NOTES ON FOSSIL OCTOCORALS AND COMPARISONS OF SOME MODERN AND ANCIENT OCTOCORAL REMAINS

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ABSTRACT

Few published reports exist describing fossil octocoral remains, and most deal only with spicules or axial structures. The calcified holdfast has been greatly neglected. Observations of numerous holdfasts indicate features that may possibly be used for identification. Macrostructures such as overall morphology, surface striations or furrows, laminations, a central depression caused by the removal of the axis and an encrusting habit may all be used for gross identification. Microstructures, however, may prove to be much more helpful and may be a key to the identification of fossil holdfasts at the generic level. Study of these microstructures is still in the early stages.

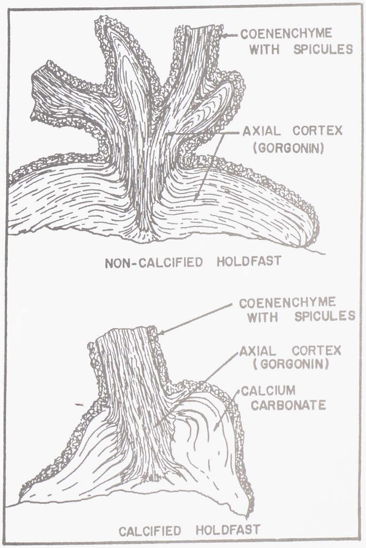
The dominant microstrucures are bundles of fibrous aragonite that form hemispheroidal mound-like features separated by thin laminae of gorgonin. The overall texture, size and configuration of the hemispheroids probably are usable for taxonomy, at least to the generic level.

INTRODUCTION

Few investigations have dealt with the problem of octocoral preservation. Colonial growth forms have been reported as fossils (*i.e.*, Williams, 1943; and Bayer, 1956), but often the specimens are poorly preserved and of questionable identity. Fossil octocorals also have been reported on the basis of spicule material and occasionally axial structures (Bayer, 1955; Giammona and Stanton, 1980; and Bengtson, 1981). According to Lindström (1978), the geologic range of octocorals is Lower Ordovician to Recent.

Information on modern octocorals is relatively abundant. The most significant taxonomic work is by Bayer (1961). Considerable work has also been done on growth forms, temperature tolerance, salinity tolerance, faunal distribution and chemistry of the colonial structures (Goldberg, 1973; Szmant-Froelich, 1974; Weber and Woodhead, 1972; and Spiro, 1971).

The purpose of this investigation is to compare modern and fossil octocoral structures and to point out that fossil octocorals may not be as rare as previously thought. For the purpose of studying fossil material, only a few parts of the colonial structure are significant. Other than rare impressions of soft parts, the calcareous spicule, the axial cortex and the calcified base or holdfast are important fossil remains.



Text-figure 1. Diagrammatic, longitudinal sections through non-calcified and calcified holdfasts.

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GENERAL MORPHOLOGY

Calcareous spicules are probably the most common remains found as fossils. They form in the coenenchyme and give structural support to individual polyps and the entire colony. Numerous types of spicules can be found in any one particular colony and these are generally used to establish the taxonomy of the organism. Fossilized spicules can be distributed throughout sediment and mixed with remains of other octocorals. The identification of a particular fossil species on the basis of these spicules is usually dificult, if not impossible. Bayer (1956) states the problem clearly: "Very possibly the seemingly hopeless problem of identifying such isolated spicular remains has prompted many investigators to ignore them when observed in samples." In some cases, however, where particular species have diagnostic spicule types, taxonomy may be established. This identification is usually based on a single spicule or a small group of spicules.

In addition to difficulties with identification, the problem is compounded by the dificulty of actually finding the spicules when their presence is known in a sample. The small size of most spicules causes many problems in separating and collecting specimens. Spicules are also often destroyed during diagenesis by dissolution or by the action of boring organisms. Original spicular material in most specimens is high-magnesium calcite (as opposed to low-magnesium calcite), and its lack of stability under certain conditions can affect the preservation of fossil material.

