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TAXONOMIC AND ENVIRONMENTAL STUDY OF TWO DIBUNOPHYLLID CORAL SPECIES FROM UPPER PENNSYLVANIAN ROCKS OF KANSAS

J. M. Cocke

Kansas Geological Survey

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ABSTRACT

Two externally similar species of Upper Pennsylvanian rugose corals *Dibunophyllum parvum* Cocke, n. sp., from the Wyandotte Formation, and *D. perplexum* Cocke, n. sp., from the Amazonia Limestone, Lawrence Formation, were studied for 1) taxonomic differentiation and 2) environmental significance. An objective test of numerical data from each species was made using discriminant analysis. Variation in dissepiment types and characters of the columella were most useful in specific assignment. On the basis of rock type and fossil analyses, specimens of *D. parvum* are considered representative of an *in situ* assemblage which grew in shallow, well-lighted marine waters with numerous other organisms. In contrast, *D. perplexum* shows evidence of being transported and sorted.

INTRODUCTION

Small dibunophyllid corals are abundant and well preserved in the Argentine Limestone Member, Wyandotte Limestone and the Amazonia Limestone Member, Lawrence Formation in Kansas (Fig. 1). Collections were selected from these two units for detailed taxonomic study. Two species, one from each formation, can be distinguished that are externally similar in size and possess septa that rise above upper limits of the epitheca. Except for these characters they resemble generally other Midcontinent dibunophyllids noted by Jeffords (1948a) or described by Newell (1935), Jeffords (1948b), Fraunfelter (1965), and Cocke (1966). In the area studied, dibunophyllids are most abundant in thin, interbedded calcareous shale and limestone; they are less common in massive limestone, and apparently do not occur in noncalcareous shale and sandstone. In contrast, those from the Lower Carboniferous of Scotland (Hill, 1938) and Spain (De Groot, 1963) are most abundant in massive limestone low in argillaceous material.

DISCUSSION

Several columella-bearing corals from Midcontinent Pennsylvanian rocks have been referred to *Axophyllum* Milne-Edwards & Haime (1850), a genus which Hill (1938) placed in synonomy with *Carcinophyllum* Thomson (1880). The original description of *Axophyllum* is brief and indicates only that the type specimen is simple, trochoid, and structurally similar to *Lithostrotion*. Type specimens of *A. rude* White & St. John have been sectioned by me. Unlike dibunophyllids, these possess lonsdaleoid dissepiments and a columella derived by the elongation and complication of the cardinal septum. Moreover, *Axophyllum?* spp. A, B, C, E, and F described by Girty (1915), *"Axophyllum"* sp. described by Duncan (1962) and *?Koninckocarinia* spp. A, B, described by Cocke (1965) are morphologically similar to *A. rude*.

That dibunophyllids commonly were referred by earlier workers to *Axophyllum* was recognized by Jeffords (1948a), Duncan (1962), and Cocke (1966). In 1875, Worthen placed in *A.*

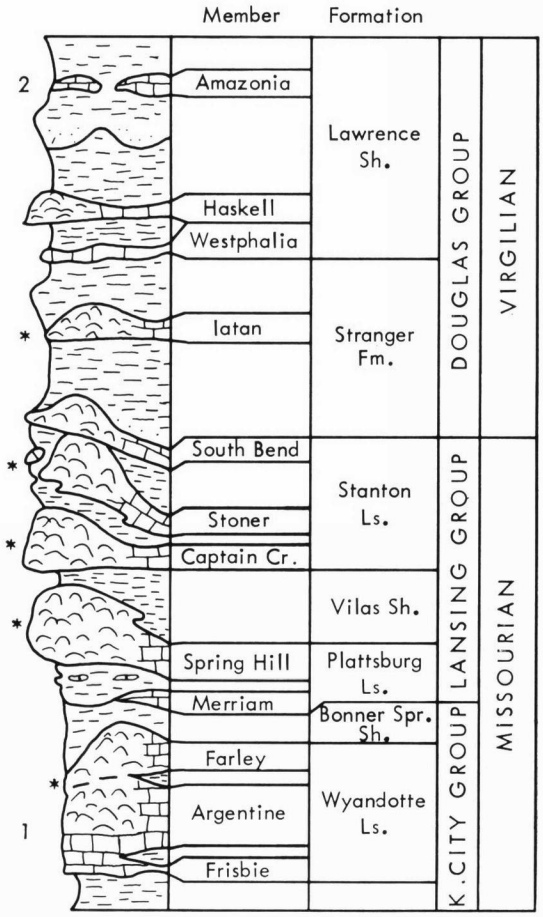

FIG. 1. Stratigraphic column of Upper Pennsylvanian deposits in Kansas showing distribution of small dibunophyllid corals. Number (1) indicates occurrence of *Dibunophyllum parvum* COCKE, n. sp., and (2) shows occurrence of *D. perplexum* COCKE, n. sp. Asterisks indicate presence of externally similar dibunophyllids.

rude two specimens which are externally similar to both species described here, but cited only the original description of the species. Efforts to locate WORTHEN's specimens have proved futile and their assignment to *Dibunophyllum* is tentative. WHITE (1884) illustrated the exterior of a coral similar to those studied here and referred it to *A. rude*. Subsequent workers (KEYES, 1894; BEEDE, 1900) added to the species other small corals which are characterized by a columella and septa that rise above the epitheca. One interior illustrated by BEEDE from Missourian or Virgilian units shows definite dibunophylloid characters. ROWLEY (1901) erected *A.? alleni,* which shows external affinities to both *Dibunophyllum parvum* COCKE, n. sp., and *D. perplexum* COCKE, n. sp. GIRTY (1915) placed similar specimens from Missourian rocks in *Lophophyllum alleni.* In summary, the concept of *A. rude* is changed to include small dibunophyllids in which septa rise above epithecal limits of the calices and to exclude forms similar to the type specimens of the new species here described.

