kansas. Specimens from Ohio are questionably referred to *Lophophyllidium profundum* (Edwards and Haime), a species that seems to be distinct from *L. proliferum*. The general character of the lower Pennsylvanian column-bearing coral fauna is described, and a terminology of lophophyllid coral structures is given.

INTRODUCTION

The fossiliferous formations of Upper Carboniferous strata of the midcontinent region contain considerable numbers of rugose corals. Especially abundant are the small solitary column-bearing types that may be designated collectively as lophophyllids. These lophophyllid corals have been grouped under a very few wide ranging "species" of little stratigraphic value.

Previous studies.—Upper Carboniferous corals from many parts of the world have been described, but most are included as a minor part of work on large faunas. Upper Carboniferous lophophyllid corals are described by Douglas (1920), Smith (1934), and Dobrolyubova (1936). Permian species are described by Yakovlev (1903), Grabau (1922, 1928), Soschkina (1925, 1928, in Licharew and others, 1939), Huang (1932), Yoh and Huang (1932), Heritsch (1933, 1936a, 1938), Chi (1935, 1938), and Felser (1937).

Many of the important faunal zones of the Lower Carboniferous, such as the *Dibunophyllum* and *Caninia* zones of Europe and the *Yuanophyllum* and *Pseudouralinia* zones of Asia, are based on corals (Vaughan, 1905, 1915; Yu, 1931). Gorsky (1937, p. 95) and Fomitchev (1938, pp. 219-222) have outlined a broad zonation of the Russian Middle and Upper Carboniferous by means of corals, but elsewhere Upper Carboniferous corals seem to have been

little used in stratigraphic studies. Heritsch (1936, 1936a, 1936b, 1936c, 1937, 1937a) and Huang (1932) have set up a general zonation of the Permian system by means of the rugose corals. Extensive investigations of Late Paleozoic coral faunas have established the general lines of coral development, and detailed studies in the future should fill many of the gaps in the knowledge of Upper Carboniferous corals.

In North America, Upper Carboniferous corals have been described in many separate papers, but no detailed study has been published. Only two species of rugose corals (Newell, 1935) from these rocks have been described since 1915, but previously described species have been widely reported in faunal studies and lists that do not give evidence of careful study of the details of the types.[1]

The first mention of an American Upper Carboniferous lophophyllid coral is the description by Edwards and Haime (1851, p. 323) of an external mold of a calyx from Flint Ridge, Ohio, which was named *Cyathaxonia profunda,* n. sp. In 1850, McChesney (p. 75) described some similar lophophyllid corals from Springfield, Ill., and western states as *Cyathaxonia prolifera,* n. sp. Both of these species were subsequently referred to *Lophophyllum* Edwards and Haime (Meek, 1872, p. 144; Foerste, 1888, p. 136), and American students of Late Paleozoic faunas have come to regard them as synonymous. A more cylindrical and irregular coral from Illinois, first described as *Cyathaxonia distorta,* n. sp., by Meek and Worthen (1875, p. 526), was placed in *Lophophyllum* by Girty (1915a, p. 318). White (1877, p. 101) described a coral from New Mexico and Colorado, that is larger and more robust than typical examples of *L. proliferum,* and designated it as a new variety, *Lophophyllum profundum* var. *sauridens.* In a general study of the Kansas Upper Carboniferous fauna, Beede (1898, p. 17) described a subcylindrical coral that bears an interrupted solid column, naming it *Amplexus westi,* n. sp. Subsequently, this species was referred to *Lophophyllum* (Beede, 1900, p. 17). A short, broadly conical coral described by Rowley (1901, p. 349) as *Axophyllum? alleni,* n. sp., has been assigned to *Lophophyllum* by Girty (1915a, p. 318). In his extensive study of the fauna of the Wewoka formation, Girty (1911, p. 122; 1915, p. 23-27) described specimens that he referred to *Lophophyllum profundum* and a new

[1] The papers on Late Paleozoic corals by W. A. Kelley and C. W. Merriam in the Jour. Paleontology, vol. 16, no. 3 were published after proof of this paper had been received.

variety of lophophyllid coral called *L. profundum* var. *radicosum*. He also discussed the generic assignment of these corals.

Scope of the present paper.—Seeming lack of interest in Upper Carboniferous corals is in rather striking contrast to their abundant general occurrence. This paper reports on part of a general study of American Upper Carboniferous coral faunas. The wide distribution of lophophyllid corals throughout the midcontinent area and the extensive collections now available suggested the study of these forms as a first division of my work on corals.

An attempt is made to clarify taxonomic problems involved in the description of lophophyllid corals and to describe new species that may be of stratigraphic value. The internal characters of the genotype of *Lophophyllidium* Grabau, which is *Cyathaxonia prolifera* McChesney, have not previously been described. They are described and illustrated here from authentic material for the first time. This paper has been limited to the rather closely allied Lower Pennsylvanian corals, but stratigraphically higher forms have been studied in a preliminary manner to determine relationships and trends in development.

Material studied.—The large numbers of lophophyllid corals from exactly determined stratigraphic horizons and precisely described localities that are contained in the collections of the Kansas Geological Survey have furnished the basic material for this study. A few lots of corals have been collected subsequent to the start of my work, and several other small collections have been made available to me. Specimens of lophophyllid corals from Springfield, Illinois, and Muskingum county, Ohio, were borrowed in order that characters of the type of *Lophophyllidium* might be determined.

The present collection of lophophyllid corals contains specimens from about 450 localities and more than 100 stratigraphic units throughout the Upper Carboniferous. All of the series and nearly all of the formations of the Kansas Pennsylvanian column are represented. The number of specimens from each locality varies from one to several hundred. Most of the material is from Kansas and Texas, but there are additional specimens from Oklahoma, Nebraska, Iowa, Missouri, Arkansas, and Colorado.

The Upper Carboniferous corals of the midcontinent area are nearly always well preserved as calcite, with little disruption of internal features or silicification. Most of the specimens have weathered completely from the surrounding limestone or shale so that external details are easily studied.

Method of study.—The rugose corals of the North American Late Paleozoic strata were originally described largely on the basis of external form and such details of internal structure as were visible on broken or weathered specimens. This method usually served to distinguish specimens of corals having a prominent axial column, a wide dissepimental zone, prominent and complete tabulae, deep fossulae, and pecularities of external form. This sort of study later was supplemented by preparation and examination of a few thin sections and polished sections. In no case, expecting a study of a few lower Pennsylvanian corals by Morgan (1924), was a series of transverse sections made, in so far as reported, and rarely were longitudinal sections used to illustrate any Pennsylvanian rugose coral, either in original descriptions or in subsequent faunal studies. Duerden (1906), Gordon (1906), and Brown (1909) illustrated the early and subsequent growth stages of some Upper Carboniferous corals, but locality descriptions and other details were omitted. The studies by Grabau (1922, 1928), Lang (1923), Huang (1932), and Schindewolf (1940) have shown that knowledge of early as well as late stages in the development of a corallite are necessary for placement of the form in the proper phylogenetic line. The work of Grabau (1922), Huang (1932), Heritsch (1936a), and Moore and Jeffords (1941) on the genera of lophophyllid corals has indicated that transverse sections of the mature or upper part of the corallite of specimens of several genera may be identical, even though striking differences in ontogenic development are shown clearly in lower sections.

Study of Upper Carboniferous corals has been carried on by me at the same time as investigations of Permian corals have been made in collaboration with R. C. Moore. The methods used in this study are essentially those described by Moore and Jeffords (1941). An extensive illustrated card catalog of published species and generic descriptions of Late Paleozoic corals has been prepared to facilitate the coral studies.

The entire collection of the Kansas Geological Survey was examined in assembling corals for this study. Species found in beds of Morrow, Lampasas, Des Moines, and Missouri age are included in this paper. Work on younger Pennsylvanian species has not been completed.

Corals from each locality, representing each of the stratigraphic units, were examined and separated first on the basis of external

features. Sections were prepared of one or more specimens of each group from each of the localities, except in cases where there were several very similar collections from the same stratigraphic horizon.

The specimens selected for study were mounted in plaster of Paris and cut transversely by means of a thin-bladed band saw, fed with a mixture of carborundum and water. This sawing removed a thickness of about 0.5 mm from the average calcareous corallites for each cut, and somewhat more than this thickness in the case of a few harder forms. One cut was made just above the apex of the coral, in order to show a very early growth stage, and another at or just below the floor of the calyx in order to observe the mature portion of the corallite. The remaining central part of the corallite was cut in one, or preferably two, places depending on the size of the specimen and the acceleration in development. These sections were covered with oil and photographed.

After determination of the counter-cardinal plane, the corals were assembled and cemented in original orientation by matching index marks and the pattern of the septal grooves. The specimens then were cut longitudinally in a plane normal to the counter-cardinal axis.

A few thin sections and nitrocellulose peels (Graham, 1933) were made to show structures not clearly indicated in the roughly cut sections. The peels were as satisfactory as the thin sections, if not enlarged over ten times, and they do not require the destruction of the specimen. In nearly all cases, however, the photographs were sufficiently clear for inking and study, and the longer procedure of preparing peels commonly was omitted.

Positive prints of the oiled transverse and longitudinal sections were made at a uniform enlargement of 5 times natural size. Inasmuch as the photographs of the sections commonly show many confusing features that are due to variations in the matrix, calcite cleavage, and replacement, it is desirable to eliminate such defects. Therefore the structural elements of the corals, as shown in the photographs, were compared with the original specimen studied under a binocular and inked with waterproof ink. The photographs were then bleached, leaving the drawing of the inked structures.

Throughout this study the illustrations of transverse sections are oriented with the counter septum uppermost. The position of the

counter, cardinal, and two alar septa are indicated on the transverse sections. The arrangement of the septa, as given in following specific descriptions, is indicated uniformly in a clock-wise direction, the counter septum being placed at the top. Measurements of the length of the corallites here described were taken in the vertical plane without regard to their slight curvature. Unless otherwise indicated diameters were determined at the calyx and are the maximum diameter.

TERMINOLOGY OF LOPHOPHYLLID STRUCTURES

Several attempts have been made to standardize the terminology of coral structures (Grabau, 1922; Hill, 1935; Sanford, 1939). Each of these studies is somewhat different from the others, and none has gained general acceptance. The terminology of rugose coral structures that has been proposed in these papers is highly technical and includes a considerable number of precisely defined terms. This precision in the definition of terms aids in the conciseness of descriptions, but the use of little known, complex technical names tends to make understanding of descriptions very difficult for those not specialized in this branch of invertebrate paleontology. A review of several recent papers on American rugose corals indicates no definite agreement as to terminology. Therefore, the somewhat simpler and less concise system of terminology employed by Moore and Jeffords (1941) is adopted. The nomenclature of structures found in lophophyllid corals is here described as an aid to the understanding of the remainder of the paper.

The skeleton secreted by a single individual is known as the *corallite*. In skeletons formed by one individual only, this is synonymous with the *corallum*, which is the entire skeletal mass, whether composed of one or many corallites. Rugose corals having a corallum formed by only one corallite have commonly been called "simple", but unless one is familiar with this usage, it may seem to indicate a lack of specialization in the corallite rather than the hard parts of a single individual. The term *solitary* seems preferable. The initial point at the small end of the corallite is the *apex*, and it is at the lowermost part of the corallite. The last-formed part is termed the upper portion. The cup-shaped depression at the upper part of the corallite is the *calyx*. It may contain a raised area, sometimes termed a *boss*, or a depression, sometimes designated as a *pit*. The external portion of the corallite is desig-

nated the *peripheral* part and the central or innermost part the *axial* area. Proximal and distal have been used by some authors in a sense equivalent to peripheral and axial, respectively, but others have designated the lower portion of the corallite as proximal and the upper portion as distal.

The form or shape of solitary corallites may vary from nearly flat discs to long cylinders. Hill (1935, p. 488) has proposed a number of terms based on the rate of expansion of the conical lower part of the corallite, as shown by the apical angle. The shape of the corallite of many rugose corals varies somewhat during growth, and it may vary among individuals. The terms conical and cylindrical, or combinations of these with common adjectives, seem sufficient to characterize the shape, at least in the case of the lophophyllid corals here described.

Study of sectioned material shows that superficial similarity of external features offers extremely little chance for accurate separation of these corals. After internal features of corals from any one locality are known, it is possible to distinguish the lophophyllid corals accurately from other genera and usually to recognize the different species. One cannot make reliable determinations, however, by applying the same criteria to corals from other localities or horizons. Some species of *"Zaphrenthis," Canina, "Axophyllum," "Amplexus," Aulophyllum?,* and other unidentified genera cannot be separated from lophophyllid corals without knowledge of internal structures, shown either in the calyx or in transverse section. It may be noted that the original spelling of the name commonly written *Zaphrentis* is as given here *(Zaphrenthis)* and emendation in dropping the second "h" is incorrect. Typically the corallite in the case of the lophophyllid corals continues to increase in diameter or remains nearly constant as it develops. Some specimens, however, show abrupt constrictions that are followed by expansion like that near the apex. This is known as *rejuvenescence.*

The outer wall of the corallite was presumed by early workers to be a layer deposited upon the original wall or theca. In well preserved specimens of the Rugosa it has been found that this outer layer, or "epitheca", extends to the highest part of the calyx, showing that it is the first formed, fundamental unit of the wall (Grabau, 1922, p. 4) and not a layer superposed on an inner wall. This single external wall of the corallite is here designated as the *theca* (Sanford, 1939, p. 305).

The outer surface of the theca may be smooth, or it may show longitudinal grooves and ridges. In the Rugosa these grooves correspond in position to the septa and are called *septal grooves.* The ridges, known as *interseptal ridges,* are formed by the bulging out of the polyp wall between the septa. In the Hexacoralla the longitudinal ridges are extensions of the septa through the wall, and the grooves correspondingly indicate interseptal positions.

The nature of the septal grooves and interseptal ridges may be of value in separating types of lophophyllid corals not otherwise separable on external features. For example, each of the Lower Permian species, *Malonophyllum kansasense, Lophamplexus eliasi,* and *Lophophyllidium dunbari,* described by Moore and Jeffords (1941) from the Florena shale member of the Beattie limestone at Grand Summit, Cowley county, Kansas, seems to have distinctive features of the septal grooves and ridges.

Transverse ornamentation may consist of fine *growth lines* or alternate expansions and broad constrictions called *wrinkles.* Some species have small tubes or rootlets projecting from the theca. These are termed *radicles.* A number of very different types of corals have these radicles and they seem to be a parallel development that is shown by species belonging to a number of different genera. The radicles may form only during the youthful stages and be restricted to the lower part of the corallite, or they may be formed throughout growth of the polyp.

The different classes of septa have been given several names. The terms primary, secondary, and tertiary septa vary in meaning according to the author using them. The designation of the septa as given by Hill (1935, p. 504-505) seems to have the advantage of both clarity and consistency. The cardinal, counter, and two alar septa are termed the *protosepta.* A variable number of other septa that are added in pairs in the cardinal and counter quadrants and that closely resemble the protosepta, are designated as *metasepta* (plate 6, figures 1b, c). The protosepta and metasepta together are termed the *major septa.* Short septa alternating with the major septa, introduced between the majors, are termed the *minor septa* (plate 5, figure 2b).

The manner of introduction of the septa in the Rugosa is well known and needs little description here. The first septa introduced are the *counter* and *cardinal* septa and indicate the plane about which most rugose corals are bilaterally symmetrical. Sub-

sequently, or more rarely at the same time as the other protosepta are formed, two lateral septa known as the *alar septa* are introduced. These divided the corallite into four quadrants, termed the counter and the cardinal quadrants, according to whether they are separated by the counter or the cardinal septum (plate 7, figure 2b). The rest of the major septa are inserted alternately in pairs in the counter quadrants and cardinal quadrants throughout growth. In the cardinal quadrants metasepta are inserted on each side of the cardinal septum. Those inserted in the counter quadrants develop on the counter side of the alar septa. The most recently inserted septa tend to be shorter than the earlier ones and to be inclined away from the point of development (plate 2, figure 3b).

The European students of rugose corals (Duerden, 1903, p. 389, 1906, p. 226, 1906a; Carruthers, 1906, p. 356; Faurot, 1909; Smith, 1916, p. 60; Gerth, 1919; Schindewolf, 1930; Hill, 1935, p. 504) also include as protosepta a third pair of septa, which are called counter laterals. Edwards and Haime (1848), Kunth (1869), Gordon (1906), Brown (1909, p. 51), Grabau (1922, p. 10), Weissermel (1927), and Sanford (1939, p. 306) consider only the first four septa as protosepta. Hudson (1935a, p. 3) designates only the cardinal and counter septa as protosepta. In the lophophyllid corals that I have examined, the counter lateral septa are not distinctive, aside from their position and early appearance. The distinct acceleration of the counter quadrants may cause the insertion of the counter lateral septa almost simultaneously with the alar septa. The counter-cardinal plane is an important morphologic feature throughout growth, inasmuch as one of each pair of the metasepta is inserted on each side of this plane. The metasepta of the counter quadrants are inserted adjacent to the alar septa. The counter laterals, on the other hand, have little relation to the further development of the corallite, and so do not seem to be worthy of inclusion with the other distinctive septa as protosepta.

In corallites having distinct septal grooves, it is possible to determine the position of the protosepta from study of the exterior. The cardinal septum is represented by a septal groove running the entire length of the corallite. The insertion of the pairs of metasepta, one on each side, is shown by the pinnate arrangement of their septal grooves. Inasmuch as no metasepta are added adjacent to the counter septum, the metaseptal grooves are parallel to its groove. The alar septa are indicated by the parallel grooves on

the cardinal side, with grooves on the counter side converging toward them.

The septal groove pattern of these lophophyllid corals is similar to that described by Vojnovskij-Krieger (1928) for the rugose corals. The grooves do not have a simple pinnate junction with the cardinal septum or the counter side of the alar septa, as shown by Grabau (1922, p. 12) and Sanford (1939, fig. 1). The traces of the alar, cardinal and counter septa extend from the apex to the calyx and are not connected to other grooves. Metasepta inserted in the cardinal quadrants start in the spaces next to the cardinal septum, and grooves are formed composed of the early parts of each of the metasepta of the cardinal quadrants. Similar grooves develop on the counter side of the alar septa (text fig. 1A-D). Thus the traces of the septa on the exterior may be divided into four similar quadrants.

The metasepta may be introduced equally in each of the quadrants, but many species are characterized by a more rapid introduction of the septa in the counter quadrant or in the cardinal quadrant. This advance in rate of increase of septa in one pair of quadrants is called *acceleration* (plate 7, figure 2b). Minor septa may be inserted between the major septa either equally or unequally in the four quadrants. They usually are present only in the later stages of development.

Long septa are those that reach almost to the axis. Short septa extend only a slight distance from the periphery. The minor septa are nearly always much shorter than the major septa. In some forms the major septa withdraw from the axis, and the septa of such types have been called amplexoid septa. Hill (1935, p. 502) points out that this term was proposed by Carruthers (1910, p. 525) for septa that are fully developed only on the upper surfaces of the tabulae. A preferable term for axially shortened major septa, therefore, is *brevisepta*.