In addition to spicular material, other octocoral structures can be preserved. Several authors have reported the existence of preserved axial structures (Hickson, 1938; Bayer, 1956; and Giammona and Stanton, 1980). The Isididae are probably the most common forms preserved, because of extensive calcification of the axis. The Primnoidae and Ellisellidae always have cal-

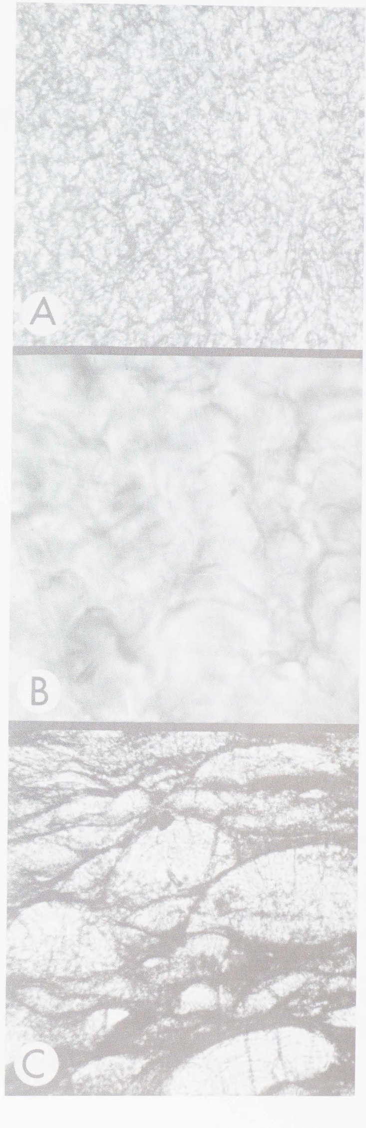
Text-figure 2. Photomicrographs of hemispheroidal structures in (A), *Plexaurella dichotoma* (a plexaurid); (B), *Pterogorgia anceps*, and (C), *Pterogorgia citrina*. B and C are gorgonids. The figure width represents 275 micrometers, and all figures represent longitudinal sections.

cified axes and are occasionally fossilized. However, these families are not the only groups that can be found as fossils, as will be pointed out later.

In most octocorals the axial structure is brown, stiff, horny material. Chemical analysis of modern axial structures indicates a composition of collagen-like protein. This axial material, often referred to as "gorgonin," has incorporated spicules and granules of calcium carbonate (Szmant-Froelich, 1974). In cross-section the axis appears to be partially concentric layers of gorgonin.

The third part of the colonial structure that can be preserved is the calcified base. Text-figure 1 is a diagrammatic longitudinal section through a typical octocoral holdfast. Although calcification does not occur in all octocorals, the holdfasts and axes of the families Plexauridae, Primnoidae, Ellisellidae, Isididae, Chrysogorgiidae and Gorgoniidae are commonly lithified. Calcification usually occurs between the coenenchyme and the axial cortex. Most of the calcification occurs in the basal structure of the colony and increases the attachment strength of the organism. With age, calcification may progress upward around the lower portion of the axis. Calcium carbonate crystallization may be promoted by the presence of carbonate granules incorporated in the gorgonin, as mentioned earlier, and these granules may act as nucleation sites for crystal growth. X-ray analysis of the calcified holdfast indicates an aragonite composition in all of the specimens examined in this study, but Bayer (1978, personal communication) stated that the composition may be aragonite or calcite, and mineralogy probably has nothing to do with taxonomy.

It should be noted that the presence of calcification in the holdfast probably has no relationship to the relative age of the colony. Small, young colonies may have



Text-figure 3. These photomicrographs indicate the diversity of microstructure configuration from one genus to another. (A), *Plexaurella grisea*, figure width represents 275 micrometers. (B), Enlargement of (A), width represents 44 micrometers. Note stacked hemispheroids. (C), *Eunicea tourneforti*, width represents 275 micrometers. All figures represent vertical sections. Both species are plexaurids.

calcified material as well as older specimens. The size and age of the colony do affect the amount of calcification and, thereby, the size of the holdfast. A moderately-sized holdfast may weight between 150 and 200 gm and measure 100 mm in diameter. Plate I shows several examples of typical holdfasts. Fracturing around the axis (pl. 1, figs. 1 and 2) is characteristic of most holdfasts and is probably related to tensional forces developing during growth of the coloy or post-mortem dessication. The calcified portion of the holdfast shows a typical laminated carbonate structure (pl. 1, figs. 3 and 4) when the axial cortex is removed by post-mortem decomposition. Striations are also common features on the calcified surface (pl. 1). The position of the small grooves is related to the overlying longitudinal coenenchymal canals.

Petrographic examination of modern calcified holdfasts indicates a diversity of microstructures. At present, the significance of these structures to taxonomy is uncertain, but general distinctions can possibly be made at the generic level. Three different microstructure forms, representing two genera and three species, can be observed in Text-figure 2. The petrographic configuration within the holdfast is dictated by the arrangement of hemispheroids or quadraspheroids of aragonite-crystal bundles. These hemispheroids are usually separated by thin sheets of gorgonin that appear as laminae. The size and arrangement of the crystal bundles vary from species to species. Typically the hemispheroids are constructed of fibrous crystals radiating from a nucleation site.