Other larger corals assigned to *Axophyllum* seemingly are related to *?Bothrophyllum kansasense* (MILLER & GURLEY, 1893), originally assigned to *Campophyllum* but changed to its present designation by EASTON (1944). On the basis of lithic and morphologic characteristics, it is evident that type specimens of *?B. kansasense* are from the Westerville Limestone (Missourian) of the Kansas City area. The description and illustrated exteriors of *A. infundibulum* WORTHEN (1875) suggest affinities to *?B. kansasense.* Polished interiors of *A. infundibulum* and *?Axophyllum* sp. D, discussed by GIRTY (1915), distinctly indicate relationship to *?B. kansasense.* Because they lack cyathopsid septal thickening in cardinal quadrants which typify *Bothrophyllum,* assignment of the corals remains uncertain.

SYSTEMATIC DESCRIPTIONS

The classification of rugose corals proposed by HILL (1956) is adopted in this paper. No changes in terminology are proposed.

Family AULOPHYLLIDAE Dybowski, 1873

Subfamily AULOPHYLLINAE Dybowski, 1873

Genus DIBUNOPHYLLUM Thomson & Nicholson, 1876

TYPE SPECIES. — *Clisiophyllum bipartitum* M'COY, 1849, Lower Carboniferous, British Isles.

DIAGNOSIS.—Small to large solitary and budding corals that possess regular dissepimentarium and columella composed of median plate joined to radiating lamellae comprise this genus. Minor septa are degenerate to strongly developed. Cardinal fossulae are well developed in some species, but obscure or missing in others.

DISCUSSION.—European Lower Carboniferous corals typified by *Dibunophyllum bipartitum* (M'COY, 1849) differ in several respects from North American Upper Pennsylvanian forms as-

signed to the genus. Most importantly, the former possesses a distinct cardinal fossula, degenerate minor septa, and numerous major septa. Pennsylvanian dibunophyllids in North America have fewer major septa, show little evidence of fossulae, and possess strongly developed minor septa which commonly attain more than one-half the length of major septa. Older forms are larger and many possess planar to peripherally concave tabellae in transverse section. Several genera have been erected to include forms with dibunophylloid characters. *Arachnolasma* GRABAU (1922), from the Lower Carboniferous of China, is similar to other solitary dibunophyllids but differs in having thinner axial structure with a thickened median plate. *Corwenia* SMITH & RYDER (1926), Lower Carboniferous, is a fasciculate dibunophyllid with numerous thin major septa and short minor septa, dibunophylloid columella, and little evidence of an inner wall. YABE (1950) erected *Heritschioides* to include Lower Permian or Upper Pennsylvanian *Corwenia*-like fasciculate corals which differ from *Corwenia* in possessing dilated septa. In 1941, HERITSCH erected *Amandophyllum* for solitary Middle and Upper Carboniferous corals which closely resemble *Corwenia*. *Dibunophylloides* FOMICHEV (1953), from the Middle Carboniferous, includes solitary to weakly fasciculate dibunophyllids. In addition, FOMICHEV assigned corals which differed from *Dibunophylloides* in possessing lonsdaleoid dissepiments to *Sestrophyllum*. In a comprehensive study of Spanish Carboniferous corals, DE GROOT (1963) placed *Amandophyllum, Heritschioides, Dibunophylloides,* and *Sestrophyllum* in synonomy with *Corwenia*. Corals studied here closely resemble *Dibunophylloides* in size, habit, number of major septa and length of minor septa, but further study of dibunophyllids is necessary to determine validity of the cited genera. However, septal dilation in corals examined in the present study may indicate a relationship to species of *Heritschioides*. However, complete or partial lack of columella in individuals of *Dibunophyllum parvum* COCKE, n. sp., may exclude this species from all recognized dibunophylloid genera.

DIBUNOPHYLLUM PARVUM Cocke, n. sp.

Figure 2,*1-3*

DIAGNOSIS.—Small, turbinate dibunophyllids in which septa generally rise above epitheca. Maximum diameter and length are 9.5 and 12 mm., respectively. A few specimens have one to three small corallites in calices. Ephebic stages have well-developed dibunophylloid columella and regular dissepimentarium; major septa number 22 to 24 and are slightly thickened in cardinal quadrants. Innermost tabulae blend with more steeply inclined tabellae of columella.

EXTERNAL CHARACTERISTICS.—This species comprises small turbinate corals. Diameters range from 2 to 11.5 mm. The epitheca is crossed by fine transverse growth lines and larger smooth wrinkles. Several corallites have three or four rejuvenescent stages, and a number have as many as three small corallite buds. Calices are deep, with septa commonly rising as much as 0.5 mm. above upper limit of the epitheca; a prominent, seemingly solid axial boss commonly rises to a slightly lower position. The columella is bladelike, with the plane of its long axis approximately bisecting the attachment area. Flattened triangular to quadrate attachment areas are slightly less than one-half the length of the corallites and the maximum widths comprise one-third the diameter.

TRANSVERSE SECTION.—The epitheca is thin, commonly with local internal ridges corresponding in position to peripheral ends of septa. In ephebic sections, major septa number 22 to 24; they are thin and crooked near the outer wall, increase gradually to maximum thickness near the inner wall, and thin into the tabularium. The major septal zone occupies two-thirds of corallite diameter; few major septa connect to radiating lamellae of the columella. Minor septa are one-half to four-fifths length of major septa; they resemble major septa but are slightly thinner. A slight thickening of both major and minor septa in the cardinal region can be noted in most specimens. No fossulae are present. Dissepimentaria comprise 3 to 5 thin, commonly complete dissepiments which are generally convex outward; complete dissepiments which are planar or curve inward are common. Particularly in areas of increased septal thickening, dissepiments are irregular, incomplete, or have both ends affixed to a single septum. One-third to one-half of the corallite diameter is occupied by the dissepimentarium. Innermost dissepiments are thickened locally to form an obscure inner wall. The tabularium occupies less than one-fourth of the diameter and is composed of thin tabulae which commonly are planar or slightly convex