Depressions in the floor of the calyx, as shown in the corallite, are termed *fossulae*. These are formed about one or more of the septa that is shortened or aborted. In the lophophyllid corals it is the cardinal septum that is shortened, forming a cardinal fossula (plate 7, figures 1b, c). The spaces left on the counter side of the alar septa, due to the poorly developed last septa and to their tendency to lean towards the counter septum, are called alar *pseudofossulae* (plate 7, figures 2b c,). They differ from a fossula in that

they are produced by a retardation in development and leaning of the septa, rather than by a structural shortening of a septum and down-sagging of the base of the polyp in these regions. Similar pseudofossulae on either side of the cardinal septum are grouped with the cardinal fossula. (text fig. 1D).

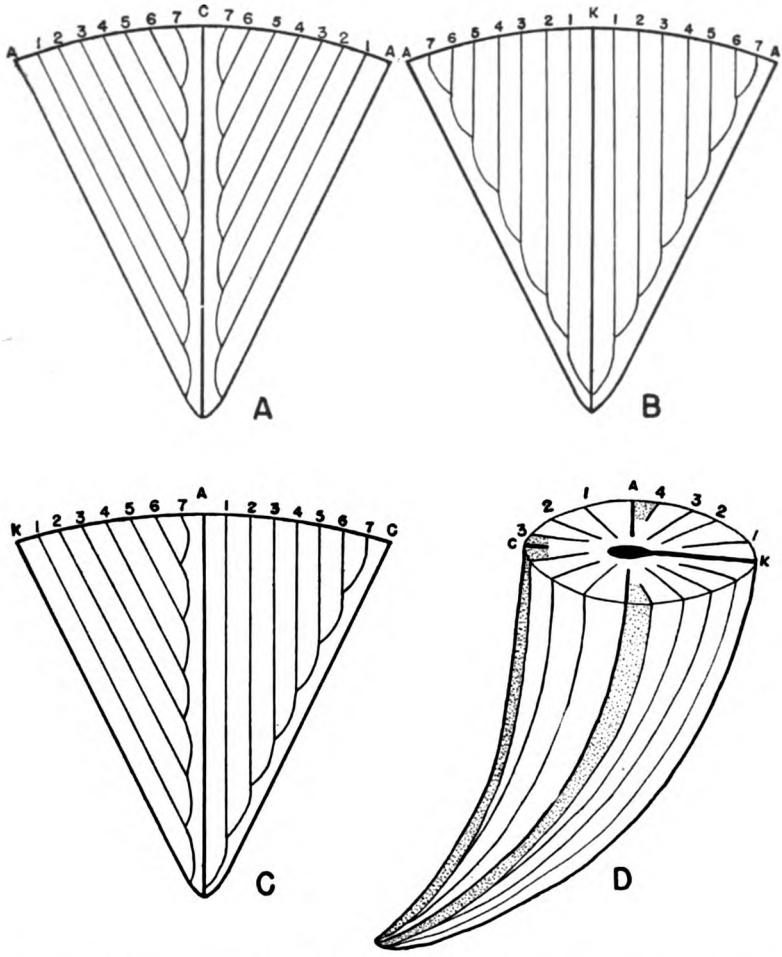

FIGURE 1. Diagrammatic sketches of the septal groove pattern of rugose corals. *A*, Septal groove pattern in the cardinal quadrants. *B*, Septal groove pattern in the counter quadrants. *C*, Septal groove pattern of the cardinal and counter quadrants seen from the side. *D*, Sketch of the relationships of septal grooves to septa, fossula, and pseudofossulae. The position of the pseudofossulae is indicated by the stippled areas.

The main transverse skeletal elements of the corallite that are not limited by the septa are called *tabulae.* They are formed by the polyp in lifting itself upward in the calyx, abandoning the underlying part of the corallite. Tabulae may have a great number of different forms and characters. *Complete tabulae* (Hill, 1935, p. 511; not Sanford, 1939, p. 309) are those that extend across the axial area, without intersecting other tabulae or an axial column, and that are joined peripherally either to the wall or to dissepiments. Other tabulae are incomplete.

Small plates arched convexly upwards between the septa and peripheral in position are known as *dissepiments.* The nature and distribution of dissepiments indicate that the polyp could lift itself up in the calyx gradually rather than all at one time as in the formation of tabulae.

In transverse sections dissepiments and some tabulae are indicated by curved bars between the septa (text fig. 2). Dissepiments develop only between the septa, and accordingly bars on opposite sides of a single septum are not parts of a single dissepiment. Tabulae extend across nonseptate parts of a coral, and where they intersect the septa they are typically not confined by the septa, as seen in transverse sections. Thus they appear as oblique bars crossing several septa. The tabulae may be slightly lower or higher on different sides of a septum. In transverse section they may show only as an occasional band between septa (plate 3, figure 1b), or slightly offset (plate 2, figure 3b). They also may curve towards the periphery adjacent to a septum (plate 5, figure 2b) and in so doing may seem not to be continuous on opposite sides of the septum.

Several recent descriptions of rugose corals reveal a tendency to interpret as dissepiments some of these intercepts of irregular tabulae in transverse sections. Inasmuch as tabulae and dissepiments are distinct structures and important features in the description of rugose corals, uniform interpretation and nomenclature of these structures is considered necessary.

The details of the axial structures seem very significant in correct generic placement of rugose corals. Detailed classifications of the axial structures have been proposed by Grabau (1922) and by Hill (1935), but there is little similarity in the terminology. These and others who have described axial structures of the Rugosa use the terms columella and pseudocolumella, with contradictory

meaning, to describe varying types of axial structures. The classification proposed by Hill is perhaps best adapted for use in describing axial structures in corals similar to *Lonsdaleia* or *Clisiophyllum*. Grabau describes a number of different kinds of axial structures, especially the solid, rodlike type, and gives descriptive names to each type. It is difficult or impossible to describe all of the characteristic types of axial structures by separate names without the use of many unfamiliar technical terms. Inasmuch as the names now used in description of axial structures have no standardized meaning or are unnecessarily technical, Moore and Jeffords (1941) have termed any axial structure of a corallite an *axial column*, regardless of its appearance or manner of formation. The features of the column of each of these forms must then be de-

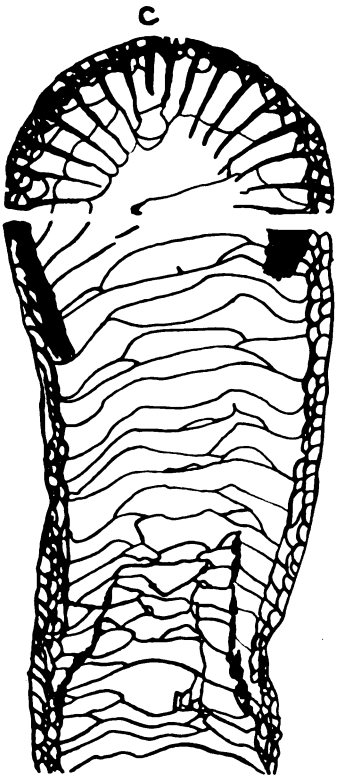

FIGURE 2. Sections of *Caninia* sp. showing tabulae and dissepiments in transverse and longitudinal section. The dissepiments occur in a narrow peripheral zone, and slightly arched tabulae cross the interior of the corallite.

scribed in detail. The significance of many features seen in axial columns of the corals studied is not clearly known.

Short longitudinal plates in the axial region are known as *lamellae.* A lamella in the counter cardinal plane is termed the *median lamella* and others lateral in position are called *radiating lamellae.*

Transverse sections of some rugose corals show the presence of an *inner wall.* This wall is concentric with the exterior of the corallite and may be formed in several ways (Grabau, 1922). When present in lophophillid corals, this is most often produced by deposition of stereoplasm around the septa and other skeletal elements. In some forms (*"Sinophyllum"* Grabau, 1928) the inner wall is reported to be formed by the sudden bending of the axial ends of the septa so as to join with each other. A consistant spacing of a change in the arching of tabulae may also produce an inner wall. The swollen axial ends of the septa supplemented by deposition of stereoplasm about this thickened part forms definite walls in other lophophyllid corals.

Greck (1936) and others compare coral species by means of transverse sections at similar diameters. The size of the corallite in many genera, especially in *Caninia,* is rather variable. This method of comparison, therefore, seems of little value for comparing many of the Rugosa. Study of lophophyllid coral structures suggests comparison of equivalent stages in development regardless of size. Differences in equivalent periods of growth and in extent of development can then be determined easily.

The peculiar features of some rugose corals as shown by Lang (1923) are common to many widely varying types. One genetic line may show any number of these different tendencies superimposed on the original genetic structural features. The *astraeoid trend* (1) is defined as the development from solitary to colonial forms having loosely bundled corallites and finally to closely packed types. The *caninioid trend* (2) is marked by change in shape of the corallite from discord through conical to cylindrical. A *cyathophylloid trend* (3) is the tendency of a corallite to go from its primary bilateral symmetry to radial symmetry. The *amplexoid* trend (4) is distinguished by a tendency of the septa to become shorter (breviseptal) and to withdraw from the axis. The *lonsdaleoid trend* (5) is expressed by a shortening of the septa at their peripheral ends, accompanied by the presence of a peripheral dissepimental zone. The *cystiphylloid trend* (6) is the uplifting of

the polyp in the calyx very gradually by dissepiments instead of periodically by tabulae. The *aulophylloid trend* (7) is the tendency for an axial column to become more highly developed and complex as a genetic line progresses. The *petraeoid trend* (8) is represented by the development of secondary thickening of the skeletal elements in a definite manner.

The conspicuous development of like trends in several distinct generic lines may produce very similar forms, known as *homeomorphs*. These are forms that show a similarity of structures but a different ancestry. Hudson (1935) considers the very similar genera *Rhopalolasma* Hudson (1935) and *Tachylasma* Grabau (1922) to be merely homeomorphic. Likewise Weissermel (1897), Schindewolf (1940), and Moore and Jeffords (1941) have shown that several different types of rugose corals have a prominent development of the amplexoid trend, or breviseptal phase, in maturity. Several of these corals that were grouped formerly in the long ranging genus "*Amplexus*" have now been separated into genera that are useful stratigraphic markers. As yet, little work has been done on the significance and extent of homeomorphism in the external and internal elements of the Rugosa.

RELATIONSHIPS OF LOPHOPHYLLID CORALS

The American lophophyllid corals commonly have been referred to the genus *Lophophyllum* Edwards and Haine (1850). Studies on the genotype species of *Lophophyllum*, which is a Lower Carboniferous coral from Belguim, and work on column-bearing corals in many parts of the world have thrown considerable doubt on this generic assignment. The understanding and application of provisions of the International Rules of Zoological Nomenclature vary widely. Differences in characters among Late Paleozoic lophophyllid rugose corals, conjoined with variations in usage and interpretation of available data by different workers, have given rise to many inaccuracies and differences in taxonomy. Before beginning a description of the lophophyllid corals some discussion of taxonomic problems is needed.

Lophophyllum, Konickophyllum, and Lophophyllidium

The original description of *Lophophyllum* by Edwards and Haime (1850, p. lxvi) is as follows:

Corallum resembling *Zaphrentis,* excepting that a crestiform columella occupies the centre of the calice, and is in continuity by one of its ends with a small septum, placed in the middle of the septal fosula. and by the other end with the opposite primary septum.

The type species was given as "*Lophophyllum Koninckl,* nob.", but this species was not described or illustrated until 1851, at which time the genus was further characterized as follows: (Edward and Haime, 1851, p. 349):

Polypier subconique, entouré d'une épithèque complète; columelle lamellaire et cristiforme occupant le centre du calice, et se continuant par une de ses extrémités avec une petite cloison située au milieu de la fossette septale, et par l'autre extrémité avec la cloison primaire opposée.

La présence d'une petite columelle cristiforme sépare bien ce genre de toutes les autres Zaphrentinae où l'organe axillaire manque complétement. Nous connaissons trois espèces, deux appartiennent au terrain carbonifère et la troisième au devonien.

The type of this species, furnished by De Koninck, was from Lower Carboniferous strata at Tournai, Belgium.

Subsequent to the work of Edwards and Haime other students of the rugose corals obtained from this original description the concept that *Lophophyllum* was a genus established for a coral of zaphrentid type, having one of the protosepta prolonged and somewhat thickened. No further study of the true characters of the genotype species was published until 1911.

In 1876 Thomson and Nicholson (1876, p. 290) established the genus *Koninckophyllum,* with *K. magnificum,* n. sp., as genotype. This genus was described as a solitary or compound coral having septa that extend only part of the distance to the axial region, bearing a wide peripheral band of very minute dissepiments, an axial region containing close-set arched tabulae, and a small, compressed, compact or imperfectly cellular column that is shown by longitudinal sections to be either continuous or interrupted. Thomson and Nicholson state that *Koninckophyllum* differs from *Lophophyllum* in the

totally different form and connexions of the columella, and the less developed conditions of the septa, and, even more strikingly, by its extraordinarily minute and dense zone of vesicular tissue forming the periphery of the corallum.

Small conical rugose corals that bear a solid column but have relatively little vesicular structure, such as *Fasciculophyllum er-*

uca McCoy from Europe and *Cyathaxonia prolifera* McChesney from America, were subsequently referred to *Lophophyllum*. Corals having a thin laterally compressed, continuous or interrupted column and a wide dissepimental zone were referred to *Koninckophyllum*.

Carruthers (1913, p. 50) has pointed out that four years before publication of Edwards and Haime's monograph proposing the new genus *Lophophyllum*, based on *L. koninckí* from Tournai, another species of rugose coral from Tournai was described by Michelin (1846, p. 258) as a new species. This was called *Cyathaxonia tortuosa*. The type specimens of both *L. koninckí* and *C. tortuosa* are missing from the remnants of the collections of these authors at the Museum de Paris and seemingly are lost (Carruthers, 1913, p. 49). Both species are described as having a smooth epitheca and a prominent axial column. Carruthers (1911, p. 152; 1913, p. 50), in making a study of topotype material from Tournai, found that there are only two corals from this locality having a prominent column. One of these, *Cyathaxonia cornu* Michelin, is "relatively very small and has strong longitudinal ribbing on the epitheca" and according to Carruthers is obviously not the form described as *C. tortuosa* or *L. koninckí*. The other coral species "agrees with the figures and descriptions" of both *C. tortuosa* and *L. koninckí*. Carruthers thereforeplaces the name *Lophophyllum koninckí* Edwards and Haime in synonomy with *Cyathaxonia tortuosa* Michelin. The presence of dissepiments and the nature of the axial column in this species, however, does not permit its assignment to *Cyathaxonia*, and so the genus *Lophophyllum* is recognized as valid, with *C. tortuosa* Michelin as the genotype.

The revised generic diagnosis of *Lophophyllum* based on the study of the topotype material by Carruthers is as follows:

> The corallites are solitary, turbinate, and enclosed by a theca; major septa meet at the center in early growth stages, one of them, generally the counter septum, is thickened at the inner end so as to form a moderately prominent axial column that projects upward into the calyx, but the column may be discontinuous; tabulae that arch upwards in the center to a varying degree occur below the floor of the calyx, and in the mature part of the corallite dissepiments appear between the tabulate area and the outer wall; unlike *Dibunophyllum*, there is no axial zone characterized by more numerous or vesicular tabulae or by a system of vertical lamellae distinct from the septa. (Moore and Jeffords, 1941 p. 80.)

Carruthers (1913, p. 53) concludes that

> those corals referred by Thomson and Nicholson and other authors to *Lophophyllum* (e. g. *L. proliferum* and *L. eruca*) do not develop dissepiments at any stage of growth, and are essentially Zaphrentes [sic] having one of the septa thickened at the inner end. It may be convenient at some future time to group them as a sub-genus of *Zaphrentis,* but for the present such a course is not considered advisable.

Carruthers (1913, p. 52) indicated that some of the species included in *Koninckophyllum* have essentially the same characters as *Lophophyllum tortuosum.* The genus *Koninckophyllum* has been interpreted in several ways (Vaughan, 1905, p. 281; Sibly, 1908, p. 70; Gregory, 1917, p. 236; Lewis, 1935, p. 133) but its taxonomic position does not call for discussion here, except for consideration of its confusion with *Lophophyllum.*

Vaughan (1915, p. 39) asserted that Carruthers has not shown any stage of *Cyathaxonia tortuosa* that resembles Edwards and Haime's (1851, pl. 3, fig. 4, 4a) figure of *Lophophyllum koninckі* and thus Carruthers merely assumes the two species to be identical. The specimen described by Carruthers, however, is taken to represent a new genus, which is named *Eostrotion* Vaughan (1915, p. 39). Hill (1939, p. 87) has pointed out that Vaughan was unduly influenced by theories of evolutionary trends in the phylogeny of *Lithostrotion;* and because the forms assigned to *Eostrotion* show seemingly continuous morphological variation from those referred to *Koninckophyllum,* she concluded that they do not constitute a distinct generic group.

If the conclusions of Carruthers are accepted and corals like those previously placed in *Koninckophyllum* are referred to *Lophophyllum,* several species already assigned to the latter genus must be removed. For these, however, no generic name was available when Carruthers published his discussion.

Girty (1915), in a study of lophophyllid corals from the Wewoka formation of Oklahoma, was uncertain as to the proper generic classification of *Lophophyllum proliferum.* He based his understanding of *Lophophyllum* on the original description of that genus and the illustrations of *L. koninckі* by Edwards and Haime, and generic descriptions given by other writers. He was rather uncertain as to the differences between *Lophophyllum* and *Cyathaxonia* but concluded that *L. profundum* shows fewer departures from the characters *Lophophyllum.* In another paper Girty (1915a, p. 319) says:

In so far as I know the facts, *Lophophyllum profundum* is not in essential agreement with the genus *Lophophyllum* as based on *Lophophyllum koninckı* which Milne-Edwards and Haime named as the genotype. It has opposite the septum [sic, error for fossula?] the fossula [sic, error for septum?] (the counter septum) connected with the pseudo-columnella, not the septum in the fossula (the cardinal septum) as in typical *Lophophyllum,* and the somewhat obscure radiating structure of the pseudo-columnella may not be found in *Lophophyllum koninckı.* Furthermore, the fossula is situated on the convex side of the corallum in *L. koninckı* and on the concave side in *L. profundum.*

Study of many of these lophophyllid corals indicates that the position of the fossula in relation to the curvature of the corallite is of little generic significance. Grabau (1922, p. 13) suggests that curvature in a plane other than that of the cardinal and counter septa is probably due to a pathologic cause. Many Upper Carboniferous and Lower Permian species of lophophyllid corals, however, are consistently curved in the alar plane.