The three species in Text-figure 2 are shown at the same magnification. The moderately-sized hemispheroids of the Gorgonids, *Pterogorgia anceps* (2B) and *P. citrina* (2c), are easily distinguishable from the minute structures found in the Plexaurid, *Plexaurella dichotoma* (2A). The small elongations or stylolite-like projections seen in *P. dichotoma* are stacked hemispheroids. This is only discernible under higher magnification. Text-figure 3 indicates the diversity of size and shape of these microstructures. Hemispheroids from *Plexaurella grisea* average 12 micrometers in width and are typically stacked (Text-figs. 3A and B). Structures typical of *Eunicea tourneforti* often exceed 200 micrometers in width and are usually surrounded by thick laminiae of gorgonin. A comparison can also be made between *Plexaurella dichotoma* (Text-fig. 2A) and *P. grisea* (Text-fig. 3A). Both photomicrographs are at the same scale. Stacked hemispheroids of *P. dichotoma* are almost twice as wide as those found in *P. grisea*. These comparisons may be of taxonomic significance; however, numerous additional samples need to be examined to determine if this size differentiation is usable as a taxonomic tool.

FOSSIL OCTOCORAL

As mentioned above, examples of fossil octocoral material have been reported in the literature. Most of these reportings deal with spicules or occasionally axial structures. The most significant fossil material, the holdfast, has been neglected by most investigators. The problem seems to be the lack of recognition or simply misidentification.

Morphology of both fossil and modern holdfasts and axial segments are generally correlatable but recrystallization of fossil material can cause difficulty in distinguishing internal structures. For this reason identification at the generic level is difficult and often impossible.

The fossil octocorals presented below were collected in six different areas and range from Eocene to late Pleistocene in age. The specimens are grouped according to location.

Location 1 . . . Middle Pleistocene, Limón, Costa Rica. Octocoral axes,

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PLATE 1

1, 2. Modern calcified holdfasts with well-developed tensional cracks around the axes. (1 = X 2.3, 2 = 2.2)

3, 4. Holdfasts showing the central depression and laminated carbonate structure. (3 = X 2.2, 4 = X 1.2)

PLATE 1

spicules and holdfasts were collected from the Moín Formation near Limón, Costa Rica. Several examples of well-preserved axial cortex or calcified gorgonin (pl. 2) were found in poorly lithified grey shales and siltstones. The Moín Formation is composed of alternating sequences of reef/shelf carbonates and clastics (Taylor, 1973). Initial deposition of clastics occurred in a water depth of approximately 50 m, as evidenced by studies of foraminifers (Taylor, 1973) and molluscs (Vokes, 1978, personal communication). The formation contains an abundant fauna including mollusca, hermatypic corals, arthropods, worms, echinoids and foraminfers. The middle part of the formation is highly bioturbated and most of the burrows are preserved by sediment infilling. Small, low-relief, coralline patch reefs are also present in the formation, with the dominant coral types *Porites*, *Diploria*, and *Montastrea* (Taylor, 1973). These reefs probably supplied the hard substrate needed for most octocoral growth.

Plate 2, figures 1 to 7 are typical examples of octocoral structures from the Moín Formation. To date, only one calcified base has been found and the identification is uncertain. However, internal microstructures, such as the hemispheroidal pattern, indicates similarity to modern forms of *Plexaurella grisea*. Identifications of the other specimens, based on internal features (*i.e.*, hemispheroid structures), are impossible, as these features are seldom observable in branch fragments. A photomicrograph (pl. 2, fig. 4) shows the typical laminated gorgonin found in branch materials. Macrostructures indicate that fragment 1 probably belongs to the isidids; whereas, fragments 2 and 3 are either primnoids or ellisellids. Without more characteristic structures, identification of these specimens at the generic level would be, at most, a guess. The specimen shown in Plate 2, figures 5 and 6 is an axial segment with numerous small branches. Petrographic analysis indicates a structure composed of calcified gorgonin with no hemispheroidal patterns. Based on morphology similarities with modern specimens, the sample is tentatively identified as *Plexaura* sp.

Location 2 . . . Pleistocene, Florida Keys, Florida. The recrystallized remnant of a large holdfast (pl. 3, fig. 1) was found in a recent excavation on Cudjoe Key. Internal structures have been destroyed by recrystallization and, as a result, identification of this specimen is questionable. Based on general shape and size (100 mm in diameter), the specimen resembles typical holdfasts of gorgonids and plexaurids. Reference should be made to Plate 1, figures 3 and 4 for similar modern specimens.

The Florida sample exhibits the typical laminated carbonate structure as described earlier. The depression in the center of the specimen was formed by decomposition of the gorgonin axis.