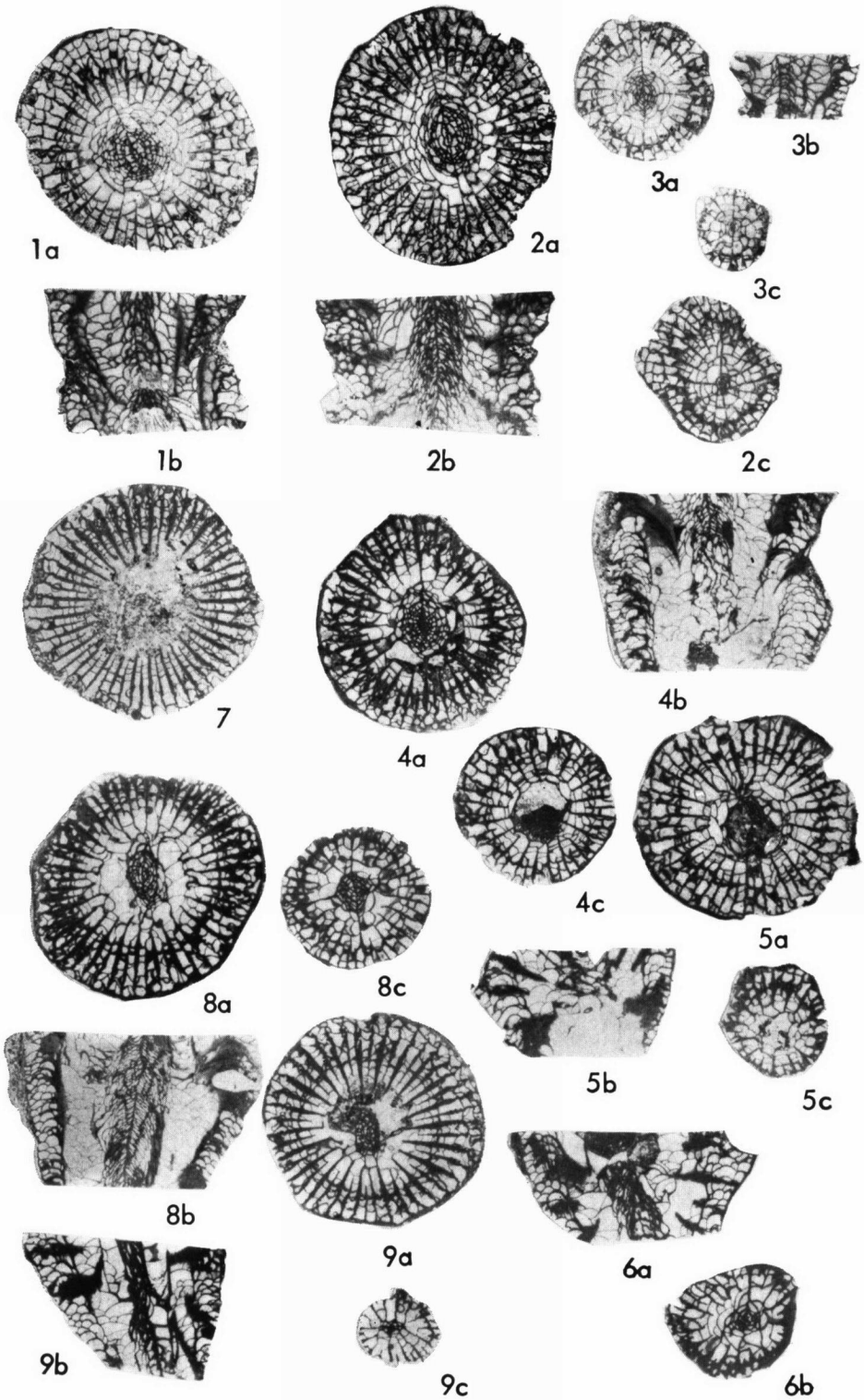

FIG. 2. Sections of *Dibunophyllum parvum* COCKE, n. sp., and *D. perplexum* COCKE, n. sp. (*continued on facing page*).

peripherally. A median plate, radiating lamellae, and tabellae comprise an oval to subcircular columella which comprises one-fifth to one-fourth of the corallite diameter. The median plate is thick and usually rimmed by large tabellae. Except in rare instances, the radiating lamellae are short and are isolated among tabellae, neither connecting to major septa nor abutting against the median plate. At diameters of 2.5 to 30 mm., 12 to 14 major septa are present; they are thin, slightly thickened in the cardinal quadrant, and extend into the tabularium. A cardinal-counter septum crosses the corallite and minor septa are thin and equal to less than one-half major septal length. The dissepimentarium is composed of a row of peripherally convex plates which are structurally similar to both tabulae and tabellae. The central area is filled with globular plates which blend with the tabulae. No radiating lamellae have been observed at this stage.

Longitudinal Section.—A peripheral band of three to six rows of globose dissepiments is terminated inwardly by an obscure inner wall. Short subhorizontal tabulae rim more steeply inclined long plates which merge with the closely packed, gently inclined tabellae of the axial structure. A locally sinuous median lamella occupies the central position.

Environmental Analysis

Sampling Procedure.—The area studied consists of a small limestone hummock measuring approximately 15 x 20 feet and rising 1 to 1.5 feet above a quarry floor. A total of 288 specimens were collected from the limestone and overlying thin calcareous shale in the lower few feet of the Argentine Limestone. Originally, the purpose of collecting these corals was to acquire a sufficiently large number of adult forms for taxonomic study. The corals were picked from slightly weathered shale or chiseled from limestone. Later, bag samples of shale were taken to acquire juvenile forms. The shale was washed; juveniles of *Dibunophyllum parvum* were collected and other faunal elements were retained for generic identification.

Lithology.—The limestone is a fossiliferous calcilutite formed by lithification of carbonate mud. Phylloid algae are moderately common in the limestone and invertebrates are more common and diversified. The overlying shale contains little silt and is highly calcareous. Above the shale, algal limestone is more common and contains abundant invertebrates.