Douglas (1920, p. 42), in describing some lophophyllid corals from South America that have a solid axial column and lack dissepiments, recognized that these could not be included in *Lophophyllum* as defined by Carruthers. No name was proposed by Douglas, and they were termed "Lophophylloid Zaphrentids" because they seemed essentially similar to *Zaphrentis* except for the column. Chi (1938, p. 161) has since referred these corals from Peru to *Sinophyllum.*

In 1928 Grabau described several types of simple column-bearing rugose corals and, for the group of forms that had been referred generally to *Lophophyllum,* he set up the new genus *Lophophyllidium,* with the American species *Cyathaxonia prolifera* McChesney as genotype. In the same paragraph in which this new genus is proposed Grabau (1928, p. 99) states:

It may, however; be remarked that since corals of the *L. tortuosum* type have been described as *Koninckophyllum,* though the majority of the species figured by Thomson and Nicholson show a more extensive peripheral zone of dissepiments, that it does not seem altogether advisable to apply the law of priority strictly in this case by removing the well-known species from the genus *Lophophyllum* and placing therein the species of *Koninckophyllum,* as suggested by Carruthers. My own opinion would be that less confusion would arise if *Lophophyllum* were to be retained for the species congeneric with *L. proliferum* McChesney or *L. profundum* E. and H. and more specialized Lower Carboniferous species retained in the genus *Koninckophyllum.*

Lophophyllidium has been used by most authors for small solitary horn corals lacking dissepiments but having tabulae and a

prominent solid rodlike column that is formed by the axial thickening of the counter septum.

Huang has employed *Koninckophyllum* and *Lophophyllum* in the sense of their usage previous to studies by Carruthers. He concludes (Huang, 1932, p. 22):

> It is to be remembered that corals congeneric with *L. proliferum* McChesney have for years been generally considered as *Lophophyllum* while those congeneric with *L. tortuosum* (Michelin) are customarily taken as *Koninckophyllum*. Such a wrong practice has been followed so long that it will cause great inconvenience and confusion if attempts are made to correct it. The creation of a new genus name is also not a good remedy since it will hardly be followed by other paleontologists. I am of the opinion therefore that *Lophophyllum* is to be applied for these species which are congeneric with *L. proliferum* while *Koninckophyllum* is to be retained for types like *L. tortuosum*. In accordance with this I have given the name *Lophophyllum* to the species described in the following, which are of the type of *L. proliferum*.

Yu (1933) recognized the new genus *Lophophyllidium* but seems to have misunderstood the statements of Grabau regarding it. He states that Grabau suggested inclusion of the more specialized Lower Carboniferous species in *Koninckophyllum*, and accordingly he writes "those forms congeneric with *L. tortuosum* (Mich.) are referred to the genus *Lophophyllum*." Yu's quoted statement seems to be in error, inasmuch as Grabau clearly held that corals of the *L. tortuosum* type should be referred to *Koninckophyllum* and those of the *L. proliferum* type to *Lophophyllum*. Although *Lophophyllidium* was proposed by Grabau, he seems not to have favored its adoption.

Lewis (1935) has described several Lower Carboniferous corals from Nova Scotia that he refers to *Lophophyllum*. The genotype is given as *Lophophyllum koninckí*, but the generic diagnosis resembles that given by Carruthers based on *L. tortuosum*. The description of *Koninckophyllum* (used as a subgenus of *Lophophyllum*) as a form having a "dissepimental zone typically narrow, but sometimes broad, when the coral is indistinguishable from *Koninckophyllum* Thomson and Nicholson" indicates his concept of the closely related character of the two genera.

Another British student of the corals, Stanley Smith (1934, p. 129) concludes that although Carruthers is probably right in considering *Lophophyllum koninckí* conspecific with *Cyathaxonia tortuosa*, "his conclusion still requires further confirmation." *C. prolifera* is considered congeneric with *L. koninckí*. It is agreed

however that if the two Tournaisian forms are identical, and if corals of the *L. proliferum* type which do not advance beyond the *L. konincki* stage cannot be retained in *Lophophyllum*, they must be placed in *Lophophyllidium*.

The relations of several of the genera of Late Paleozoic lophophyllid corals were reviewed by Heritsch in 1936. The corals similar to *Lophophyllum proliferum* (McChesney) are definitely separated by him from *Lophophyllum* and placed in *Lophophyllidium*. It is recognized that the diagnosis of *Lophophyllum*, as given by Carruthers, approaches *Koninckophyllum* Thomson and Nicholson very closely but the two genera are regarded as possibly separable on morphologic grounds. Heritsch (1936a, p. 108) seems to have been misled by Grabau's incorrect use of the term *dissepiments* in describing *Lophophyllidium profundum* (Edwards and Haime). Chi (1938), Sanford (1939), Fomitchev (1938, 1939), and Moore and Jeffords (1941) have also assigned corals similar to *Cyathaxonia prolifera* to *Lophophyllidium*.

Hill reports (1939, p. 86) that Smith examined material presumed to have been studied by Edwards and Haime and that he thought one specimen possibly the same as figured by Edwards and Haime. Externally this specimen shows a zaphrentid arrangement of the septa and a column, but it has no dissepiments.

Hill (1939, p. 86) agrees that the specimens referred by Carruthers to *L. tortuosum* undoubtedly have the structural characteristics of *Koninckophyllum*. The statement that only one species from Tournai corresponds to the description of *L. konincki* she thinks is not necessarily true and cannot be proved because it is based only on negative evidence. *Koninckophyllum* is recognized as a valid genus by Hill, and the characters of *Lophophyllum* are considered to be unknown until the presumed type is sectioned.

Lang, Smith, and Thomas (1940, p. 81) report that recent examination of material from Tournai supports the conclusions of Carruthers, but final decision can come only after re-examination of the types of *L. konincki*.

Summary.—This review of studies on genera of lophophyllid corals indicates that there are three different opinions as to the status of *Lophophyllum*, *Koninckophyllum*, and *Lophophyllidium*. A few authors entirely disregard the International Rules in using the name *Lophophyllum* for corals like *L. proliferum* and the name *Koninckophyllum* for species congeneric with *L. tortuosum* (the

designated type of *Lophophyllum*). A second group accept the interpretation of Carruthers, and they refer lophophyllid corals that lack dissepiments to *Lophophyllidium*. Still others maintain either that the type of *Lophophyllum koninckí* is still available and should be studied, or that Carruthers was incorrect in assuming his specimens to be conspecific with *L. koninckí*. Those who concur in the belief that the characters of *Lophophyllum* are still unknown tend to refer corals similar to *Cyathaxonia prolifera* to *Lophophyllum*, and they do not recognize *Lophophyllidium*. Whether *Koninckophyllum* is synonymous with *Lophophyllum*, as inferred by Carruthers, is not a concern of this study.

Examination of the original figures of *L. koninckí* by Edwards and Haime (1851, pl. 3, fig. 4, 4a) support Vaughan's contention that the specimen illustrated by Carruthers does not especially resemble the types. Carruthers (1911, p. 152), however, states that study of topotype material shows the original type of *L. koninckí* to be only an immature form of *L. tortuosum*. The appearance of the weathered calyx also may show differences from the transverse sections. Recognition of this topotype material is believed justifiable inasmuch as unquestioned type material is not available and the genus *Lophophyllum* is taken to be based upon the species *Cyathaxonia tortuosa* Michelin (Carruthers, 1913, p. 50). Corals similar to *C. prolifera* are then properly placed in the genus *Lophophyllidium* as proposed by Grabau.

Lophocarinophyllum

The genus *Lophocarinophyllum* Grabau (1922, p. 46) with the genotype *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau (1922, p. 51), was established for Chinese species that resemble *Lophophyllidium* in many respects but that seem to have a distinct origin. The youthful stage of these forms is characterized by the development of carinae of the *Lopholasma* type. These appear in cross sections as septal spines. Grabau believes that sections of young specimens of the genotype species are practically identical, except for the projecting column, with sections of adult examples of *Lopholasma carinatum* Simpson (1900, p. 207). Inasmuch as these structures have not been observed in any American species of *Lophophyllidium*, it is quite likely, as Grabau suggests, that these Chinese forms represent a different line of descent. They have been derived from some *Lopholasma* type of coral, whereas

the American forms probably are derived from a coral of the *Stereolasma* type.

Sinophyllum

The genus *Sinophyllum* was established by Grabau (1938, p. 99) in his second volume on the Chinese Rugosa, the genotype being *Lophophyllum pendulum* Grabau (1922, p. 48). This new genus was stated to differ from *Lophophyllidium* in having a thick and pendulum-shaped axial column and an inner wall formed by the flexed ends of the major septa (not seen in sections of the mature portions of the corallite). The shape of the column does not seem to be especially diagnostic, for this is observed to vary widely in American species that are though to represent *Lophophyllidium.* The inner wall, formed by bending of the axial ends of the septa, as described by Grabau for *Sinophyllum,* is not found in American species assigned to *Lophophyllidium.* An inner wall that is commonly present in these forms is produced merely by thickening of the axial portions of the septa, supplemented by the addition of steroplasm. The illustrations of the genotype species given by Grabau (1922, pl. 1, figs. 15a-b, 16a-b; 1928, pl. 4, figs. 1a-e, 2a-d, 3a-c) do not show clearly this bending of the septa and many of the transverse sections show an inner wall identical with that of many American species of *Lophophyllidium.*

According to Grabau, *Sinophyllum* has fewer dissepiment than *Lophophyllidium.* Neither the genotype of *Lophophyllidium* nor other species correctly referred to the genus, however, have any dissepiments. Study of figures that are said by Grabau to contain dissepiments and careful reading of his introductory discussion of rugose coral morphology and terminology shows that he considered dissepiments to be obliquely placed troughlike structures, the bottom sloping inwards and the concavity being towards the polyp. They were also described as appearing in transverse section as connecting plates between the septa. This definition of dissepiments is not generally accepted by other students of corals. These plates between the septa in *Sinophyllum* are simply parts of the arched tabulae intersected by the transverse section. The reference to dissepiments in *Lophophyllidium* and *Sinophyllum,* as given by Grabau and repeated by others (Heritsch, 1936, 1936a; Chi, 1938, p. 159) is deemed incorrect. Species that have dissepiments, such as *Lophophyllum profundum* (Heritsch, 1936a, p. 108) must be assigned to other genera.

Sinophyllum resembles *Lophophyllidium* in all major features except for the nature of the inner wall. It is questionable whether this feature is sufficiently well developed in the genotype of *Sinophyllum* and is of sufficient importance to merit generic separation.

Rylstonia and other Genera

Hudson and Platt (1927, p. 40) state that some of the North American corals usually referred to *Lophophyllum profundum* have axial columns similar to those of *Rylstonia* Hudson and Platt (p. 39) and differ mainly in the strong longitudinal ribbing of the theca. The type of *Rylstonia*, which is *R. benecompacta* Hudson and Platt (p. 44), is a small conical-cylindrical form having a thick solid column, numerous tabulae, and several rows of dissepiments. The column of another variety from the same locality shows conspicuous radiating lamellae around its periphery. The dissepiments, and especially the nature of the axial column and tabulae, indicate that *Rylstonia* is more closely related to clisiophyllid corals than to *Lophophyllidium*.

Okulitch and Albritton (1937, p. 24) described the genus *Malonophyllum*, with the type species *Malonophyllum texanum*, n. sp., on the basis of silicified fragments of column-bearing corals from the Leonard series, Permian, from the Malone Hills, Texas. This genus is assumed to differ from *Lophophyllidium* in the entire absence of tabulae, but the nature of the septa and major features of the column are essentially similar in these two genera (Moore and Jeffords, 1941, p. 76).

A new genus, *Lophamplexus* (Moore and Jeffords, 1941, p. 90), the type species of which is *Lophamplexus eliasi*, n. sp., was established to include small solitary conical-cylindrical corals resembling "*Amplexus*" in nature stages but having an axial column that is attached to the counter septum in the youthful parts of the corallite. These corals can be separated from those included in *Lophophyllidium* by the disappearance of the column in the mature part of the corallite and by the thin complete tabulae that are present above the termination of the column.

A number of types of Upper Carboniferous lophophyllid corals have been placed in genera more or less closely related to *Lophophyllidium*. Many of these, such as *Lophophyllum*, *Arachnolasma* Grabau (1922, p. 59), *Carruthersella* Garwood (1912, p. 555), *Koninckocarinia* Dobrolyubova (1937, p. 51, 77), *Lophophylloides*

Stuckenberg (1904, p. 92) (?=*Lophophyllum*), *Neokoninckophyllum* Fomitchev (in Gorsky and others, 1939, p. 58), and *Yuanophyllum* Yu (1933, p. 26) may be distinguished readily by the presence of dissepiments. In addition, they have a very different type of axial column.

Taxonomic Status of Lophophyllid Corals

The classification of the Rugosa is now in an extremely confused state. Some students recognize many families and others only a few. As yet, too little information as to phylogeny of the corals is available, and too many examples of homeomorphy among these fossils are described or suspected to permit reliable determination of relationships of many genera.

Grabau (1928, p. 97) placed *Lophophyllidium* with other column-bearing corals in a new family called Lophophyllidae. *Lophophyllum,* to which corals belonging to *Lophophyllidium* were formerly referred, has been assigned to the Zaphrentidae by Zittel (1900) and others and to the Streptelasmidae (Grabau, 1922; Yoh and Huang, 1932; and Huang, 1932). The solitary horn corals that have a solid rodlike axial column and lack dissepiments, like *Lophophyllidium, "Sinophyllum", Malonophyllum,* and *Lophocarinophyllum,* seem to constitute a closely related group. Their relationship to the more highly developed but stratigraphically older genera, such as *Lophophyllum, Arachnolasma, Histophyllum,* Thomson (1879), and *Yuanophyllum* is not accurately known.

Uncertainty and difficulty that is encountered in seeking to formulate a satisfactory family classification justify omission of family assignment of the lophophyllid corals at this time.

SYSTEMATIC DESCRIPTIONS

Genus Lophophyllidium Grabau, 1928

Diagnosis.—Characteristics of *Lophophyllidium,* as determined from study of the genotype species and other Upper Carboniferous and Permian material, are summarized in the following description.

The genus includes medium-sized, straight to curved, solitary corals of conical to conical-cylindrical shape. The theca bears well developed longitudinal grooves and ridges that are crossed by

transverse growth lines and wrinkles of varying prominence. The depth of calyx is moderate in some forms, large in others. A prominent solid axial column projects upward in the center of the calyx. The septa are straight and thin in adult forms but may be curved and rhopaloid (thickened at their inner margin) in youth. The counter septum is extended so as to join the axial column, and the cardinal septum is shortened. Other major septa reach almost to the center but are not joined directly to the column. Minor septa may be well developed or absent. Counter quadrants are much accelerated. A conspicuous open fossula is formed by the partial abortion of the cardinal septum and alar pseudofossulae are developed in immature stages. Tabulae arch upward in varying degree and either extend from the periphery to the axial column or become slightly anastomosing. Dissepiments are absent. The characteristic axial column, a solid rodlike structure that in most specimens is compressed laterally, is formed by the thickened axial part of the counter septum and the very steeply upbent axial portions of the tabulae, thickened by steroplasm. Near the calyx the column may be separate from the counter septum. The median lamella of the column is a direct continuation of that in the counter septum. A few short lateral lamellae may be present.

Genotype.—Cyathaxonia prolifera McChesney, Missouri series, Pennsylvanian (Upper Carboniferous), Springfield, Ill.; also reported, probably incorrectly, from numerous other Upper Carboniferous and Permian beds of North America, Europe, and Asia.

Discussion.—The genotype of *Lophophyllidium* was designated as *Lophophyllum proliferum* (McChesney) by Grabau (1928, p. 99) in the original description of the genus, but some differences in interpretation of the type have developed. Heritsch (1936a, p. 109) selected as "lectotype" the specimen described by Yakovlev (1903, p. 1) as *Lophophyllum proliferum* (McChesney). This form is also given by Chi (1938, p. 161) as the "genolectotype" of *Lophophyllidium*. A lectotype is a specimen, selected from a number of specimens upon which an author based a species. (Arkell 1933, p. 601; Schenk and McMasters, 1936, p. 6). Inasmuch as the material studied by Yakovlev was not part of that used by McChesney in describing the species, the Russian specimen cannot become a lectotype. Yakovlev's specimen cannot be a neotype of *L. proliferum* because it does not come from the type locality of the species. Smith (1934, p. 129) has published the opinion that the form de-

scribed by Yakovlev is not conspecific with *L. proliferum* (McChesney) and that it belongs instead to *Lophophyllum orientale* Smith. Fomitchev (1938, p. 220) has redescribed Yakovlev's specimen, designating it a new species, *Lophophyllidium yakovlevi.*

A number of new species, such as *Lophophyllidium newelli, L. minutum, L. distinctum, L.* sp. A, and *L.* sp. B, differ from others referred to this genus in the restriction of the immature characters to a very small part of the apical region, the scarcity or absence of tabulae, and the large alar pseudofossulae. The youthful septa are separated into four symmetrical groups by the cardinal fossula, the two prominent alar pseudofossulae, and the two large interseptal spaces between the counter laterals and the counter septum. Mature parts have very straight septa with little or no axial thickening. Minor septa are very short or absent.

The lack of tabulae indicates similarity to *Malonophyllum.* The inadequate nature of the illustrations, lack of description of sectioned material, poorly preserved silicified type material, and the manner in which some structural features are described give reason for question as to the actual nature of the genotype described by Okulitch and Albritton (1937, p. 24) as *Malonophyllum texanum.* The lack of tabulae alone does not seem to be a satisfactory basis for the generic sub-division of lophophyllid corals. Both the incompletely known genotype and the Permian species called *M. kansasense* Moore and Jeffords (1941, p. 76) show lack of distinct alar pseudofossulae, more prominent rhopaloid septa, and a more independent axial column in the upper part of the corallite. Inasmuch as the significance of the distinctive features observed in this group of new corals is not known, corals of the *L. newelli* type are not now separated from *Lophophyllidium.*

LOPHOPHYLLIDIUM PROLIFERUM (McChesney)

Plate 1, figures 1-3; plate 8, figure 2

[1]*Cyathaxonia prolifera* McCHESNEY, *1860,* Descr. new Paleozoic fossils, p. 75; *1865.* Illustrations of new species of fossils, pl. 2, figs. 1-3; *1867,* Chicago Acad. Sci. Trans., vol. 1, p. 1, pl. 2, figs. 1-3.

Lophophyllum proliferum MEEK and WORTHEN, *1873,* Illinois Geol. Survey, vol. 5, p. 56, pl. 24, fig. 1.

[not] *Cyathaxonia prolifera* FOERSTE, *1887,* Denison Univ. Sci. Lab., Bull., vol. 2, p. 86, pl. 8, fig. 15.

[1] Synonyms include only those forms sufficiently well illustrated and described to permit determination of significant features.

[not] *Lophophyllum proliferum* KAYSER, *1883*, in Richtofen, China, Bd. 4, Abh. 8, p. 194, pl. 29, figs. 7-10—SOSCHKINA, *1925*, Soc. Nat. Moscow, Bull., sec. geol., n. s., vol. 33, p. 88, pl. 2, figs. 7, 7a; *1928*, Same, vol. 5, p. 371, pl. 12, figs. 15-18, text fig. 14.—SCHINDEWOLF, *1930*, Palaeont. Zeitschr., Bd. 12, p. 220. text fig. 15.—HERITSCH, *1931*, Abh. Geol. Bundesanstalt, Bd. 23, Heft 3, p. 5, text fig. 1.—HUANG, *1932*, Palaeontologia Sinica, ser. B, vol. 8, fasc. 2, p. 23, pl. 2, figs. 1a-d.

This species was originally described on external features alone, the internal features being indicated only by weathered calices. The description of this species by McChesney (1860, p. 75) is quoted in full.

Coral pointed below, gradually widening to the top in the form of a reversed cone, bent in a horn-like curve, sometimes nearly straight; circular, cavity moderately profound; radiating lamellae often more or less distorted, numbering at the margin from thirty-five to fifty according to the size of the individual; often every alternate one only extending a short distance from the margin.

Columella or axis comparatively large lenticular in outline in its free portion, the greater diameter being in the direction of the curvature, and sometimes becoming almost or entirely cylindrical below.

Surface marked by distinct, narrow, rounded longitudinal ribs, crossed by bands or wrinkles of growth of irregular width, which in an occasional specimen present a few short spines or tubes.

The usual height is from one-half an inch to an inch; diameter of the calyx very variable.

Geological position and locality.—In the Coal measures, very widely distributed in the Western States.

The revised publication (1867, p. 1) is identical with this except for the statement of geological position and locality. This is given as "in the coal measures at Springfield, Ill., and widely distributed throughout western U.S.A."

There is no record of the specimens used by McChesney in his original description and they are presumably lost. J. Marvin Weller of the Illinois Geological Survey, has kindly loaned to me 9 specimens of a lophophyllid coral from the "Coal Measures near Springfield, Illinois," collected by A. H. Worthen, stating that "most of the fossils recorded from the 'Coal Measures of [Springfield] Sangamon county, Illinois,' in Worthen's time were obtained from the Trivoli cyclothem." He also indicates that there is no known place in the county where equally well preserved corals can be obtained from the beds above coal No. 8.

In external details the lophophyllids from the Worthen collection show much similarity to the illustrations given by McChesney. Indeed, each of the three figures accompanying the original de-

scription can be duplicated almost perfectly by one of the specimens sent by Dr. Weller. The specimens also fit the description in nearly every detail. There is no indication of radicles on any of the specimens however. McChesney gives the number of septa in this species as 35 to 50, but he included the minor as well as the major septa in this count. There are about half this number of major septa in corallites of the Worthen group of specimens. The illustrations of other specimens from the same horizon given by Meek and Worthen (1873, pl. 24, figs. 1a-d), seemingly somewhat generalized, are essentially identical.

Inasmuch as McChesney's types are lost and the corals sent to me by Dr. Weller come from as close to the type locality as can be determined from the original description, and inasmuch as they conform almost exactly with the description and illustrations of the original specimens, it seems desirable to designate one of them as a neotype of the species *Cyathaxonia prolifera* McChesney, the genotype of *Lophophyllidium*. The description of *L. proliferum* based on this neotype is as follows:

Solitary conical corallites with the lower one-third curved through an arc of nearly 90 degrees in the plane of the countercardinal septa are included in this species. The theca is moderately thick, having deep relatively narrow septal grooves and broadly rounded symmetrical interseptal ridges. Fine growth lines and moderately coarse wrinkles run transverse to the septal grooves. The calyx is moderately deep, and a thin laterally compressed axial column projects into its lower part. In several weathered specimens the column extends a few millimeters above the rest of the corallite. The neotype specimen is 30.0 mm in length and 12.7 mm in diameter, at the calyx. Eight other specimens in the same lot range from 12.1 mm to 33.3 mm in length and 8.2 mm to 10.4 mm in diameter.

The major septa are strong and straight, reaching nearly to the column. The arrangement in the upper part of the neotype is as follows: counter septum, 7 metasepta, alar septum, 3 metasepta, cardinal septum, 3 metasepta, alar septum, 7 metasepta, and counter septum again, a total of 24 major septa. The strong counter acceleration is also indicated by the septal arrangement in another specimen, which has the following septal plan: counter septum, 5 metasepta, alar septum, 3 metasepta, cardinal septum, 3 metasepta, alar septum, 5 metasepta, and back to the counter septum. In a

mature example, the septa are nearly equal in size, except for the very short cardinal septum and the prolonged counter septum. Sections of the lower part of the corallite show the septa almost touching the column or even united to it and to each other by stereoplasm. The elements of the septa, except for the counter septum, are individually distinct and they can be differentiated from the column, however. The part of the corallite near the apex of the neotype is so filled with stereoplasm that it is difficult to identify the details of structure. Sections close to the apex, however, show that the median lamella of the counter septum extends at least to the axis, whereas the lamellae of the other septa nowhere invade this axial area. A section slightly more than half way up the corallite reveals a distinct axial thickening of the septa. In the section just below the calyx the septa are slightly or not at all thickened axially.

The very thin and short cardinal septum lies in a conspicuous open fossula. The alar pseudofossulae are inconspicuous, even in youthful stages. Thin regular slightly anastomosing tabulae rise steeply from the periphery, flatten or slant downward slightly, and then rise to join the column. There are no dissepiments. The axial column is broadly oval in transverse section and is directly connected to the counter septum throughout most of the corallite, al-

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EXPLANATION OF PLATE 1

(All figures 3 times natural size. In each transverse section the counter septum is placed at the top.)

Lophophyllidium proliferum (McChesney), beds over coal no. 8, Trivoli cyclothem, Missouri series, Pennsylvanian, near Springfield, Illinois.

1a-c—Specimen (Illinois Geol. Survey and State Museum no. W4064b). *a*, Longitudinal section. *b-c*, Transverse sections.

2a-f—Specimen (Univ. Kansas no. 4761-21a). *a*, Longitudinal section containing counter septum. *b*, Longitudinal section containing cardinal septum. *c-f*, Transverse sections.

3a-e—Type specimen (Illinois Geol. Survey and State Museum no. W4064-a). *a*, Longitudinal section. *b-e*, Transverse sections.

Lophophyllidium profundum (Edwards and Haime)?, recorded as questionably from the Lower Mercer limestone, lower Pottsville, Pennsylvanian, from northeastern Muskingum county, Ohio.

4a-d—Transverse thin sections of specimen (Ohio State Univ. no. 17850).

Lophophyllidium confertum, n. sp., Lester limestone, Dornick Hills group, of Lampasas age, Pennsylvanian, southeast of Ardmore, Oklahoma.

5a-d—Type specimen (Univ. Kansas no. 6806-21c). *a*, Longitudinal section. *b-d*, Transverse sections.

6—Transverse section of specimen (Univ. Kansas no. 6806-21b).

7a, b—Transverse section of specimen (Univ. Kansas no. 6806-21a).

PLATE 1

though free in the uppermost part. Transverse sections of the column near the calyx show the presence of fine lateral lamellae as well as the prominent median lamella.

Weathered specimens show the exterior of the column to be covered with many somewhat anastomosing longitudinal ridges, slightly curved towards the counter septum and intersected by short transverse ridges. The counter side is marked by a sharp smooth longitudinal keel, but the other ridges show no relationship to the remaining septa.

Discussion.—In 1872 Meek (p. 144) described some specimens of a small column-bearing coral from Nebraska. These were compared with corals from the "Coal-Measures of Illinois" and reported to agree in all respects. Several longitudinal sections were reported, but only one fragment is illustrated and it shows distinct tabulae arching steeply toward the column. Inasmuch as tabulae were thought by Meek to be absent in the Cyathaxonidae, he referred *Cyathaxonia prolifera* to the genus *Lophophyllum.*

A number of years prior to the description published by McChesney, an internal mold of the calyx of a column-bearing coral from Flint Ridge, Ohio, had been described as *Cyathaxonia profunda,* n. sp., by Edwards and Haime (1851, p. 323). No illustrations accompanied this description or a later one in 1860 (Edwards and Haime, 1860, p. 331). Specimens of Flint Ridge corals, along with the rest of that fauna, were studied by Foerste in 1887 (p. 86) who identified them as *Cyathaxonia prolifera* McChesney. The next year Foerste, (1888, p. 136) published a brief note giving his conclusion that the structure of the column in the Flint Ridge corals necessitates placing the species in *Lophophyllum. L. proliferum* was considered to be one of many variations of *Lophophyllum profundum* and Foerste thought that McChesney's species should be regarded as a junior synonym of *L. profundum.*

Since 1900 most American authors have considered *Cyathaxonia prolifera* as equivalent to *C. profunda* and almost no specimens have been assigned by them to *Lophophyllum proliferum.* Foreign authors, except Heritsch (1936a) uniformly have used the name proposed by McChesney for corals of this type. The Illinois specimens of *Lophophyllidium proliferum* that have been described differ from examples of *L. profundum* from Flint Ridge in the larger size and more cylindrical form of the corallite, more numerous septa and tabulae, and greater development of minor septa.

Lophophyllidium proliferum can be distinguished from *L. dunbari* Moore and Jeffords (1941, p. 83) by its larger size and the more curved character of the corallite, the greater size and symmetry of the axial column and the character of the arched tabulae. The curvature of the corallite in the Permian species is in the plane of the alar septa whereas the cardinal septum lies on the concave side of the corallite in *L. proliferum*. This species is separated from *L. yakovlevi* (Fomitchev, 1938) by the large and solid column, absence of a strongly marked breviseptal mature stage, and presence of distinct rhopaloid septa in immature parts.

Occurrence.—Beds over Coal No. 8, Trivoli cyclthem, Missouri series, Pennsylvanian (Upper Carboniferous), near Springfield, Ill.

Neotype.—Illinois Geological Survey and Illinois State Museum no. W46064a. Other specimens studied include eight corallites that are associated with the neotype in the Illinois collection no. W40604 and two specimens from Springfield, Ill., contained in collections of the University of Kansas, no. 4761-21.

LOPHOPHYLLIDIUM PROFUNDUM (Edwards and Haime)?

Plate 1, figure 4; plate 8, figure 4

Cyathaxonia profunda EDWARDS and HAIME, *1851,* Mon. Polyp. Fossiles Terr. Pal., Arch. Mus. Hist. Nat., vol. 5, p. 323; *1860,* Histoire naturelle des coralliaires ou polypes proprement dits: vol. 3, p. 331.

Cyathaxonia prolifera FOERSTE, *1887,* Denison Univ., Sci. Lab., Bull., vol. 2, p. 86, pl. 8, fig. 15.

[not] *Lophophyllum profundum* BEEDE, *1900,* Kansas Univ. Geol. Survey, vol. 6, pt. 2, p. 17, pl. 2, fig. 7, 7b.—WOODRUFF, *1906,* Nebraska Geol. Survey, vol. 2, pt. 2, p. 260, pl. 5, fig. 4.—GIRTY, *1915,* U. S. Geol. Survey, Bull. 544, p. 19, pl. 2, figs. 1-6a, pl. 6, figs. 12, 14.—MATHER, *1915,* Denison Univ., Sci. Lab., Bull., vol. 18, p. 91, pl. 1, figs. 11-13.—PLUMMER and MOORE, *1921,* Univ. Texas, Bull. 2132, p. 79, pl. 13, fig. 14, pl. 20, figs. 1, 2, 4, 5, pl. 23, figs. 3-6.—MORGAN, *1924,* Oklahoma Bur. Geol., Bull. 2, p. 192, pl. 32, figs. 2a-d.—CRONEIS, *1930,* Arkansas Geol. Survey, Bull. 3, p. 134, pl. 27, fig. 1.—KELLY, *1930,* Jour. Paleontology, vol. 4, p. 136, pl. 11, figs. 1, 2.—SAYRE, *1930,* Kansas Geol. Survey, Bull. 17, p. 85, pl. 1, figs. 3-5.—HERITSCH, *1936,* Palaeontographica, Bd. 83, Abt. A, p. 108, pl. 17, figs. 15-18, text-fig.—pl. 2, fig. 9.

Small solitary corals straight or nearly straight and conical in form comprise this species. The moderately thick theca shows conspicuous rounded septal grooves and interseptal ridges with fine transverse growth lines. The calyx is not well shown by specimens available for my study, but it is probably deep. Two slightly crushed unsectioned specimens are 19.0 mm and 13.0 mm in length and 7.5 mm and 8.1 mm in diameter, respectively.

The septa in the upper portion are long and slightly to moderately rhopaloid. Their arrangement is as follows: counter septum, 5? metasepta, alar septum, 3 metasepta, cardinal septum, 3 metasepta, alar septum, 5 metasepta, and back to the counter septum again. Minor septa are not shown in any of the sections but seem to be indicated in the theca of the uppermost section. A lower section shows the major septa reaching nearly to the axial column and joined to it and to each other by steroplasm. The cardinal septum is short throughout. The thin long counter septum is greatly thickened axially to form the column.

An open cardinal fossula and large alar pseudofossulae are developed. A few thin uparched tabulae are present but are rare in upper portions. The axial column is directly connected to the counter septum except probably in the calyx. Transverse sections of early stages show a strongly marked median lamella running from the counter septum through the column. An upper transverse section shows this same median lamella and several other small lateral lamellae. These small radiating lamellae do not correspond to the other major septa. The uncentered longitudinal section shows only a few arched tabulae and indicates absence of dissepiments.

Discussion.—Description of *L. proliferum* by Edwards and Haime (1951, p. 323) was based on a mere external mold of the calyx of a column-bearing coral from Flint Ridge, Ohio. It was described as having a deep subcircular calyx that contains a straight column of subelliptical cross section and 24 well developed thick major septa. No illustrations were given.

In 1887 Foerste (p. 86) described corals from Flint Ridge as *Cyathaxonia prolifera*. This species was characterized by him as including conical corals, nearly straight to curved below, bearing a thin theca that is marked by longitudinal grooves and ridges. The calyx is deep and nearly circular. Major septa are 20 to 28 in number, alternating minor septa being present only in the uppermost part of the calyx. The axial column is laterally compressed. A cardinal fossula and alar pseudofossulae are rather prominent. The largest of Foerste's specimens is reported to be 22 mm in length and 17 mm in diameter, at the calyx.

As indicated in the discussion of *Lophophyllidium profundum*, Foerste (1888, p. 136) later considered this Flint Ridge coral to be more properly identified as *Lophophyllum profundum*. Foerste

(1888) also states that the characterization of *L. profundum* given by Edwards and Haime is very good, considering the nature of the specimens usually found.

The specimens here referred to *L. profundum* with question are from a collection loaned for study by J. W. Wells of Ohio State University. They were not collected at Flint Ridge, but are thought to come from the same horizon in Muskingum county, the next county east of that containing Flint Ridge. The lot sent by Dr. Wells includes two complete corallites, one longitudinal thin section, and four transverse thin sections, seemingly from the same corallite. This sectioned material does not show the extremely deep calyx figured by Foerste nor is the distinct inner wall indicated. Until more is known of the characters of *L. profundum* and more specimens are sectioned, these specimens may be assigned questionably to this species.

The specimens differ from *L. proliferum* in the smaller size and more conical form of the corallite, smaller number of septa and tabulae, and absence of minor septa.

Occurrence.—The studied specimens are recorded with question as coming from the lower Mercer limestone, lower Pottsville, Pennsylvanian (Upper Carboniferous), northeastern Muskingum county, Ohio.

Studied Specimens.—Ohio State Univ. no. 17850 (two corallites and five thin sections).

LOPHOPHYLLIDIUM CONFERTUM, n. sp.

Plate 1, figures 5-7

The description of this species is based on a number of solitary long conical-cylindrical corallites that are straight or only very slightly curved in the plane of the alar septa. The moderately thick theca shows fine deep septal grooves and rounded longitudinal ridges. Fine growth lines and rare low wrinkles run transverse to the ridges and grooves. The calyx is deep and it contains a tall pointed spikelike column. The type specimen is 21.5 mm in height and 10.8 mm in diameter, just below the calyx.

A transverse section through the uppermost part of the type specimen reveals only broken and displaced septa. A section slightly lower shows 24 major septa, the alar not being determined from study of the sections. Another specimen shows the septal arrangement clearly in a section half way up the corallite, as fol-

lows: counter septum, 6 metasepta, alar septum, 3 metasepta, cardinal septum, 3 metasepta, alar septum, 6 metasepta, and the counter septum again. In the upper parts the septa are long and only slightly thickened at the axial ends. The cardinal septum is short at all stages of development. The counter septum is extended to the axis to form the column in all except the very mature stages and then remains longer than other septa. Slightly lower sections show the long and rhopaloid major septa slightly joined to each other and to the column by stereoplasm. Still lower sections reveal that the septa are distinctly teardrop shaped and all are joined closely together and to the column by stereoplasm. Very short minor septa alternate with the major septa in upper portion.

The cardinal septum lies in a prominent open fossula. Alar pseudofossulae are visible in sections about half way up in the corallite but are not apparent in the mature stages. Widely spaced thin tabulae rise from the periphery at an angle of about 45 degrees, flatten out slightly, and then rise abruptly as they join the axial column.

The thickening of septa and deposition of stereoplasm in the lower half of the corallite conceals most of the details of this part. This is a consistent feature of the specimens studied. The median lamellae of the septa can be recognized usually and they remain distinct where the septa are thickened by stereoplasm. In the solid portion of the corallite the column is not differentiated except for the extension of the lamella of the counter septum to and beyond the axis. In upper sections the column persists as a solid rod-like structure and passes from a broad oval shape to an elongated thin ellipse in successive transverse sections.

Discussion.—The coral named *Lophophyllidium confertum* is characterized by the narrow conical-cylindrical shape and by the thick deposit of stereoplasm in the lower half of the corallite. This species is readily distinguished from *L. mundulum,* n. sp., by its numerous tabulae, rhopaloid septa, and thick deposits of stereoplasm.

The calyx in most of the specimens of this species are broken and the septa of the uppermost sections are displaced. The thickening of the corallite in the apical region may have developed as a means of strengthening the long, thin-walled corallite against strong currents or waves.

Occurrence.—Lester limestone, Dornick Hills group, of Lam-

pasas age, Pennsylvanian (Upper Carboniferous), Murray Lake State Park, southeast of Ardmore, Oklahoma. Collected by R. C. Moore.

Type.—Univ. Kansas no. 6806-21c. Three other specimens from same locality were also studied.

LOPHOPHYLLIDIUM MUNDULUM, n. sp.

Plate 2, figure 1

Solitary steeply conical corallites, the lower part slightly curved in the plane of the alar septa, are included in this species. The thin theca shows deep narrow longitudinal grooves and broad rounded interseptal ridges. Transverse ornamentation consists of fine growthlines. The calx is deep and a tall spikelike projection of the column occurs in the center. The type specimen is 20.0 mm in length and 11.7 mm in diameter, at the calyx.