Faunal Analysis.—The preserved fauna that accompanies the corals is diversified (Table 1). Brachiopods dominate the assemblage, with productids particularly abundant. Crinoid stem fragments also are common. Shapes of individuals are highly variable, with planar, cylindrical, conical, and irregular constituents present. Size ranges vary from microscopic ostracodes to brachiopods that attain maximum dimensions of 60 mm. Abrasion is slight. No organisms are replaced by silica or pyrite. Several fossils are broken, but this feature was ignored because

(All sections ×4, cardinal septum at top of transverse section.)

1. *Dibunophyllum parvum* Cocke, n. sp., KUMIP no. 500515, Argentine Limestone Member, Wyandotte Formation; *1a,* transv. sec. slightly below base of calyx; *1b,* long. sec. perpendicular to counter-cardinal plane.
2. *Dibunophyllum parvum* Cocke, n. sp., holotype, KUMIP no. 500516; *2a,* transv. sec. slightly below base of calyx; *2b,* long. sec. perpendicular to counter-cardinal plane; *2c,* transv. sec., late neanic stage.
3. *Dibunophyllum parvum* Cocke, n. sp., KUMIP no. 500517; *3a,* transv. sec. of small specimen slightly below calyx; *3b,* long. sec. perpendicular to counter-cardinal plane; *3c,* transv. sec. of neanic stage.
4. *Dibunophyllum perplexum* Cocke, n. sp., holotype, KUMIP no. 500518; *4a,* transv. sec. slightly below base of calyx, note dibunophyllid columella; *4b,* long. sec. perpendicular to counter-cardinal plane, showing lack of columella in lower part; *4c,* transv. sec. of early ephebic stage showing absence of columella.
5. *Dibunophyllum perplexum* Cocke, n. sp., KUMIP no. 500519; *5a,* transv. sec. in calyx showing absence of columella; *5b,* long. sec. (relation to counter-cardinal plane not known) showing dissepimentlike vesicles in upper part; *5c,* transv. sec. showing neanic stage above attachment area.
6. *Dibunophyllum perplexum* Cocke, n. sp., KUMIP no. 500520; *6a,* long. sec. perpendicular to counter-cardinal plane showing dibunophylloid columella in lower part replaced vertically by cystose structures; *6b,* transv. sec. of early ephebic stage showing dibunophylloid columella.
7. *Dibunophyllum perplexum* Cocke, n. sp., KUMIP no. 500521; transv. sec. of calyx.
8. *Dibunophyllum perplexum* Cocke, n. sp., KUMIP no. 500522 showing dibunophylloid columella in all sections; *8a,* transv. sec. slightly below calyx; *8b,* long. sec. perpendicular to counter-cardinal plane; *8c,* transv. sec. of early ephebic stage.
9. *Dibunophyllum perplexum* Cocke, n. sp., KUMIP no. 500523; *9a,* transv. sec. in lower part of calyx; *9b,* long. sec. perpendicular to counter-cardinal plane; *9c,* transv. sec. of late neanic stage.

TABLE 1. *Faunal list of organisms collected with* D. parvum *Cocke, n. sp., from Wyandotte Formation, Argentine Member, in SW SW sec. 25, T. 12 S., R. 23 E., Johnson County, Kansas.*

ALGAE
- *Archaeolithophyllum?* sp.
- *Anchicodium?* sp.

FORAMINIFERA
- Fusulinids
- Arenaceous forms

RUGOSA (corals)
- *Lophophyllidium* (=*Stereostylus*) sp.
- *Lophamplexus* sp.
- *Dibunophyllum parvum* COCKE, n. sp.
- *Geyerophyllum* sp.

BRYOZOA
- *Rhombopora* sp.
- *Fenestrellina* sp.
- *Tabulipora* sp.

BRACHIOPODA
- *Hustedia* sp.
- *Composita* spp.
- *Punctospirifer* sp.
- *Neospirifer* sp.
- *Lissochonetes* sp.
- *Hystriculina* sp.
- *Reticulatia* sp.
- *Cancrinella* sp.

GASTROPODA
- *Anomphalus* sp.

BIVALVIA
- *Myalina* sp.

ECHINODERMATA
- Crinoids, 3 genera
- Crinoid stems, abundant
- Echinoid plates and spines

ARTHROPODA
- Trilobita
  - *?Ditomopyge* sp.
- Ostracoda
  - *Bairdia* sp.

QUESTIONABLE FORMS
- Encrusting Foraminifera
- Worm borings
- Worm tubes

breakage probably was due to quarry activity. All bivalves observed are articulated. The epifauna consists largely of encrusting bryozoans which are distributed evenly along the circumference of crinoid stems and other moderate-sized organisms. On large specimens of the brachiopod *Neospirifer,* bryozoans are present only on the brachial valve and along the margins of both valves. Burrows were not observed; boring occurs in a few crinoid stems and brachiopods. The general fauna recorded was not studied in detail. However, lack of abrasion, shape variation of constituents, wide size range, occurrence of articulated shells, and concentration of epifauna on a single slide of large specimens strongly suggest that the assemblage is essentially *in situ.*

The abnormal smallness of *Dibunophyllum parvum* specimens suggests that they are juvenile forms of a larger species. Septa that rise above upper limits of the epitheca further suggest they are early growth forms. In an attempt to determine their relative age, two approaches were used: 1) transverse sections taken in the upper parts of calices were compared to transverse sections of adult dibunophyllids from other Pennsylvanian formations. It is beyond the scope of the paper to present all results; however, they show conclusively that larger specimens of *D. parvum*

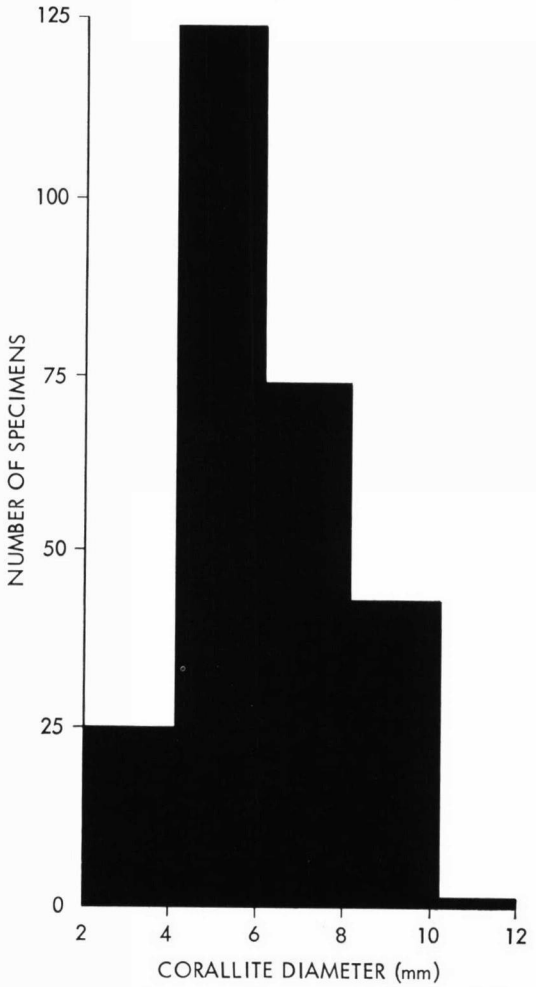

FIG. 3. Size-frequency histogram of *Dibunophyllum parvum* COCKE, n. sp. Only diameters of solitary forms were measured.

are adults; 2) a larger dibunophyllid species from a different interval of the Wyandotte Formation was sectioned at diameters within the upper range of *D. parvum* diameters. Other dibunophyllid species from underlying and overlying formations were similarly sectioned; all exhibited juvenile or early mature characteristics. Further evidence of adult forms is the occurrence of budding individuals. In rugose coral species that are typically colonial, budding may occur in very early stages; however, dibunophyllids rarely bud and in all Pennsylvanian species known to me, budding occurs in late maturity or adult stages. Thus with growth stages of larger *D. parvum* reasonably established, the next problem to be solved is: Do these specimens represent a meaningful sample of a previously existing population or community?

Size-distribution analyses indicate small specimens of *Dibunophyllum parvum* are more numerous (Fig. 3) than large ones, which yields a positively skewed diagram indicative of high juvenile mortality (Fagerstrom, 1964). Rowell (1960), and Percival (1944) believed that such mortality rates are indicative of many marine organisms. The extant coelenterate *Hydra* has a similar curve (Forrest, 1963). The curve of *D. parvum* differs from the ideal curve in having no representatives in the 0 to 2 mm.-diameter class and relatively few in the 2 to 4 mm.-diameter class. This apparent anomaly can be explained in at least three ways. First, most individuals survived during 0-4 mm. growth in diameter, perhaps by very rapid early growth. Growth lines are faint below diameters of 2 mm., which perhaps indicates rapid growth, although other mechanisms are possible. Many specimens were found in upright positions in the limestone, suggesting that they are preserved in growth position. In calcareous shales, corals were either upright or lying subhorizontally.

Second, the condition may be due to sampling error. This seems unlikely, because small specimens are easily detected in washed shale samples. Third, selective preburial and postburial destruction of the small fraction may have occurred. Thus, rapid growth, selective removal of juveniles, or a combination of these factors offer adequate explanation.

Many specimens of *Dibunophyllum parvum* are found attached to skeletal material with a great variety of sizes. This is accepted here as suggesting lack of transportation by currents. In spite of the dearth of knowledge of hydrodynamics of skeletal material, it seems unlikely that specimens with the observed diameter ranges of *D. parvum* would be simultaneously transported and deposited with crinoids and brachiopods that have dimensions up to 60 mm. Coral specimens, as well as other faunal elements, are essentially unabraded. Further, the restriction of these corals to a single hummock, practically eliminates the possibility that the forms were transported into the area by currents.

In summary, evidence garnered from lithic and biotic relationships indicates that specimens of *Dibunophyllum parvum* are representative of an *in situ* population or populations, which, because of the small number of corals in the collected assemblage, suggests that the number of generations was relatively small. Size distribution, analysis of juvenile and adult sections, and presence of budding individuals have been used to establish that the assemblage represents 1) a diminutive species, not juveniles of a larger species, and 2) relatively few generations of this species as shown by positively skewed size distributions. Each line of evidence is subjected to more than one logical alternative and accordingly the conclusions remain somewhat open to question. The highly variable accompanying fauna, as well as analogues with present-day coral occurrences, suggests normal salinity. Depth was well within the photic zone as shown by proliferation of algae. Turbulence was not great, for both carbonate and aluminosilicate muds are common. That little transportation occurred is suggested by lack of abrasion and by poor sorting of fossil debris.

Material Studied.—Nearly 300 specimens were collected from basal beds of the Argentine Limestone in an active quarry in SW SW sec. 25, T. 12 S., R. 23 E., Johnson County, Kansas; a few specimens were collected from equivalent beds exposed in Sunflower Quarry in SE NW sec. 28, T. 11 S., R. 23 E., Wyandotte County, Kansas. Approximately 100 transverse and 25 longitudinal sections were studied. All specimens are deposited in The University of Kansas Museum of Invertebrate Paleontology. Holotype KUMIP no. 500516.

DIBUNOPHYLLUM PERPLEXUM Cocke, n. sp.

Figure 2, *4a-c; 5a-c; 6a,b; 7; 8a-c; 9a-c*

Diagnosis.—Small ceratoid corals that are

generally solitary. A few individuals have two or three buds. The epitheca is smooth and crossed by small growth lines. Rejuvenescent forms are rare. Major septa number 22 to 26 and are irregular near the periphery, thicken abruptly, and thin in the tabularium. Dissepiments are more highly varied in the cardinal quadrant than in others. The axial region is highly variable and may be occupied by 1) a typical dibunophylloid columella, 2) widely spaced irregular central tabulae rimmed by steeply inclined clinotabellae, or 3) combinations in single corallites of 1) and 2).

External Characteristics. — Specimens are small, ranging from 8 to 11 mm. in diameter and 7 to 20 mm. in length. They are commonly ceratoid. Two orders of transverse elements, fine growth lines and larger, smooth wrinkles, are present. Few specimens show rejuvenescence or budding. Calices are deep, with septa rising a short distance above the epitheca. A bladelike columella extends to the upper limit of the calyx in some specimens. Attachment areas are triangular and small, rarely attaining dimensions of 2 mm.