The two uppermost transverse sections show 26 major septa arranged as follows: counter septum, 7 metasepta, alar septum, 4 metasepta, cardinal septum, 4 metasepta, alar septum, 7 metasepta, and counter septum again. The cardinal septum is very short but the counter septum is attached to the column almost up to the calyx. The other major septa reach close to the column and are about equal in length. Very short minor septa appear about half way up the corallite. In mature stages the major septa are thin and curve slightly towards the counter septum. No stage marked by development of conspicuous rhopaloid septa is observed in this species, but in the lower part of the corallite the septa are joined to each other and to the column by stereoplasm.

The cardinal fossula is large. No tabulae are shown in the transverse or longitudinal sections but there is a thick concealing deposit of stereoplasm in the lower part of the corallite.

Discussion.—This species has relatively simple internal structures. No tabulae are recognized but it seems probable that they actually are present, though concealed by stereoplasm. *Malonophyllum* has been assumed to contain corals similar to *Lophophyllidium* but without tabulae. This feature alone may not be usable for precise generic separation. *L. newelli, L. minutum, L. distinctum, L.* sp. A, and *L.* sp. B. also have very few tabulae or seem entirely to lack them. These corals and the Permian species *M. kansasense* are characterized by very rapid development of the

corallite and restriction of internal structures to the lower part. *L. mundulum*, on the other hand, closely resembles most species of *Lophophyllidium* in the septal arrangement, rate of development, and long relatively slender form.

Lophophyllidium mundulum is distinguished from *L. confertum*, n. sp., by the lack of rhopaloid thickening of the septa, little stereoplasm except at the column, and absence of recognizable tabulae.

Occurrence.—Pumpkin Creek limestone, 220 feet above Lester limestone, Dornick Hills group, of Lampasas age, Pennsylvanian (Upper Carboniferous). Collected by R. C. Moore, southwest of the Country Club, about 3 miles north of Ardmore, Oklahoma.

Type.—Univ. Kansas no. 68-21a.

LOPHOPHYLLIDIUM COMPRESSUM, n. sp.

Plate 2, figure 2; plate 8, figure 1

This species comprises medium-sized solitary conical corallites that are distinctly curved in the plane of the alar septa or nearly so. The moderately thick theca bears well defined septal grooves that are about as broad as the rounded ridges. Prominent wrinkles and fine growth lines run transverse to the septal markings. The calyx is deep and a broad laterally flattened column projects nearly to its

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EXPLANATION OF PLATE 2

(All figures 3 times natural size. In each transverse section the counter septum is placed at the top.)

Lophophyllidium mundulum, n. sp., Pumpkin Creek limestone, 220 feet above Lester limestone, Dornick Hills group, of Lampasas age, Pennsylvanian, southwest of the Country Club, about 3 miles north of Ardmore, Oklahoma.

1a-d—Type specimen (Univ. Kansas no. 68-21a). *a*, Longitudinal section. *b-d*, Transverse sections.

Lophophyllidium compressum, n. sp., Millsap Lake group, Des Moines series, Pennsylvanian, 3.5 miles east of Rochelle, Texas.

2a-c—Type specimen (Univ. Kansas no. 7208-21a). *a*, Longitudinal section. *b*, *c*, Transverse sections.

Lophophyllidium murale, n. sp., about 8 feet above base of Memorial shale, Des Moines series, Pennsylvanian, from center south road in sec. 2, T. 33 S., R. 12 E., Montgomery county, Kansas.

3a-c—Specimen (Univ. Kansas no. 2615-21c). *a*, Longitudinal section. *b*, *c*, Transverse sections.

4a-c—Transverse sections of the type specimen (Univ. Kansas no. 2615-21b).

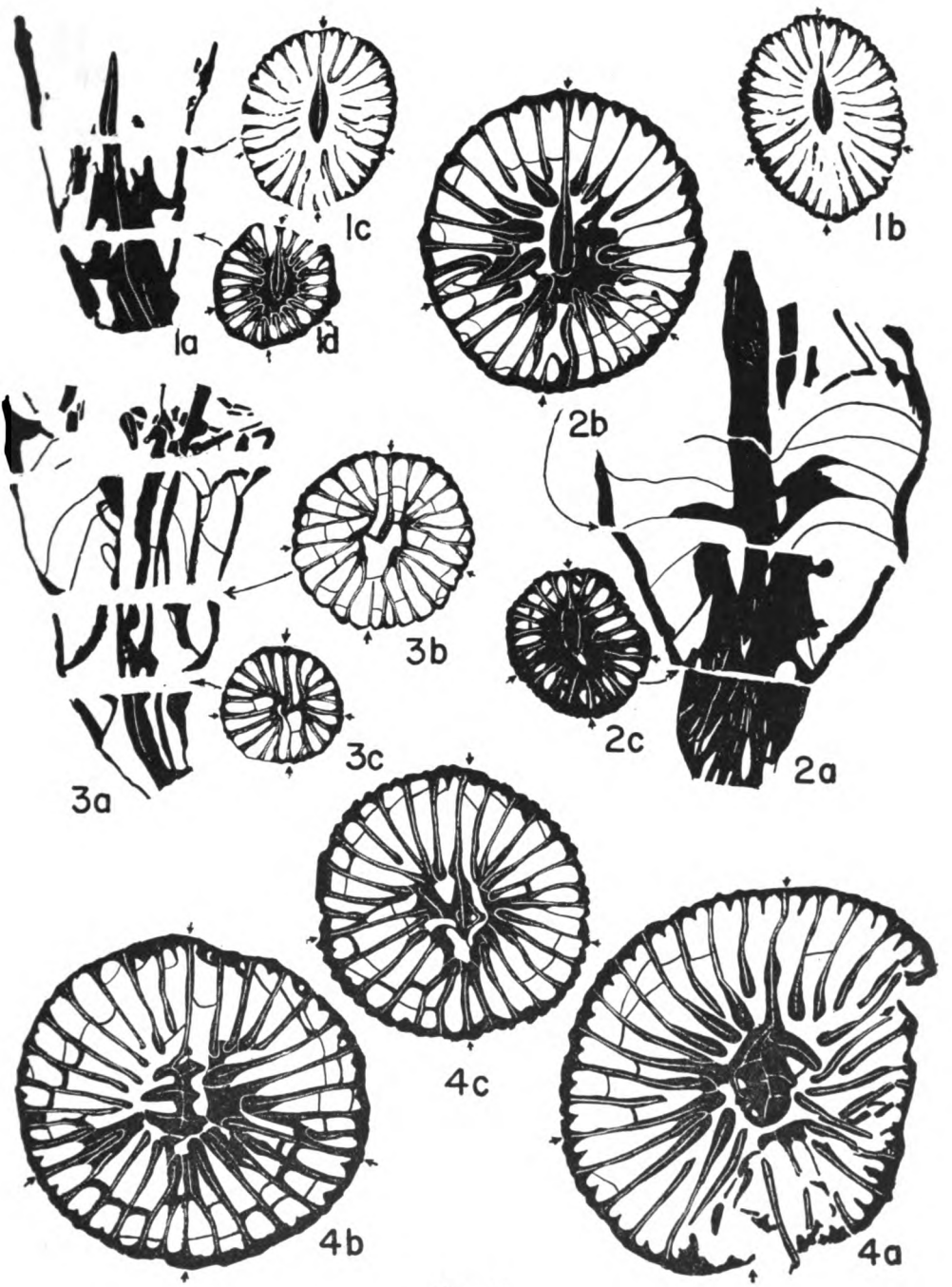

PLATE 2

rim. The type specimen which is slightly above average size, is 25.6 mm in length and 15.2 mm in diameter.

The uppermost transverse section of the type specimen shows 32 unequal major septa, arranged as follows: counter septum, 9 metasepta, alar septum, 5 metasepta, cardinal septum, 5 metasepta, alar septum, 9 metasepta, and the counter septum again. The cardinal septum is very short, but the counter septum extends beyond the middle of the coral, its inner or axial edge being thickened to form the laterally compressed column. In the type specimen, a transverse section slightly below the calyx shows the septa to be of unequal and varying lengths. The majority reach close to the column and are much thickened axially. The others are about two-thirds as long and only slightly rhopaloid. In immature stages the septa are slightly rhopaloid, closely packed axially, and thickened by considerable stereoplasm. At successively higher positions in the corallite, the amount of this deposit is diminished and the septa are accordingly more distinct. The minor septa are introduced first in the counter quadrants in an irregular manner and remain very short. The cardinal fossula is conspicuous but alar pseudofossulae are rather poorly defined at all stages. The thin regularly spaced tabulae rise gradually from the periphery and then curve gently downward. Just before joining the column they once more turn slightly upward. These tabulae are seen in longitudinal section as nearly symmetrical curves, with the concave side downward. The laterally compressed column is distinct and solid at all stages, although the axial portion of the early part of the corallite is strengthened by deposition of stereoplasm. No vertical striae are visible on the column.

Discussion.—This species is characterized by the broadly conical form of the corallite, the thick solid axial column, and the nearly flat tabulae that dip downward near the column. It can be distinguished easily from *Lophophyllidium murale*, n. sp., by its shorter cardinal septum, more rhopaloid septa, and the absence of parallel open spaces on either side of the counter-cardinal plane.

Occurrence.—Millsap Lake group, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by R. C. Moore in a small stream bed 0.8 miles from highway, 3.5 miles east of Rochelle, Texas.

Type.—Univ. Kansas no. 7208-21a. Other studied material includes about a dozen corallites and sectioned specimens.

LOPHOPHYLLIDIUM COMPLEXUM, n. sp.

Plate 3, figure 1

This species includes medium-sized solitary conical corallites having almost no curvature. The moderately thick theca shows wide rounded septal grooves and interseptal ridges. There are growth lines and low wrinkles transverse to these longitudinal markings. The calyx is not well preserved in available specimens but it seems to be moderately deep and it contains a long spikelike column. The type specimen is 23.5 mm in length and 14.1 mm in diameter, at the calyx.

The section just below the calyx reveals 28 major septa. The septal arrangement in a section slightly lower with 26 septa is as follows: counter septum, 7 metasepta, alar septum, 4 metasepta, cardinal septum, 4 metasepta, alar septum, 7 metasepta, and counter septum once more. In a section about 3 mm below the disrupted uppermost section of the type specimen the major septa are of two lengths. One group is long and rhopaloid. The others are short and straight. Transverse sections through the lower part of the corallite show the septa to be distinctly thickened axially in such manner that they are joined together and to the column. The cardinal septum is very short and unthickened throughout. The counter septum is distinctly thickened at the axis up to the place where, in mature specimens, it separates from the column. Minor septa about half as long as the cardinal septum are present near the calyx.

The cardinal fossula is well developed. Two pseudofossulae are distinct but not prominent in early stages and are inconspicuous in the adult stages. The slightly anastomosing tabulae are rather closely spaced. In the lower portion they arch steeply from the periphery, dip down slightly, and arch again just as they join the column, but they are more or less horizontal in the upper portion of the corallite. The column is relatively narrow in longitudinal section and distinctly oval in transverse section. It is free from all septa above a point slightly below the floor of the calyx and tapers upward to a sharp crest.

Discussion.—The more or less horizontal tabulae of the upper part of the corallite of *Lophophyllidium complexum* are the most diagnostic feature of this species. It is distinguished from *L. expansum,* n. sp. by the more irregular length of the major septa, and absence of a distinct space each side of the counter-cardinal plane

in immature parts. The nearly flat tabulae and relative breadth of the corallite separate *L. complexum* from *L. proliferum*. The cardinal septum of *L. murale*, n. sp. is longer and the theca much thinner than in the species here described.

Occurrence.—Upper Labette shale, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by N. D. Newell in road cut at center sec. 9, T. 21 N., R. 15 E., west of Claremore, Rogers county, Oklahoma.

Type.—Univ. Kansas no. 2306-21a.

LOPHOPHYLLIDIUM MURALE, n. sp.

Plate 2, figures 3, 4; plate 8, figure 6

The description of this species is based on two well preserved specimens of a rather large solitary broadly conical coral that is gently curved in the plane of the alar septa. The theca is marked longitudinally with low ridges and broad rounded septal grooves. There are broad low transverse wrinkles and fine growth lines. Short radicles are developed near the apex and rarely one or two occur higher on the corallite. The calyx is not well preserved but seems to have been broad and shallow, containing only a low column. The type specimen is 35.4 mm in length and 23.0 mm in diameter, at the calyx.

There are 33 septa in the upper part of the type specimen, the septal arrangement being counter septum, 9 metasepta, alar septum, 5 metasepta, cardinal septum, 6 metasepta, alar septum, 9 metasepta, and the counter septum again. This uneveness is also shown in a lower section of another specimen. The arrangement of the septa in this is as follows: counter septum, 7 metasepta, alar septum, 5 metasepta, cardinal septum, 4 metasepta, alar septum, 6 metasepta, and counter septum once more. The major septa are nearly of equal length but there is some irregularity. The counter septum is long, reaching the axial column even in the region close to the calyx. The cardinal septum, on the other hand, is about two-thirds the length of the metasepta in upper sections but it reaches the column in early immature stages. Minor septa, which occur only high up in the corallite, are extremely short. The major septa approach the column closely in all growth stages but do not join it. Near the calyx the septa are long, distinctly rhopaloid, and mostly separate. Lower sections reveal that they are joined to each other at their axial ends by stereoplasm. The septa on either side of the

counter-cardinal plane are each joined together. This forms a long narrow open rectangle occupied by the cardinal and counter septa.

The partial abortion of the cardinal septum produces a distinct open fossula. Alar pseudofossulae are not well developed. Thin regularly spaced complete tabulae arch steeply from the periphery and join the column or the inner wall near the axis. The column formed by the axial end of the counter septum and axial ends of the uparched tabulae is small and not distinctly differentiated from the septum in early periods of growth. In upper transverse sections it steadily becomes more irregular in shape, and there are several protruding bulges that contain distinct lamellae. These do not appear to be directly related to any of the septa, but may be produced by attachment to the column of parts of the wall formed around axial ends of the septa in earlier stages. The inner wall is formed by the junction of the septa on each side of the counter-cardinal opening and by addition of stereoplasm. It is well shown in the longitudinal section of the second specimen as two solid vertical structural deposits parallel to the narrow axial column.

Discussion.—The irregular shape of the axial column in mature portions of *Lophophyllidium murale* is a characteristic feature. This species is separated from *L. expansum,* n. sp., by the thin theca of youthful stages, slight stereoplasmic thickening of the septal ends, more widely spaced tabulae, and poorly developed minor septa. *L. compressum,* n. sp., has a much shorter cardinal septum and more horizontal tabulae.

Occurrence.—About 8 feet above the base of the Memorial shale, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by J. M. Jewett from road cut in sec. 2, T. 33 S., R. 13 E., Montgomery county, Kansas.

Type.—Univ. Kansas no. 2615-21b. The material studied includes 9 specimens

LOPHOPHYLLIDIUM EXPANSUM, n. sp.

Plate 3, figure 2

Large conical solitary corallites slightly but regularly curved in the plane of the alar septa comprise this species. The moderately thick theca is crossed by prominent wrinkles but growth lines are absent. The septal grooves are wide and broad as are the longitudinal ridges. The calyx is very deep, the narrow pointed column being present in the lower part. The type is 33.9 mm in length and 33.4 mm in diameter.

There are 28 major septa in the upper part of the corallite of the type, the septal arrangement being as follows: counter septum, 7 metasepta, alar septum, 5 metasepta, cardinal septum, 5 metasepta, alar septum, 7 metasepta and the counter septum again. The counter septum is extended to the axis in early stages and thickened to form the column. It withdraws from the column about half way up in the corallite and progressively decreases in length until in a section just below the calyx it is shorter than the counter lateral septa. The cardinal septum is very short in the mature parts of the corallite, but although very thin in the lower parts, it is extended to the column. The other major septa are of two lengths in the mature portion, the counter lateral septa and about every alternating pair being slightly longer. The major septa are notably rhopaloid in adolescence but upper sections show only a few such thickened septa. In upper sections minor septa, about one-third as long as the major, alternate with the longer septa. A feature of most of the major and minor septa of the type specimen is a diamond-shaped thickening that occurs a short distance from the periphery, as seen in transverse section just below the calyx. The short cardinal septum lies in a prominent open fossula. In lower sections the position of the fossula is indicated by the extremely thin cardinal septum.

Numerous regularly spaced tabulae rise steeply from the periphery to the axial column. This column is formed by the thickened counter septum supplemented by the ascending axial ends of the tabulae. Transverse sections of the column show no differentiation into tabular structures or radiating lamellae.

Discussion.—The coral named *Lophophyllidium expansum* is separated from *L. complexum*, n. sp., by its larger size, more steeply

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EXPLANATION OF PLATE 3

(All figures 3 times natural size. In each transverse section the counter septum is placed at the top).

Lophophyllidium complexum, n. sp., upper Labette shale, Des Moines series, Pennsylvanian, in road cut at center sec. 9, T. 21 N., R. 15 E., west of Claremore, Rogers county, Oklahoma.

1a-e—Type specimen (Univ. Kansas no. 2306-21a). *a*, Longitudinal section. *b-e*, Transverse sections.

Lophophyllidium expansum n. sp., Cherokee shale, Des Moines series, Pennsylvanian, at Tillman Pit, NE NE sec. 23, T. 42 N., R. 26 W., Henry county, Missouri.

2a-d—Type specimen (Univ. Kansas no. 323-21a). *a*, Longitudinal section. *b-d*, Transverse sections.