Internal Description

Transverse Section.—The epitheca is thin but thickens to form faint internal ridges at junctions of septal ends. Typically, 22 to 26 major septa cross two-thirds of the corallite diameter. A typical septal formula is C3A7K7A3 (C, cardinal septum; A, alar septum; K, counter-septum). Few septa connect to radiating lamellae. Both orders of septa are thin and crooked peripherally; a few terminate against peripheral dissepiments. Septal thickness increases sharply a short distance from the epitheca and decreases gradually in the tabularium. In a few corallites, small spines on both major and minor septa simulate carinae. Minor septa are approximately four-fifths of major septal length. Septa of cardinal quadrants are somewhat thicker than those of counter quadrants. A few "perforate" septa are formed by coincident thickening and partial merging of septa and adjacent dissepiments. In the cardinal quadrants the dissepimentarium is composed of 1) irregular complete dissepiments that are peripherally convex, 2) incomplete dissepiments, and 3) dissepiments in which both ends terminate against a single septum. Dissepiments are slightly thicker in cardinal quadrants. Planar dissepiments are thinner near the epitheca. The dissepimentarium occupies approximately two-fifths of the corallite diameter. Stereoplasmic thickening on innermost dissepiments creates an obscure inner wall.

The species is divided into two gradational groups: 1) individuals that possess a continuous dibunophylloid columella, and 2) others that have no columella but possess widely spaced, irregular tabulae. Gradational forms are common. In specimens possessing a columella throughout, the tabularium consists of an outer zone of planar to curved tabulae which generally parallel the dissepiments and an inner area comprised of planar to curved tabellae inclined on the columella. The median plate is thick and commonly obscured by stereoplasmic deposits, and radiating lamellae are either prominently or poorly developed. Tabellae are thick and cystlike. They are largest adjacent to the median lamellae and considerably thickened at the outer edge of the columella. In specimens lacking a columella, the tabularium consists of two or three rows of thick, axially convex to planar clinotabellae; commonly the central area is either empty or traversed by a few tabulae.

Early ephebic stages of columellate forms show 10 to 12 major septa that are slightly thicker in cardinal quadrants than elsewhere. The cardinal and counter septa form a continuous bar which is somewhat thickened medially. Minor septa have lengths less than one-half those of major ones. A few dissepiments are slightly thickened and resemble the adjacent tabulae. The columella is formed by a thickened median portion of the counter-cardinal cross bar, irregular tabellae, and major septal ends. Tabulae which surround the axial area of noncolumellate forms are convex axially and somewhat thicker than normal.

Longitudinal Section.—Peripherally, 2 to 8 rows of globose dissepiments comprise the dissepimentarium; an obscure inner wall marks its boundary with the tabularium. Steeply inclined axially convex tabulae are common at the outer limit of tabularium and broad, distally curved tabulae generally occupy its inner edge. Some specimens have a combination of cystlike anastomosing plates and subhorizontal to faintly curved tabellae. If present, the columella consists of a sinuous median plate surrounded by steeply inclined tabellae. In corals without a columella, the

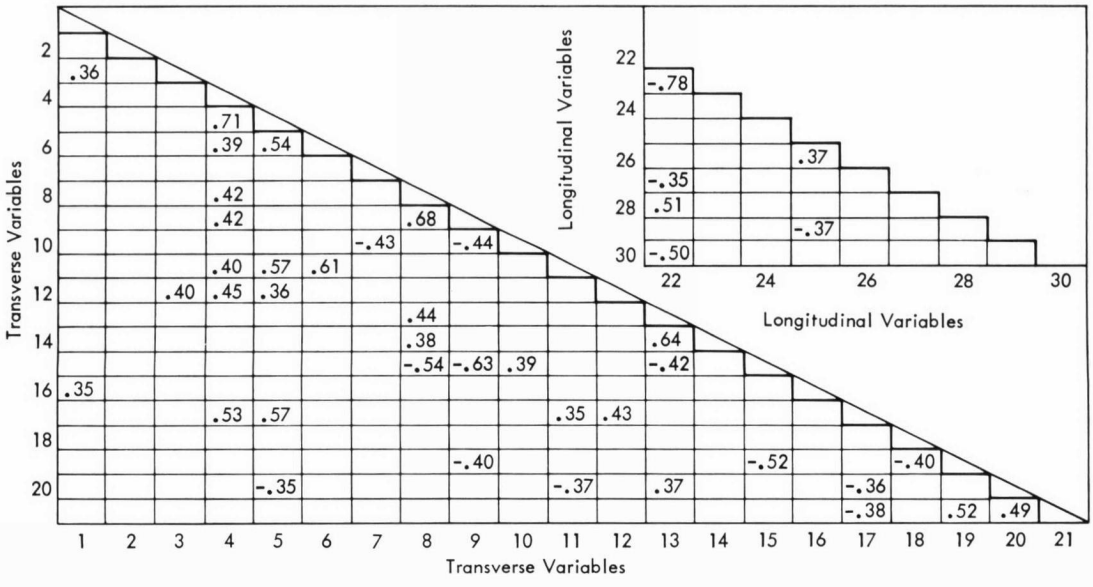

FIG. 4. Correlations between variables measured on transverse and longitudinal sections of *Dibunophyllum parvum* COCKE, n. sp., and *D. perplexum* COCKE, n. sp. The two groups are pooled. Only correlations greater in magnitude than 0.30 are shown. For explanation of character numbers, see Table 2.

central area commonly has axially convex, irregular tabulae. In a few specimens flat to cystlike plates fill the axial zone. In corals which are noncolumellate in early stages but develop an axial structure later, the columella commonly rests on an irregular complete tabula. In these, lower portions of the median plate are crooked and the tabellae are subhorizontal to irregular. Distally, the median plate becomes straighter and tabellae are normal.