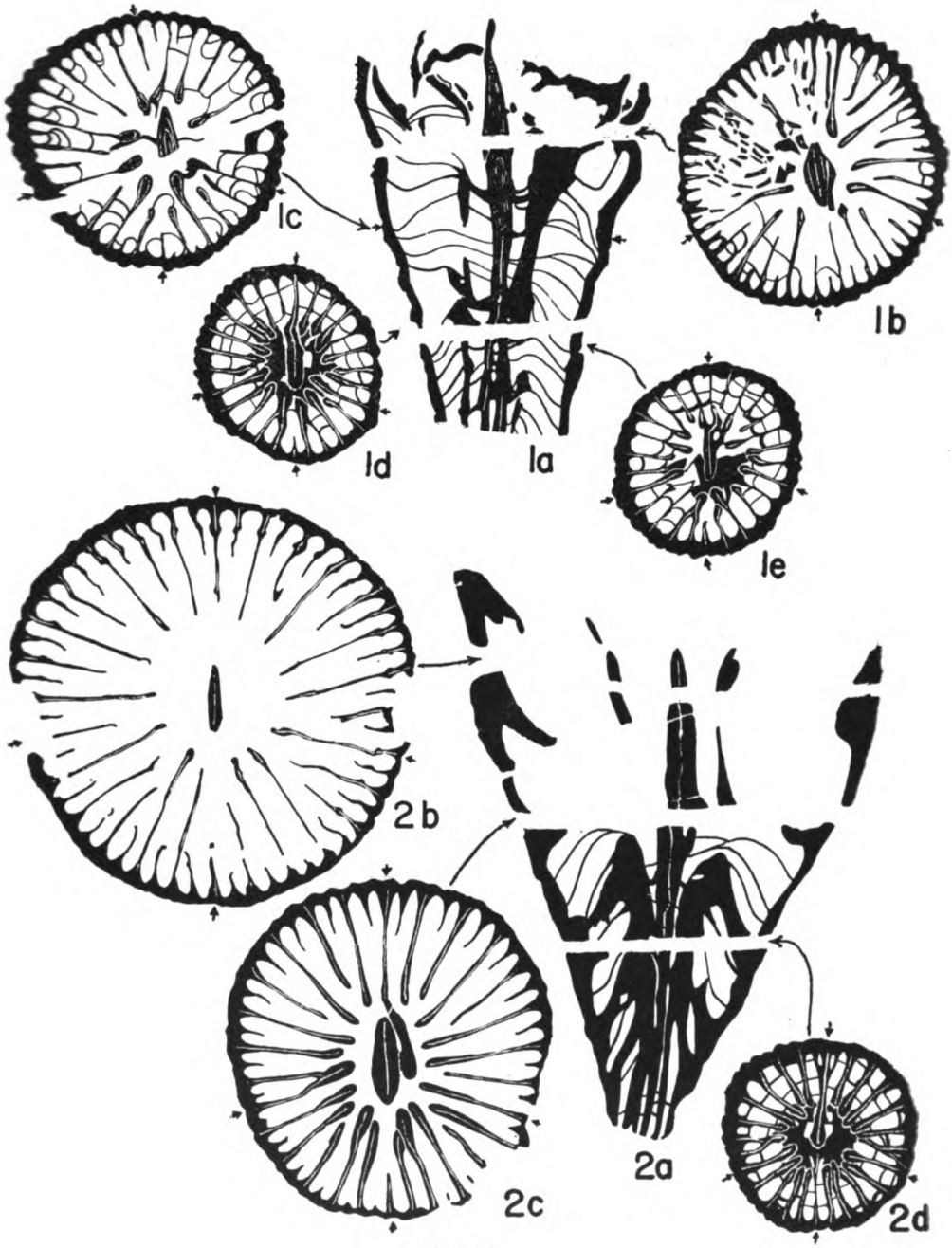

PLATE 3

arched tabulae, and the long cardinal septum in young forms. This species differs from *L. proliferum* in the broadly conical form and the more or less open spaces on either side of the counter and cardinal septa in young stages.

Study of the transverse and longitudinal sections shows that the counter septum is not extended along one side of the column as is suggested by the second highest transverse section. This is a peculiarity of this part of the corallite and seemingly is formed by stereoplasm, perhaps as a result of injury to the polyp.

Occurrence.—Cherokee shale, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by J. B. Owen at Tillman pit, NE NE sec. 23, T. 42 N., R. 26 W., Henry county, Missouri. Also from the Cherokee shale along road in secs. 4 and 8, T. 31 S., R. 24 E., Crawford county, Kansas, collected by H. W. Compton.

Type.—Univ. Kansas no. 323-21a. Other material included several dozen specimens from the Kansas locality.

Lophophyllidium girtyi, n. sp.

Plate 7, figures 7, 8; plate 8, figure 3

This species includes solitary conical corallites that are curved only near the apex. The theca has distinct longitudinal grooves and ridges, the former being about as wide as the interseptal ridges. The surface is more or less covered by numerous stubs of hollow radicles placed in irregular rows over the entire corallite. The theca surrounding the calyx is not preserved, and accordingly the nature of the calyx is unknown. The type specimen is 27.4 mm in length and 17.4 mm in diameter.

There are 32 major septa in the type specimen, about the same number occurring in other specimens. The septa are arranged as follows: counter septum, 9 metasepta, alar septum, 5 metasepta, cardinal septum, 5 metasepta, alar septum, 9 metasepta and the counter septum again. The nearly equal metasepta reach close to the column even in the mature part of the corallite. The cardinal septum is distinctly shortened and the counter septum is prolonged to the axis where it is thickened to form the axial column. Minor septa are small inconspicuous ridges between some of the major septa or are entirely absent. The shortened cardinal septum lies in a relatively inconspicuous open fossula.

Numerous tabulae ascend steeply from the periphery for a distance equal to about two-thirds the radius of the corallite and then

bend down slightly before rising abruptly to join the column. Most longitudinal sections show the tabulae to be numerous and regularly spaced. There are no dissepiments.

The solid rodlike laterally compressed column is formed by the thickened axial portion of the counter septum and the ascending axial ends of the tabulae. It is closely allied to the counter septum throughout the corallite and may be joined to the other major septa by stereoplasm.

Discussion.—This species shows much similarity in external form to the specimens called *Lophophyllium profundum* var *radicosum* by Girty (1911, p. 122; 1915, p. 27, pl. 2, figs. 7-9). Different forms are described from several localities, none of which are designated as a definite type locality. Material from one of these localities includes horn corals that bear a prominent column and external spines. The internal structures of these specimens and this species seem to be different.

Girty's variety is presumed to have a much more laterally compressed column in mature stages, and a more prominent cardinal fossula and alar pseudofossulae in immature stages. The septal development and deposition of stereoplasm seems to be of a different character. Accordingly, it seems likely that more than one rugose coral species was represented in the material described by Girty. Study of his type material is needed before the form named by him can be recognized properly.

This species is characterized by its numerous radicles and its flat or laterally compressed axial column. It differs from *Lophophyllidium murale*, n. sp., in the more numerous tabulae, relatively thick peripheral parts of the septa, and in the shorter cardinal septum of youthful stages. The septa are seen in a number of transverse sections to be thick out to the intersection with a tabulae, beyond which they decrease in thickness sharply.

This species is named for the late George H. Girty of the U. S. Geological Survey. He has contributed much to the knowledge of the Upper Carboniferous coral faunas, and published several important observations on the lophophyllid corals.

Occurrence.—The type specimen is from the lower shale of Wewoka formation, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by N. D. Newell, 0.25 miles north and 200 feet east of Lovelady School, SW sec. 4, T. 3 N., R. 7 E., Pontotoc county, Oklahoma; other specimens from the Wewoka for-

mation were collected by R. C. Moore, 1300 feet north of SW cor. sec. 4, T. 3 N., R. 7 E., Oklahoma.

Type.—Univ. Kansas no. 2289-21b. The material studied includes about 15 corallites associated with the type and numerous specimens from the other locality.

LOPHOPHYLLIDIUM ELONGATUM, n. sp.

Plate 4, figures 1-3

The description of this species is based on numerous well preserved specimens of large conical solitary corals that exhibit only slight curvature in the plane of the alar septa. The rate of expansion is very regular and continues throughout growth. The thick theca is externally marked with sharp low ridges and broad grooves. Transverse ornamentation consists of many very fine growth lines and rare low wrinkles. The calyx is deep and it contains a spike-like column in the lower part. The type specimen is 35.4 mm in length and 16.2 mm in diameter. Other specimens range from 18.4 mm to 52.6 mm in length and 10.3 mm to 19.0 mm in diameter.

There are 28 major septa in the uppermost part of the type specimen and other specimens have 28 to 30. The septal arrangement in the type specimen is as follows: counter septum, 8 metasepta, alar septum, 4 metasepta, cardinal septum, 4 metasepta, alar septum, 8 metasepta, and the counter septum once more. The cardinal septum is short in all stages but the counter septum is extended to the axis where it is slightly thickened. Other major septa are of unequal length in uppermost part of the corallites, but are nearly equal in lower portions. In maturity the septa are only slightly thickened axially. Transverse sections low in the corallite show

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EXPLANATION OF PLATE 4

(All figures 3 times natural size. In each transverse section the counter septum is placed at the top.)

Lophophyllidium elongatum, n. sp., top of Hogshooter limestone, Skiatook group, Missouri series, Pennsylvanian, west of bridge, south side of river from Sand Springs, Oklahoma.

1a-f—Type specimen (Univ. Kansas no. 3217-21c). *a*, Longitudinal section. *b-f*, Transverse sections.

2a-c—Transverse sections of specimen (Univ. Kansas no. 3217-21b).

3—Longitudinal section of specimen (Univ. Kansas no. 3217-21y) showing interrupted axial column.

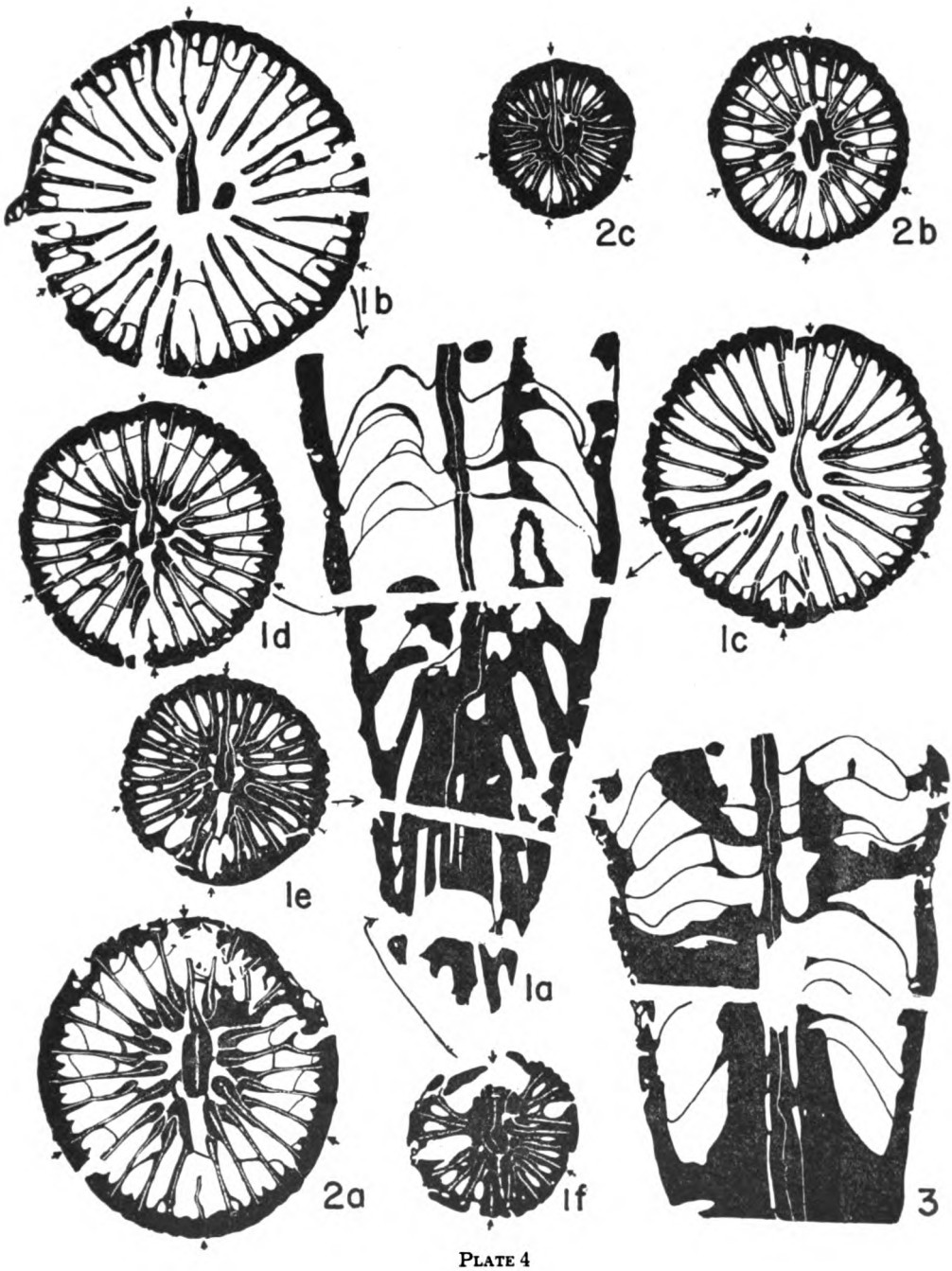

PLATE 4

the long septa joined together by stereoplasm, but separate from the axial column. Even in lowermost sections the axial column and each septum are distinct. Minor septa alternating with the major septa are short and thick.

The cardinal septum lies in a deep fossula throughout growth. In very early stages the cardinal septum is very thin and extends through the fossula to the column. Alar pseudofossulae are poorly developed. The axial column is a direct continuation of the counter septum but becomes separated from it in the uppermost parts of the corallite. Regular anastomosing tabulae rise steeply from the periphery to the inner wall formed by thickened axial portions of the septa. Beyond the wall they curve downward slightly and then rise abruptly just as they join the axial column. The inner wall is present in all but mature stages. It is seen in longitudinal section as two vertical deposits of stereoplasm parallel to the column, and in transverse section as a band surrounding the column.

Discussion.—This species is distinguished by its large size, conical form; and thick long septa in maturity. *Lophophyllidium expansum,* n. sp., has a somewhat similar mature stage but differs in the more rapidly expanding form and more numerous, more steeply ascending tabulae and a much more solid lower portion.

One specimen shows an abrupt termination of the axial column, and above a space that lacks a column, the axial structure reappears. This seems to be the result of a peculiarity in growth probably due to an injury sometime previous to the death of the polyp.

Occurrence.—Top of Hogshooter limestone, Skiatook group, Missouri series, Pennsylvanian (Upper Carboniferous). Collected by N. D. Newell, west of bridge, south side of the river from Sand Springs, Oklahoma.

Type.—Univ. Kansas no. 3217-21c. The collection includes several hundred corallites of which 10 representative specimens were selected for sectioning.

LOPHOPHYLLIDIUM RADIATUM, n. sp.

Plate 5, figures 1, 2; plate 8, figure 7

This species is based on a large number of medium-sized solitary corallites, conical to conical-cylindrical in upper portions and either straight or slightly curved. The moderately thick theca shows distinct broad septal grooves and ridges with rather coarse growth lines and low transverse wrinkles. The calyx is shallow. The type

specimen is 26.1 mm in length and 16.1 mm in diameter. Other specimens range from 6.0 mm to 38.0 mm in length and 3.4 mm to 18.0 mm in diameter.

In the upper parts the septa are long, straight, and slightly thickened axially. Lower down they form an inner wall close to the column, their inner ends being thickened and joined together by stereoplasm. The cardinal septum is short, only about half the length of the other major septa. The counter septum is extended to the axis and slightly thickened. Other major septa are of nearly equal length. The septal arrangement of the major septa in the upper part of the type specimen is counter septum, 8 metasepta, alar septum, 4 metasepta, cardinal septum, 4 metasepta, alar septum, 8? metasepta, and the counter septum again. Short minor septa are developed in upper portions only.

The cardinal septum lies in a prominent fossula throughout. Alar pseudofossulae are weakly developed in the earliest stages and inconspicuous above. Numerous regularly spaced thin and slightly anastomosing tabulae rise steeply from the periphery and then arch more gently to the column. In transverse sections these evenly arched tabulae form a thin inner wall, one-third to one-half the distance to the axis.

The small axial column is well developed in the lower part of all the corallites but becomes shorter and does not quite reach to the axis in the most mature portions of a few of the specimens studied. Longitudinal sections of the axial region reveal a narrow solid column that is formed by the axial thickening of the counter septum, supplemented by addition of numerous tabulae.

Discussion.—The numerous thick septa, abundant tabulae, and the subsegmented appearance of the crooked column characterize this species. It differs from *Lophophyllidium proliferum* in its larger size, more conical form and jointed and thinner axial column. *L. radiatum* resembles *L. complexum,* n. sp., in having numerous tabulae but it does not have the arched tabulae or the distinctive union of the paired tabulae and the axial column that are seen in *L. complexum.*

Occurrence.—Checkerboard limestone, Skiatook group, Missouri series, Pennsylvanian (Upper Carboniferous). Collected by R. C. Moore from the shale pit, NW sec. 35, T. 34 S., R. 16 E., northwest part of Coffeyville, Montgomery county, Kansas.

Type.—Univ. Kansas no. 1164-21g. A dozen representative spec-

imens from the lot of several hundred corallites were sectioned for study.

LOPHOPHYLLIDIUM MAGNIFICUM, n. sp.

Plate 6, figures 1, 2; plate 8, figure 5

Lophophyllum profundum MORGAN, *1924*, Oklahoma Bur. Geology, Bull. 2, pl. 32, figures 2, 2a; not 2b?d.

This species is based on several well preserved specimens showing structural details with remarkable clarity. All the specimens are broadly conical solitary corallites that are slightly bent in the plane of the alar septa. The moderately thick theca shows sharp narrow septal grooves and broad interseptal ridges, crossed by a few fine transverse growth lines and low wrinkles. The type specimen is about average in size, 27.1 mm in length and 16.7 mm in diameter. The large solid column projects into the lower part of the deep calyx as a sharp spine.

There are 29 long straight major septa with alternating short minor septa. The septal arrangement near the calyx is counter septum, 8 metasepta, alar septum, 5 metasepta, cardinal septum, 4 metasepta, alar septum, 8 metasepta, and the counter septum again. This is uneven due to several injuries to the corallite. Lower down in the corallite the septal arrangement is counter septum, 7 metasepta, alar septum, 4 metasepta, cardinal septum, 4 metasepta, alar septum, 7 metasepta, and back to the counter septum. In the mature part of the type specimen the septa are of unequal length, some reaching two-thirds and others one-half the distance

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EXPLANATION PLATE 5

(All figures 3 times natural size. In each transverse section the counter septum is placed at the top.)

Lophophyllidium radiatum, n. sp., Checkerboard limestone, Skiatook group, Missouri series, Pennsylvanian, from shale pit, NW sec. 35, T. 34 S., R. 16 E., northwest part of Coffeyville, Montgomery, Kansas.

1a-e—Type specimen (Univ. Kansas no. 1164-21g). *a*, Longitudinal section. *b-e*, Transverse sections.

2a-d—Specimen (Univ. Kansas no. 1164-21j). *a*, Longitudinal section, *b-d*, Transverse sections.

Lophophyllidium sp. B, Seminole formation?, (Fossiliferous shale 50 feet below the Checkerboard limestone), Missouri series, Pennsylvanian, center north side sec. 34. T. 13 N., R. 10 E., 2 miles south of Okmulgee, Oklahoma.

3a-c—Specimen (Univ. Kansas no. 2166-21b). *a*, Longitudinal section. *b-c*, Transverse sections.

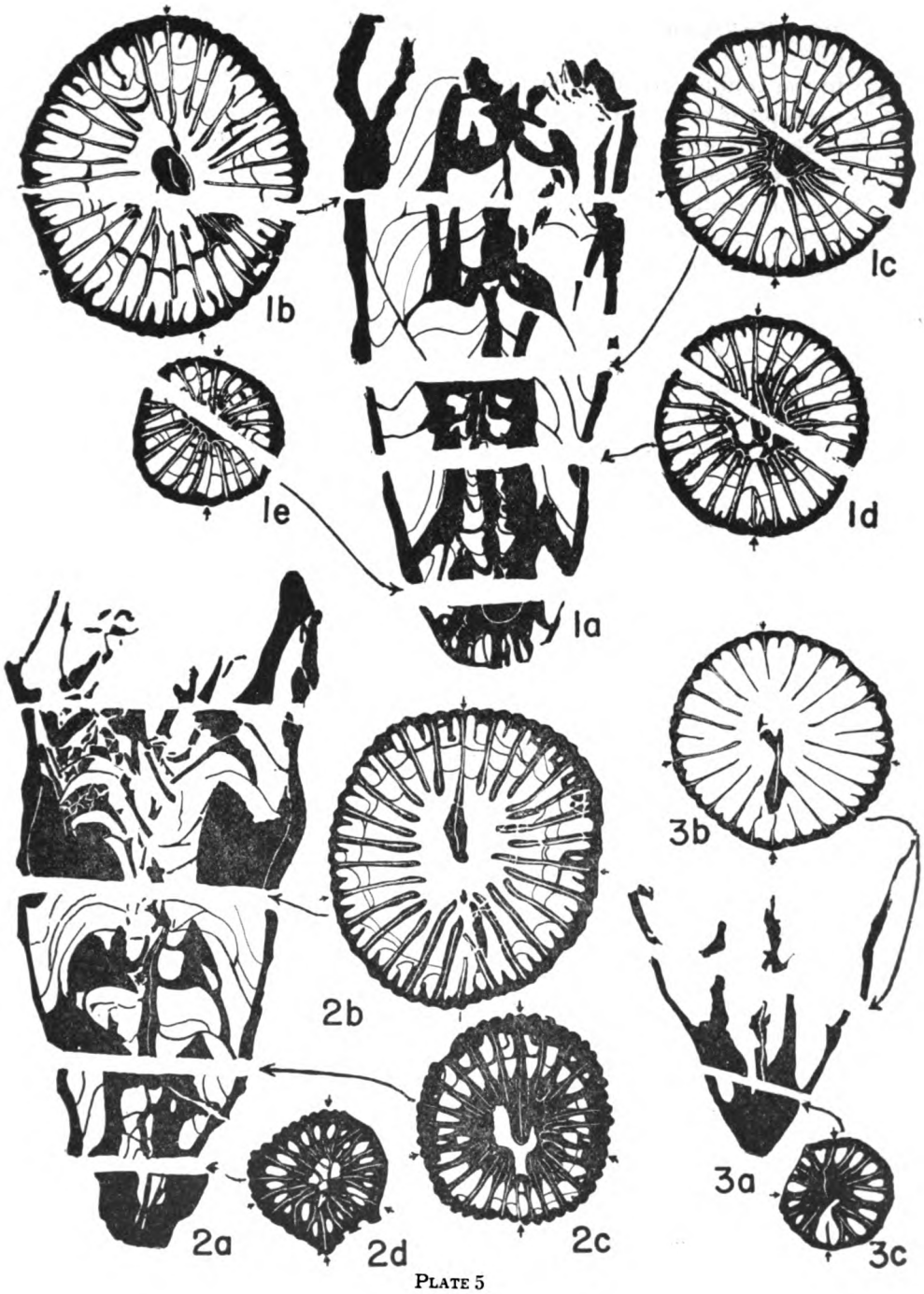

PLATE 5

to the column. Aside from the protosepta, the relative length of the septa is not constant either for the same septum throughout the same individual or for equivalent septa in different individuals. The cardinal septum is the shortest major septum in all stages. The counter septum is connected to the column in the immature growth stages but after withdrawing from the column, it becomes shorter than the other major septa. Minor septa are present in only the mature part of the corallite, and are introduced in an irregular manner. In the lower part the septa closely approach the column and are united to it by steroplasm. This youthful stage shows a very prominent open cardinal fossula and less prominent alar pseudofossulae. The counter quadrants are considerably accelerated over the cardinal.

Tabulae are limited to the lower one-fourth of the corallite and may be entirely concealed by the deposits of stereoplasm. There are no dissepiments. The laterally compressed column shows prominent regular striae near the calyx but less so lower in the corallite. Concentric layers formed by the closely packed conelike tabelae and the distinct median lamella are seen in transverse sections of the axial column. The tabellae are crossed by numerous lateral lamellae and thickened by stereoplasm so as to form a large solid column having a fine reticulate appearance in transverse section. The column retains about the same maximum diameter in cross section throughout the corallite but close to the calyx the alar diameter increases considerably.

Discussion.—The large, conspicuously striated axial column and thin radiating septa of the adult part distinguish *Lophophyllidium*

EXPLANATION OF PLATE 6

(All figures 3 times natural size. In each transverse section the counter septum is placed at the top).

Lophophyllidium magnificum, n. sp., lower Boggy shale, Des Moines series, Pennsylvanian, at NW sec. 22, T. 2 S., R. 7 E., southeast of Ada, Oklahoma.

1a-c—Transverse sections of specimen (Univ. Kansas no. 175-21b).

2a-e—Type specimen (Univ. Kansas no. 175-21a). *a*, Longitudinal section. *b-e*, Transverse sections.

Lophophyllidium newelli, n. sp., middle Savanna formation, Des Moines series Pennsylvanian, from center south side sec. 34, T. 3 N., A. 13 E., Oklahoma.

3a-c—Transverse sections of specimen (Univ. Kansas no. 2562-21d).

4a-d—Type specimen (Univ. Kansas no. 2562-21b). *a*, Longitudinal section. *b-d*, Transverse sections.

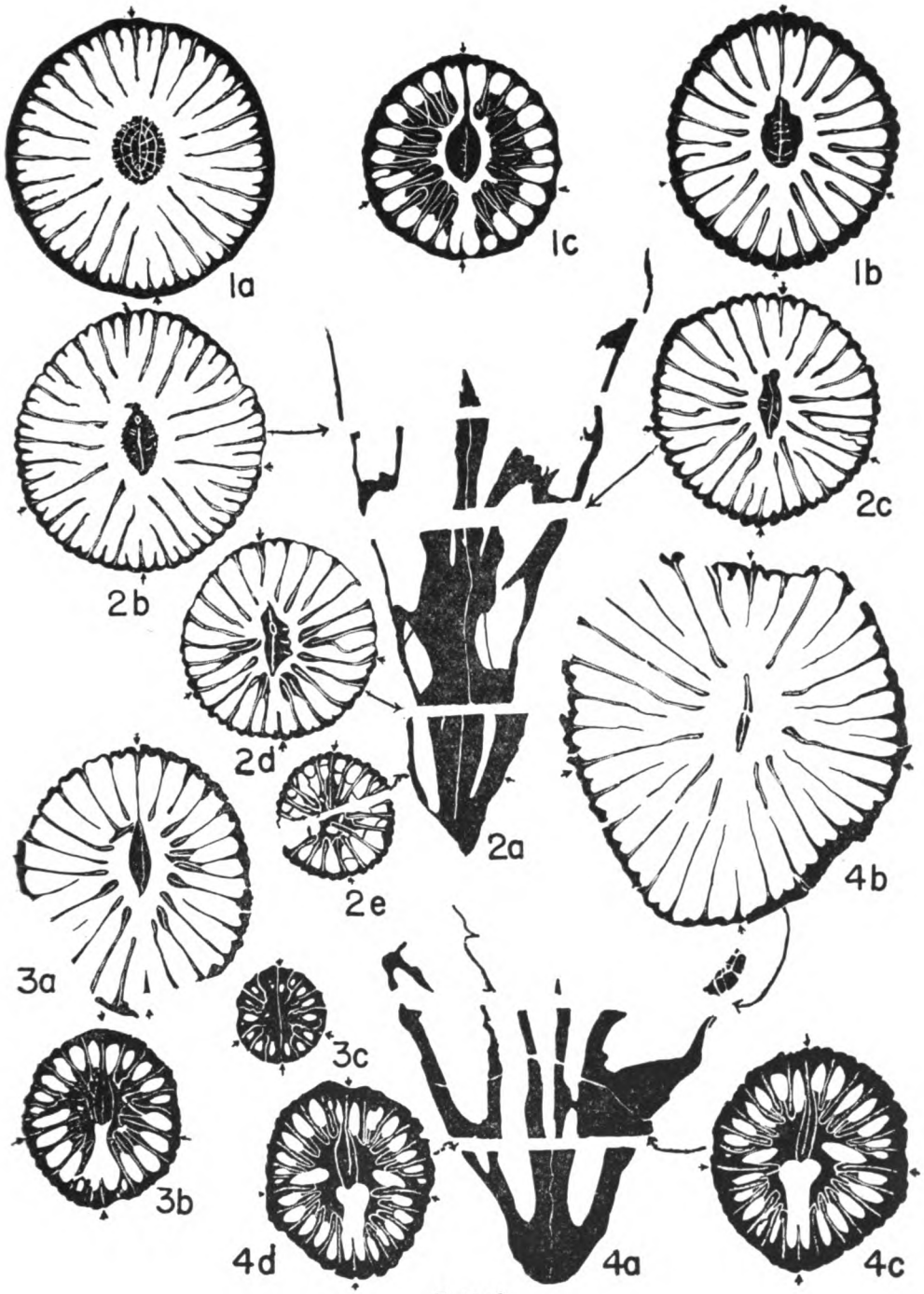

PLATE 6

magnificum from other species of this genus. The concentration of the few tabulae in the lower portion and the structure of the axial column separate it from other similar species such as *L. newelli,* n. sp., and *L. minutum,* n. sp.

Occurrence.—Lower Boggy shale, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by R. C. Moore, at NW sec. 22, T. 2 S., R. 7 E., southeast of Ada, Oklahoma.

Type.—Univ. Kansas no. 175-21a. Half a dozen corallites from the abundant available material were als osectioned for study.

LOPHOPHYLLIDIUM NEWELLI, n. sp.

Plate 6, figures 3, 4.

This species comprises broadly conical corallites, the lower parts of which are slightly curved in the plane of the alar septa. There are well developed septal grooves and wide interseptal ridges on the exterior of the theca and these are crossed by a very few transverse markings. The moderately deep calyx contains a thin lath-like column projecting upward. The type is a specimen preserved in hematite, 22.7 mm in length and 21.0 mm in diameter, at the calyx.

There are 32 unequal major septa thickened slightly at the axial ends but not distinctly rhopaloid. Minor septa are mere ridges. The cardinal septum is very short in all periods of growth but the counter septum is long and connected to the axial column except in and close to the calyx, where it rapidly becomes even shorter than other major septa. The septal arrangement is as follows: counter septum, 8 metasepta, alar septum, 6 metasepta, cardinal septum, 6 metasepta, alar septum, 8 metasepta, and counter septum once more. The sections in the lower parts of the corallite of this species are especially noteworthy and characteristic. The short cardinal septum lies in a deep long fossula whereas other major septa are joined at their inner ends to the column. The two large oval-shaped alar pseudofossulae show the slight acceleration of the counter quadrants.

No tabulae or dissepiments are recognized, although the lower one-eighth of the corallite is solidly filled with stereoplasm that conceals the details.

Discussion.—This species most closely resembles *Lophophyllidium distinctum,* n. sp., but can be separated by its larger cardinal fossula in immature stages, thinner laterally compressed col-

umn in adult stages, and slightly rhopaloid nature of some of the septa near the calyx. This species lacks the conspicuously striated axial column of *L. magnificum*, n. sp. *Lophophyllidium newelli* and similar species such as *L. minutum*, *L. distinctum*, *L.* sp. A, and *L.* sp B, form a group of corals differing from other species assigned to *Lophophyllidium* in the restriction of the immature characters to the lower part of the corallite, scarcity or seeming absence of tabulae, and development of large alar pseudofossulae. The major septa are thickened axially only a little at most and minor septa are rudimentary or lacking. These species differ from *Malonophyllum* in the occurrence of prominent alar pseudofossulae, nature of development of the septa, the straight unthickened character of the septa, and the close proximity of the septa and axial column even in upper part of the corallite. Although corals of the *L. newelli* type differ somewhat from the genotype of *Lophophyllidium*, they are tentatively referred to this genus.

This species is named for N. D. Newell, formerly of the University of Kansas and the Kansas Geological Survey, who has contributed much to the knowledge of the paleontology and stratigraphy of midcontinent Upper Carboniferous rocks.

Occurrence.—Middle Savanah formation, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by N. D. Newell, from a gully by a railroad bridge at center south side sec. 34, T. 3 N., R. 13 E., Oklahoma.

Type.—Univ. Kansas no. 2562-21b. The material available for study includes about a dozen well preserved corallites.

LOPHOPHYLLIDIUM DISTINCTUM, n. sp.

Plate 7, figure 1

Solitary steeply conical corallites of very gently curved form and having the cardinal fossula on the concave side are included in this species. The thick even theca shows fine septal grooves, broad interseptal ridges and moderately well developed transverse growth lines and wrinkles. The lower part of the deep calyx contains the laterally compressed axial column. The type is 17.8 mm in length and 14.1 mm in diameter.

There are 24 straight unequal major septa in the mature part of the type, and in addition there are minor septa, indicated by small ridges. The septal arrangement in a clockwise direction is as follows: counter septum, 6 metasepta, alar septum, 4 metasepta, card-

inal septa, 4 metasepta, alar septum, 5 metasepta, and counter septum again. The cardinal septum is short throughout, but the counter septum is joined to the column except in the most mature part of the corallite.

The cardinal fossula is very prominent in early growth stages in which all septa, except the cardinal, are united closely to the axial column by stereoplasm. The fossula is roughly rectangular in transverse section and closed in these stages but open in the mature portions. Tabulae are very rare or absent. The column is large and pear-shaped in transverse sections of youthful stages but it becomes elliptical in outline near the calyx. The median lamella of the counter septum is extended throughout the diameter of the column in the counter-cardinal plane.

Discussion.—A species that seems to be most closely similar to *Lophophyllidium distinctum* is *L. newelli*, n. sp. Immature forms resemble one another especially but *L. distinctum* has more ang-

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EXPLANATION OF PLATE 7

(All figures 3 times natural size. In each transverse section the counter septum is placed at the top.)

Lophophyllidium distinctum, n. sp., shale in middle Altamont limestone, Marmaton group, Des Moines series, Pennsylvanian, from middle north side sec. 7, T. 34 S., R. 17 E., Montgomery county, Kansas.

1a-d—Type specimen (Univ. Kansas no. 5210-21a). *a*, Longitudinal section. *b-d*, Transverse sections.

Lophophyllidium minutum, n. sp., Morrow age, Pennsylvanian.

2a-c—Specimen from Wapanucka limestone, Coal Creek, sec. 15, T. 1 N., R. 7 E., Oklahoma (Univ. Kansas no. 2747-21a). *a*, Longitudinal section. *b*, *c*, Transverse section.

3a-b—Type specimen (Univ. Kansas no. 7385-21c) from east side dam at Greenleaf Lake, southwest of Bragg, Oklahoma. *a*, Longitudinal section. *b*, Transverse section.

4—Transverse section of specimen (Univ. Kansas no. 3342-21a) from the Otterville limestone, north of Berwyn, Oklahoma.

Lophophyllidium sp. *A*, Frensley limestone, of Lampasas age, Pennsylvanian, from Murray State Park, southeast of Ardmore, Oklahoma.

5a-d—Specimen (Univ. Kansas no. 6808-21b). *a*, Longitudinal section. *b-d*, Transverse sections.

6—Transverse section of specimen (Univ. Kansas no. 6808-21c).

Lophophyllidium girtyi, n. sp., Wewoka formation, Des Moines series, Pennsylvanian, Oklahoma.

7a-d—Specimen (Univ. Kansas no. 84-21b) from 1300 feet north of SW cor. sec. 4, T. 3 S., R. 7 E., Oklahoma. *a*, Longitudinal section. *b-d*, Transverse sections.

8a-c—Transverse sections of the type specimen (Univ. Kansas no. 2289-21b) from lower shale in Wewoka formation, 0.25 miles north and 200 feet east of Lovelady School, SW sec. 4, T. 3 S., R. 7 E., Oklahoma.

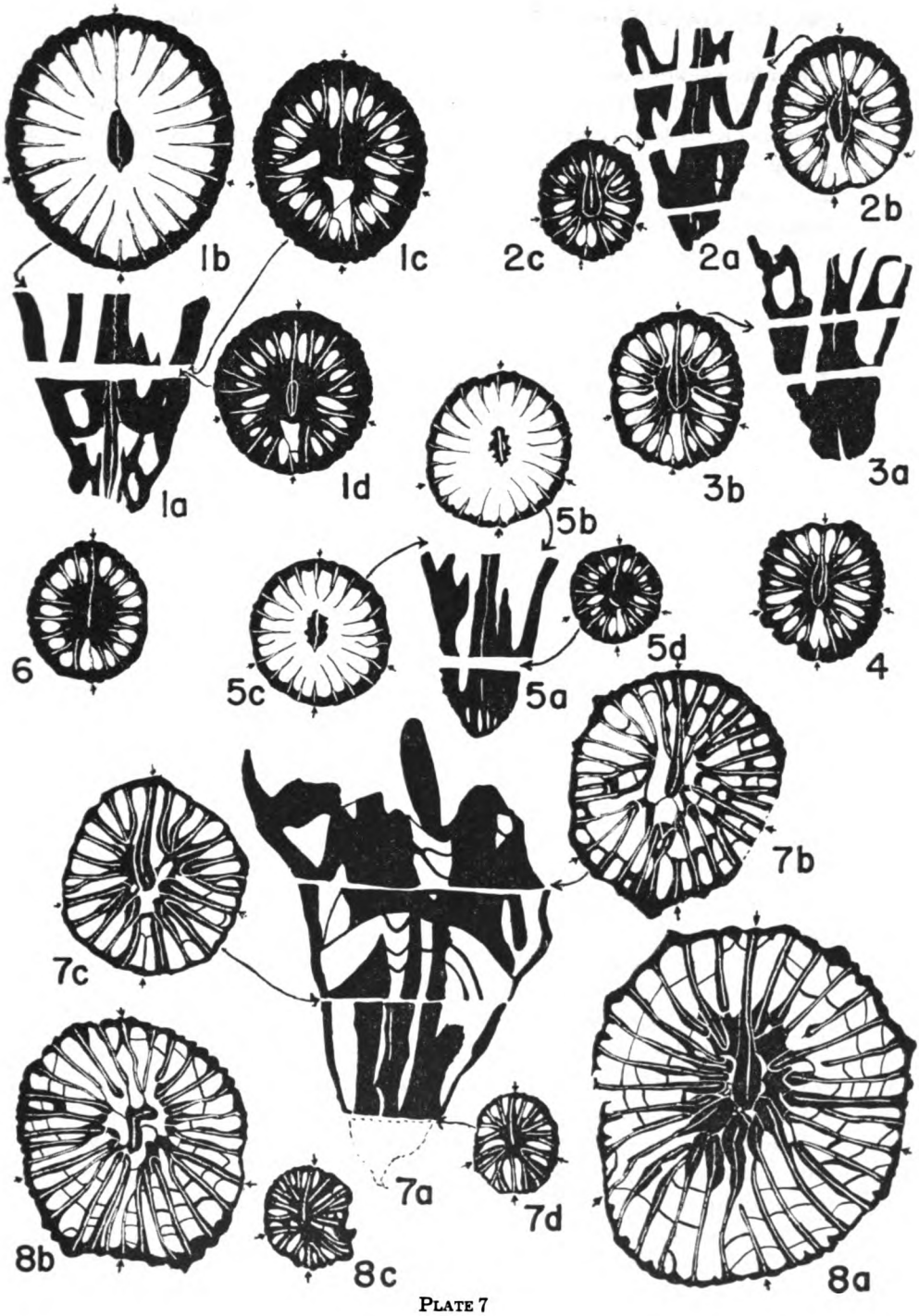

PLATE 7

ular alar pseudofossulae, a markedly thicker counter septum, and a shorter cardinal fossula. In the mature parts of the corallite this species has distinctly wedge-shaped septa that have no axial thickening. The theca is also much thicker than in *L. newelli*. From *L. minutum*, n. sp., the species called *L. distinctum* may be distinguished by its larger and more solid axial region in youth and by its much more prominent breviseptal stage.