ENVIRONMENTAL ANALYSIS.—Lithic and faunal evidence suggests strongly that specimens of *Dibunophyllum perplexum* have been transported from their place of growth to a turbulent environment. They are enclosed in a calcarenitic limestone composed of sorted and rounded echinoderm, brachiopod, and bryozoan fragments. Many corals are broken and apparently abraded. Sorting of *D. perplexum* is indicated by restriction of collected specimens to a diameter range of 8 to 11 mm. and by observation that none are in growth position. My study of the living hexacoral *Manicina* from the Florida Bay calcareous sands shows that these corals most commonly attach to skeletal debris on the bay floor. Progressive growth forces the attachment material and early parts of *Manicina* deeper into the substrata, thus intruding across sediment that accumulated for several years. Probably due to chemical activity within the sediment, outer walls are badly altered and in some instances the juvenile epitheca is completely destroyed. Specimens that expire prior to deep burial are subjected to sorting and destructive forces of bottom currents.

MATERIALS STUDIED.—Approximately 50 specimens of *Dibunophyllum perplexum* were collected from an abandoned quarry in SE NE SW sec. 5, T. 4 S., R. 22 E., Doniphan County, Kansas. From these, 41 transverse and 15 longitudinal sections were made. Thin sections, complete and partial specimens are deposited at the University of Kansas Museum of Invertebrate Paleontology. Holotype KUMIP no. 500518.

DISCRIMINANT ANALYSIS.—An objective test of the specific assignment of the two dibunophyllids

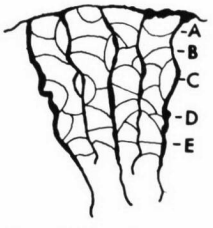

FIG. 5. Classification of dissepiment types in dibunophyllid corals: A, convex inward; B, convex outward; C, septal; D, incomplete and E, straight.

was made using discriminant analysis. Twenty-one characters were measured on transverse sections of the corals, as well as nine characters from longitudinal section (Fig. 4). Means of variables are listed in Table 2. Some variables show weak to moderate intercorrelation, indicating some redundancy but the overall efficiency of the variables selected for characterization is high. Dissepiment types proved to be particularly meaningful (Fig. 5).

Separation of the two groups was tested using a discriminant analysis program developed by WOLLEBEN, PAUKEN & DEARIEN (1967). Transverse and longitudinal sections proved to be equally effective in separating the two species, although transverse sections were used primarily in the original qualitative definition of each species. MAHALANOBIS' distance (D^2) between the two species in transverse was 77.5, yielding an F-value of 5.9, with 21 and 6 degrees of freedom for testing the significance of the discrimination. The separation produced by the discriminant function is significant at the 95 percent level. Four misclassifications were produced by the function, of which three are misclassification of *Dibunophyllum parvum* as *D. perplexum*.

Longitudinal sections supplied effective variables, although fewer were utilized for characterization. MAHALANOBIS' distance between *Dibunophyllum perplexum* and *D. parvum* was 4.7, with an associated F-value of 3.1 and 9 to 22 degrees of freedom. The discrimination is significant at the 95 percent level. Three misclassifications were produced, all *D. parvum* as *D. perplexum*.

TABLE 2. *Means of Variables Measured in* Dibunophyllum perplexum *and* D. parvum.

TRANSVERSE SECTIONS	*D. perplexum*	*D. parvum*
1. Average diameter	7.85	7.27
2. Wall thickness	0.10	0.09
3. Minor septal length	1.74	1.91
4. Maximum septal thickness (cardinal quadrants)	0.24	0.17
5. Maximum septal thickness (counter quadrants)	0.19	0.11
Cardinal quadrants		
6. Dissepiment A	5.85	3.73
7. Dissepiment B	3.08	3.13
8. Dissepiment C	6.08	4.27
9. Dissepiment D	10.54	7.00
10. Dissepiment E	2.92	3.87
Counter quadrants		
11. Dissepiment A	8.08	4.40
12. Dissepiment B	4.23	2.23
13. Dissepiment C	2.08	2.73
14. Dissepiment D	5.23	4.07
15. Dissepiment E	2.92	4.67
16. Major septal number	24.00	23.00
17. Dissepiment thickness	0.06	0.03
18. Tabulae thickness	0.03	0.02
19. Tabellae thickness	0.03	0.03
20. Tabellae along median lamellae	5.46	11.40
Longitudinal Sections		
21. Number radiating lamellae	5.46	7.60
22. Number dissepiments along wall	5.80	4.38
23. Number dissepiments laterally	3.69	4.07
24. Thickness of inner wall	0.07	0.07
25. Number tabulae against dissepimentarium	4.30	4.71
26. Number tabulae against columella	3.67	3.50
27. Number tabellae against median lamellae	6.07	7.12
28. Dissepimental thickness	0.05	0.03
29. Tabulae thickness	0.02	0.02
30. Outer wall thickness	0.07	0.08

REFERENCES

BEEDE, J. W., 1900, *Carboniferous invertebrates:* Kansas Geol. Survey, v. 6, pt. 2, 187 p.

COCKE, J. M., 1965, *Occurrence of a Carboniferous coral not previously reported from North American rocks:* The Compass, v. 42, no. 3, p. 180-188.

———, 1966, *New species of* Dibunophyllum *from the Dewey Formation:* Oklahoma Geol. Survey, Circular 72, pt. 2, p. 35-56.

DE GROOT, G. E., 1963, *Rugose corals from the Carboniferous of northern Palencia (Spain):* Leidse Geologische Mededelingen, Deel 29, 123 p.

DUNCAN, HELEN, 1962, *Phylum Coelenterata:* in MUDGE, M. R., & YOCHELSON, E. L., Stratigraphy and paleontology of the uppermost Pennsylvanian and lowermost Permian rocks in Kansas, U.S. Geol. Survey, Prof. Paper 323, p. 64-66.

DYBOWSKI, W. N., 1873, *Monographie der Zoantharia Sclerodermata Rugosa aus der Silurformation Estlands, Nord-Livlands und der Insel Gotland:* Arch. Naturk. Liv-, Esth-u. Kurl. [1], v; Lief. 3, p. 257-414.

EASTON, W. H., 1944, *Revision of* Campophyllum *in North America:* Jour. Paleontology, v. 18, p. 119-132.

FAGERSTROM, J. A., 1964, *Fossil communities in paleoecology: their recognition and significance:* Geol. Soc. America, Bull., v. 75, p. 1197-1216.

FORREST, H., 1963, *Immortality and Pearl's survivorship curve for* Hydra: Ecology, v. 44, p. 609-610.

FOMICHEV, V. D., 1953, *Koralli Rugosa i stratigrafiya Sredne i verchnekamen- nouyolnich i Permskich otlochenii Donetzkogo Bassuna [Rugose corals and stratigraphy of middle and upper Carboniferous and Permian deposits of the Donets basin]:* Trudy Vses.

Nauch.-Issl. Geol. Inst. (VSEGEI) Min. Geol. Moscow, 1953, p. 1-622.

FRAUNFELTER, G. H., 1965, *A new Pennsylvanian dibunophyllid coral from Missouri:* Missouri Geol. Survey, Rept. of Invest. no. 32, 8 p.

GIRTY, G. H., 1915, *Invertebrate paleontology (of the Pennsylvanian of Missouri):* Missouri Bur. Geology Mines, Ser. 2, v. 13, p. 263-376.

GRABAU, G. W., 1922, *Paleozoic corals of China. Part I, Tetraseptata:* Paleont. Sinica (Geol. Surv. China) ser. B., v. 2, fasc. 1, 76 p.

HERITSCH, F., 1941, Polythecalis *and* Dibunophyllum *aus dem Perm von Attika.:* Sitz. ber. Akad. Wiss. Wien, Math.-naturw. Kl., I, 150, p. 37-44.

HILL, DOROTHY, 1938, *The Carboniferous rugose corals of Scotland:* Palaeontograph. Soc. Mon. (London), 213 p.

———, 1956, *Rugosa;* in Coelenterata, pt. F of MOORE, R. C. (ed.), Treatise on invertebrate paleontology: Geol. Soc. America and Univ. Kansas Press, p. 233-323.

JEFFORDS, R. M., 1948a, *New Pennsylvanian dibunophyllid corals (Oklahoma-Kansas):* Jour. Paleontology, v. 22, p. 617-623.

———, 1948b, *The occurrence of corals in the late Paleozoic rocks of Kansas:* Kansas Geol. Survey, Bull. 76, pt. 3, p. 31-52.

KEYES, C. R., 1894, *Paleontology of Missouri, Pt. 1:* Missouri Geol. Survey, v. 4, 271 p.

M'COY, F., 1849, *On some new genera and species of Paleozoic corals and Foraminifera:* Ann. Mag. Nat. Hist., ser. 2, v. 3, p. 1-20, 119-136.

MILLER, S. A., & GURLEY, W. F. E., 1893, *Descriptions of some new species of invertebrates from the Paleozoic rocks of Illinois and adjacent states:* Illinois State Museum Nat. Hist., Bull. 3, 81 p.

MILNE-EDWARDS, H., & HAIME, J., 1850-54, *British fossil corals:* London, Palaeontograph. Soc., Mon. Introduction and pt. 1 (1850), p. i-lxxxv, 7-71; pt. 2 (1851), p. 73-145; pt. 3 (1852), p. 147-210; pt. 4 (1853), p. 211-244; pt. 5 (1854), p. 245-299.

NEWELL, N. D., 1935, *Some mid-Pennsylvanian invertebrates from Kansas and Oklahoma; Pt. 2, Stromatoporoidea, Anthozoa, and Gastropoda:* Jour. Paleontology, v. 9, no. 4, p. 341-355.

PERCIVAL, E., 1944, *A contribution to the life-history of the brachiopod* Terebratella inconspicua *Sowerby:* Royal Soc. New Zealand Trans., v. 74, p. 1-23.

ROWELL, A. J., 1960, *Some early stages in the development of the brachiopod* Crania anomala *(Muller):* Annals Mag. Nat. History, ser. 13, v. 3, p. 35-52.

ROWLEY, R. R., 1901, *Two new genera and some new species of fossils from the upper Paleozoic rocks of Missouri:* Am. Geologist, v. 27, p. 343-355.

SMITH, S., & RYDER, T. A., 1926, *The genus* Corwenia, *gen. nov.:* Ann. Mag. Nat. Hist. (9), xvii, p. 149-159.

THOMSON, J., 1880, *Contributions to our knowledge of rugose corals from the Carboniferous limestone of Scotland:* Phil. Soc. Glasgow, Proc., v. 12, p. 225-261.

———, & NICHOLSON, H. A., 1876, *Contributions to the study of the chief generic types of the Paleozoic corals:* Ann. Mag. Nat. Hist., Ser. 4, Vol. 17, no. 1, p. 60-70; no. 2, p. 123-128; no. 4, p. 290-305; no. 6, p. 451-461; Vol. 18, no. 7, p. 68-73.

WHITE, C. A., 1884, *The fossils of the Indiana rocks, no. 3:* Indiana Dept. Geol. Nat. History, Ann. Rept. 13 (1883), pt. 2, p. 107-180.

———, & ST. JOHN, O. H., 1867, *Description of new sub-Carboniferous and coal measures fossils collected upon the geological survey of Iowa: together with a notice of new generic characters observed in two species of brachiopods:* Chicago Acad. Sciences, Trans., v. 1, p. 115-127.

WOLLEBEN, J. A., PAUKEN, R. J., & DEARIN, J. A., 1967, *FORTRAN IV program for multivariate paleontologic analysis using an IBM 360-40 computer:* in Computer programs for multivariate analysis in geology, D. F. MERRIAM (ed.), Kansas Geol. Survey Computer Contrib. 20, p. 1-12.

WORTHEN, A. H., 1875, *Coal Measures:* Illinois Geol. Survey, v. 6, 8 p.

YABE, H., 1950, *Permian corals resembling* Waagenophyllum, *and* Corwenia: Proc. Japan Acad., v. 26, no. 3.