Occurrence.—Shale in middle Altamont limestone, Marmaton group, Des Moines series, Pennsylvanian (Upper Carboniferous). Collected by J. M. Jewett from middle of north side sec. 7, T. 34 S., R. 17 E. Montgomery county, Kansas.

Type.—Univ. Kansas no. 5210-21a.

LOPHOPHYLLIDIUM MINUTUM, n. sp.

Plate 7, figures 2-4

This species includes small solitary conical-cylindrical corallites having only a very slight curvature near the apical end. The relatively thick theca bears deep narrow septal grooves and moderately broad interseptal ridges. Transverse growth lines and wrinkles are low and inconspicuous. The calyx is not well preserved but seems to be of moderate depth. The type specimen is 14.1 mm in length and 10.0 mm in diameter.

The type specimen has 21 major septa in the uppermost part of the corallite and about the same number of septa occur in the other specimens studied. No indication of minor septa is seen in any of the sections. The cardinal septum which is very short, lies in a prominent fossula. The counter septum is prolonged and attached to the column in all growth stages, although it shows a tendency to become separate close to the calyx. The counter acceleration is shown by the position of the large alar pseudofossulae, which are seen in all the transverse sections. The arrangement of the septa in the uppermost section of the type specimen in a clockwise direction is as follows: counter septum, 5 metasepta, alar septum, 3 metasepta, cardinal septum, 3 metasepta, alar septum, 6 metasepta, and counter septum again.

The septa are joined to the axial column in early stages by thick deposits of stereoplasm but tend to become more distinct in upper parts of the corallite. The highest sections show that the septa have a distinct axial swelling and are still united with the column. In well preserved specimens it is possible to recognize the elements of

the septa and the column and to see that the union of the septa with the column is not a primary structural feature.

The two last-formed septa in the counter quadrants are short and bend towards the counter septum, leaving wide spaces or pseudofossulae on the counter side of the alar septa. The last-formed septa in the cardinal quadrants join the adjacent earlier septum so that the cardinal fossula is enclosed by the two lateral septa and the column.

The laterally compressed column, produced by the thickened end of the counter septum, is increased in size by the close approach of the axial ends of the septa and the stereoplasm deposited between the septa and the column. No tabulae are recognized

Discussion.—The species here described is a very small form in which the septa are joined rather closely to the axial column, even in adult portions of the corallite. It seems to be a rather primitive species. The prominent alar pseudofossulae, thick theca, and unstriated thick axial column are characteristic features. The solid central or axial portion is smaller than in *L. distinctum,* n. sp., and pseudofossulae are more developed than in *L.* sp. A.

Occurrence.—Morrow beds, Pennsylvanian (Upper Carboniferous). The type specimen was collected by R. C. Moore from the Brentwood limestone member of the Bloyd shale, center sec. 10, T. 13 N., R. 20 E., on Greenleaf Lake, southwest of Bragg, Oklahoma. Other specimens are from the Otterville limestone, collected by R. C. Moore north of Berwyn, Oklahoma; and from the Wapanucka limestone, collected by R. C. Moore at Coal Creek, sec. 15, T. 1 N., R. 7 E., Oklahoma.

Type.—Univ. Kansas no. 7385-21c. The material studied includes sectioned specimens from each of the three localities given above and several corallites associated with the type specimen.

Lophophyllidium sp. A

Plate 7, figures 5, 6

A number of different lophophyllid coral types have been found during this study but the unsatisfactory nature of the preservation or insufficiency of the material does not permit adequate specific description. The two specimens here called *Lophophyllidium* sp. A show the characters of this genus, but more material must be sectioned in order to determine their significant structural features.

These small solitary uncurved conical-cylindrical corallites have

a moderately thick theca that bears indistinct narrow septal grooves and transverse growth lines but no wrinkles. The calyx is poorly preserved but seemingly was deep, containing a sharply pointed column. One specimen is about 14 mm in length and 7.9 mm in diameter.

There are 22 unequal major septa arranged in the following order; counter septum, 6 metasepta, alar septum, 3 metasepta, cardinal septum, 3 metasepta, alar septum, 6 metasepta, and counter septum again. The counter quadrants are considerably accelerated. Minor septa are only irregularly developed as small ridges. The major septa are quite thick near the periphery but taper rapidly towards the axis.

The short cardinal septum lies in a prominent fossula in immature stages but the fossula is not conspicuous in sections near the calyx. Alar pseudofossulae are well developed in the youthful part of the corallite and near the calyx are indicated by the two shortened major septa. No tabulae are observed. The thick strong axial

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EXPLANATION OF PLATE 8

(All figures 3 times natural size.)

Lophophyllidium magnificum, n. sp., from the Lower Boggy shale at NW sec. 22, T. 2 S., R. 7 E., southeast of Ada, Oklahoma.

1—View of a typical specimen showing well developed groove pattern and conical shape (Univ. Kansas no. 175-21g).

Lophophyllidium proliferum (McChesney), from the beds over coal no. 8 Trivoli cyclothem, near Springfield, Illinois.

2—Side view of a complete specimen showing the curvature and well developed grooves and ridges (Ill. State Mus. no. W4064).

Lophophyllidium girtyi, n. sp., from the Wewoka formation, 1300 feet north of the SW cor. sec. 4, T. 3 N., R. 7 E., Oklahoma.

3—View of the cardinal side of a typical specimen with prominent septal grooves, wrinkles and short spines (Univ. Kansas no. 84-21d).

Lophophyllidium profundum (Edwards and Haime)?, questionably from the Lower Mercer limestone of northeastern Muskingum county, Ohio.

4—Side view of a slightly crushed specimen (Ohio State Univ. no. 17850).

Lophophyllidium radiatum, n. sp., from the Checkerboard limestone at the shale pit, northwest part of Coffeyville, Kansas.

5—A side view of a medium-sized specimen showing the slight curvature and distinct grooves and ridges. (Univ. Kansas no. 1164-21f).

Lophophyllidium compressum, n. sp., from the Millsap Lake Group, 3.5 miles east of Rochelle, Texas.

6—Side view of a typical specimen (Univ. Kansas no. 7208-21c).

Lophophyllidium murale, n. sp., from the Memorial shale, at center south road, sec. 2, T. 33 S., R. 13 E., Montgomery county, Kansas.

7—A side view of a specimen with numerous wrinkles and radicles (Univ. Kansas no. 2615-21d).

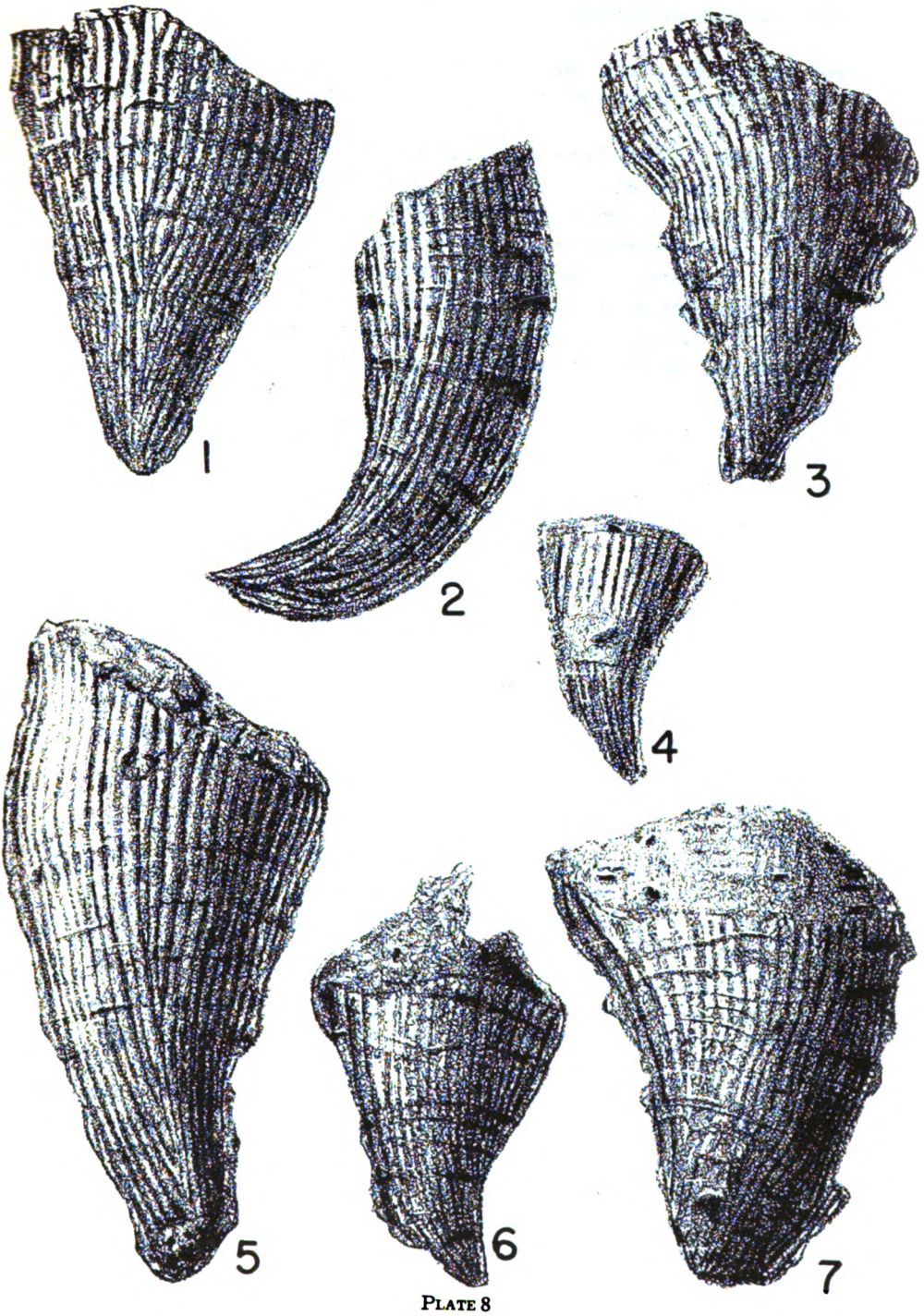

PLATE 8

column is prominently but irregularly striated. It is distinct from the counter septum in more than one half the height of the corallite.

Discussion.—This form is characterized by its small size and prominently striated axial column. The septa in the adult stage resemble those of *Lophophyllidium distinctum,* n. sp., but the latter species has more prominent minor septa and lacks the striated column. This species seems easily separated from *L. newelli,* n. sp., and *L. minutum,* n. sp., by its poorly developed alar pseudofossulae in the youthful parts of the corallite. It differs from *L. magnificum, n. sp.,* in the smaller size and different development of the immature portions.

Occurrence.—Frensley limestone, of Lampasas age, Pennsylvanian (Upper Carboniferous). Collected by R. C. Moore from Murray State Park, southeast of Ardmore, Oklahoma.

Studied specimens.—Univ. Kansas no. 6808-21b and 6808-21c.

LOPHOPHYLLIDIUM sp. B

Plate 5, figure 3

This form is a solitary conical corallite that is slightly curved in the plane of the alar septa throughout its length. The moderately thick theca has fine narrow septal grooves and broad low interseptal ridges. The calyx is deep, and a laterally compressed irregular column projects into its lower part. The only specimen studied is 20.9 mm in length and 13.5 mm in diameter.

In the uppermost transverse section there are 22 major septa arranged as follows: counter septum, 5 metasepta, alar septum, 4 metasepta, cardinal septum, 4 metasepta, alar septum, 5 metasepta and counter septum again. In this stage the cardinal septum is very short and the counter septum is slightly shorter than other major septa. The alar septa are the longest. The last septa to be introduced in both the cardinal and counter quadrants are noticeably shorter. Very short minor septa alternate with the major septa.

In a youthful stage the counter septum is extended to the axis, forming a moderately thick laterally compressed column. In the mature part of the corallite the column is not connected to any of the septa and has moved close to the cardinal septum. The weakly developed last septa in the counter quadrants form small pseudofossulae on the counter side of the alar septa. No tabulae are shown and dissepiments are absent.

Discussion.—This specimen is characterized by its rapidly expanding form and accelerated early growth. It is distinguished from *Lophophyllidium magnificum,* n. sp., by its more rapid development, less prominent minor septa and small axial column. The thick septa and poorly developed alar pseudofossulae separate this species from *L. minutum,* n. sp., and *L. newelli,* n. sp.

Other specimens of this type need to be examined in order to determine the significance of the migration of the axial column from a position attached to the counter septum in youth to one close to the cardinal septum in mature stage.

Occurrence.—Seminole formation?, (fossiliferous shale 50 feet below the Checkerboard limestone) Missouri series, Pennsylvanian (Upper Carboniferous), from center north side sec. 34, T. 13 N., R. 10 E., 2 miles south of Okmulgee, Oklahoma.

Studied specimen.—Univ. Kansas no. 2166-21b.

STRATIGRAPHIC SUMMARY

The species described in this paper show but little resemblance to published lophophyllid coral faunas. The Permian forms from Asia and Europe are simpler in structure, have fewer tabulae, and show thicker rhopaloid septa in mature stages than the lower Pennsylvanian corals from the central United States. The Upper Carboniferous column-bearing corals of Peru (Douglas, 1920) also seem to be more like the Permian species of *Lophophyllidium* and *"Sinophyllum"*. In the Donetz Basin of the U.S.S.R., *Lophophyllidium* first appears in the C $\frac{2}{3}$ zone (Fomitchev, 1938), which is equivalent to the upper Des Moines series in North America. It seems, therefore, that lower Upper Carboniferous lophophyllid coral faunas are either not well developed in other areas or have not been described adequately.

The significant features of the midcontinent Pennsylvanian coral faunas are the relative abundance of material and the considerable number of distinct species. The genus *Lophophyllidium* is recognized and 17 forms are here assigned to it. The material now available includes many new species too poorly preserved or insufficiently studied to be described at this time.

Beds of Morrow age are characterized by a considerable variety of rugose coral genera, most of which are quite different from those occurring in higher beds. One species, of the *Lophophyllidium newelli* type, is described from the Brentwood limestone member

of the Bloyd shale, the Otterville limestone, and the Wapanucka limestone.

Only a few corals are available from beds of Lampasas age. The new species, *Lophophyllidium mundulum*, and *L. confertum*, are recognized in the Pumpkin Creek and Lester limestones of Oklahoma.

The lophophyllid corals are much more abundant and widespread in the Des Moines series and 8 different types of corals are described.

The corals from the lower part of the Missouri series are represented by a large number of specimens. Three types of these corals are described.

Undescribed column-bearing corals from upper Missouri and Virgil beds have a strikingly different appearance. As a group they are characterized by thinner and more distinct structural elements, more cylindrical shape, narrower axial column, and absence of stereoplasm. Upper Pennsylvanian rocks also contain corals of the *Lophophyllidium newelli* type that have persistent large alar pseudofossulae, few or no tabulae, and condensed growth stages. The corals from the Wewoka formation described as *L. profundum* by Girty (1915, p. 19) and similar forms from the Cherokee shale, Jacksboro limestone, and Gunsight limestone seem to represent a third genetic group of lophophyllid corals. They are characterized by a very large cardinal fossula, large axial column having a projection into the fossula, a seeming lack of tabulae, and a corallite almost completely filled by stereoplasm.

It is unwise to attempt to set up definite zones and ranges of lophophyllid species on the basis of the present study. The coral faunas of the lower Pennsylvanian are highly varied and contain many distinct species, but more study and collecting needs to be done before the significant features of the fauna are established. Examination of several hundred sectioned specimens of lophophyllid corals from many different Pennsylvanian formations has indicated that these corals have many characters that change rapidly throughout late Paleozoic time. This fact, together with their abundant occurrence, suggests possible wide stratigraphic usefulness of lophophyllid corals.

Hill (1938) has pointed out that rugose coral faunas were greatly influenced by ecologic conditions and certain types were common only in particular environments. This indicates that care is needed

to avoid correlation of faunas representing merely similar facies rather than faunas that are contemporaneous.

The following table summarizes the stratigraphic distribution of the coral species here described.

Stratigraphic and Geographic Distribution of Described Species of Lophophyllidium in Pennsylvanian Rocks of North America

SERIES OR MAJOR STRATIGRAPHIC DIVISIONS	MORROW	LAMPASAS	DES MOINES	MISSOURI	VIRGIL
L. proliferum (McChesney)	—	—	—	I	—
L profundum (Edwards and Haime)	—	? Ohio	—	—	—
L. minutum, n. sp.	O	—	—	—	—
L. confertum, n. sp.	—	O	—	—	—
L. mundulum, n. sp.	—	O	—	—	—
L. girtyi, n. sp.	—	—	O	—	—
L. compressum, n. sp.	—	—	T	—	—
L. complexum, n. sp.	—	—	O	—	—
L. murale, n. sp.	—	—	K	—	—
L. expansum, n. sp.	—	—	M,K	—	—
L. magnificum, n. sp.	—	—	O	—	—
L. newelli, n. sp.	—	—	O	—	—
L. distinctum, n. sp.	—	—	K	—	—
L. radiatum, n. sp.	—	—	—	K	—
L. elongatum, n. sp.	—	—	—	O	—
L. sp A	—	O	—	—	—
L. sp. B	—	—	—	O	—
L. profundum var. *radiocosum* (Girty)	—	—	O	—	—
L.? distortum (Worthen)	—	—	—	—	I
L. westi (Beede)	—	—	—	K	—
L. ? proliferum var. *sauridens* (White)	? Carb., N. Mex., Colo. ?				

In the table *I* indicates Illinois; *K*, Kansas; *M*, Missouri; *O*, Oklahoma; and *T*, Texas.

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