Location 3 . . . Upper Pleistocene, northeastern Yucatan Peninsula, Mexico. This calcified holdfast (pl. 3, figs. 2 and 3) was found in shoreface storm deposits (Ward, 1978, personal communication). The specimen is well-preserved and exhibits numerous typical features found in most calcified holdfasts: 1) striated surface; 2) laminated carbonate; 3) central depression formed by removal of gorgonin; 4) encrusting nature, as seen in cross-sectional view; and 5) hemispheroid structures observed in thin-section. The sample was sectioned before photographing and as a result only one-half of the holdfast is

PLATE 2

1-3. Branch fragments of octocorals. These stems are composed of calcified gorgonin. (1 = X 2.4, 2 = X 2.2 and 3 = X 2.4) Specimen 3 is partially encrusted by a scleractinian coral.

4. Cross-sectional view, in thin-section, of the calcified axis figured as (3). (X 16.4)

5, 6. Calcified axis with surface striations. Note the attachment points of smaller branches (*Plexaura* sp.) (X 2.4)

7. Small calcified holdfast encrusting a mudstone concretion. (X 1.6)

Note: All samples were collected from the Moín Formation, Limón, Costa Rica.

PLATE 2

available. Based on the observable features, primarily hemispheroid structures, this specimen is tentatively identified as *Pterogorgia*. Internal structures closely resemble features found in modern examples of *Pterogorgia anceps*.

Location 4 . . . Plio-Pleistocene, Bowden Formation, Jamaica. Lamb and Beard (1972) established the age of the Bowden Formation at the Plio-Pleistocene boundary on the basis of foraminifers. This conflicts with previous work by Woodring (1925) who placed the formation in the Middle Miocene. Woodring describes the Bowden as an ". . . imperfectly consolidated gravel . . . in a marly matrix . . . with perfectly preserved fossils . . ."

The holdfast collected from the Bowden Formation (pl. 3, figs. 4 and 5) is indeed well-preserved and is one of the better holdfasts in the collection. Both macro- and microstructures are observable even though some recrystallization to calcite has occurred. Based on the size of the center depression the axial cortex of the colony is estimated to be 25 mm in diameter. This would indicate that the living colony was rather large and stout. Microstructures within the base most clearly resemble those of the modern genus *Plexaurella*.

Location 5 . . . Lower Oligocene, Red Bluff Formation, Mississippi. Holdfasts from the Red Bluff Formation (pl. 4, fig. 1) are typically small (10 to 15 mm in diameter) and are found attached to marine mudstone nodules. Spicules also can be found in the sediment, although none are diagnostic enough for a firm identification.

The Red Bluff holdfasts, though small, exhibit typical octocoral features found on modern calcified bases: 1) grooved or furrowed surface; 2) laminated carbonate; 3) central axial depression; and 4) encrusting habit. There is no doubt that these specimens are octocorals, but because of extensive recrystallization further identification at this time is speculative. Only remnants of gorgonin material and hemispheroids are observable in thin-section (pl. 4, fig. 2).

Location 6 . . . Upper Eocene, Danville Landing Beds, Jackson Group, Louisiana. These holdfasts (pl. 4, figs. 3 and 4) closely resemble specimens from the Red Bluff Formation (Location 5). They are also small, encrusting forms attached to mudstone nodules. Based on general appearance they are probably of the same genus as the Oligocene samples, but again recrystallization has destroyed most of the microstructures.

CONCLUSION

Many of the specimens presented in this report may represent extinct genera. Due to the lack of work on microstructures within the holdfast it would be premature to establish new names for these fossils. At the present time it is sufficient to simply relate the fossil forms to modern counterparts.

Recognition of the holdfast as octocoralline is significant, as its presence in a formation can give an investigator more insight into paleoecologic conditions. Confusion of the holdfast structure with other organisms could also be an important problem. The laminated nature, encrusting habit, and presences of organic layers (gorgonin) might easily be confused with stromatolitic structures.

Examination of microstructures within the bases of modern octocorals indicates that different species may have different configurations of hemispheroids (aragonite bundles). Size, shape and position within the holdfast seem to be significant. At this time, a considerable amount of work needs

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PLATE 3

1. Large calcified holdfast from the Florida Keys. Recrystallization has destroyed the microstructure but most macro-features are easily observable. (X 0.9)

2, 3. Well-preserved holdfast from the Yucatan Peninsula. Note lamination and surface striations. (X 2.1) Figure 3 represents a vertical section.

4, 5. Calcified holdfast from the Bowden Formation. The central depression is particularly well-developed. (X 1.2)

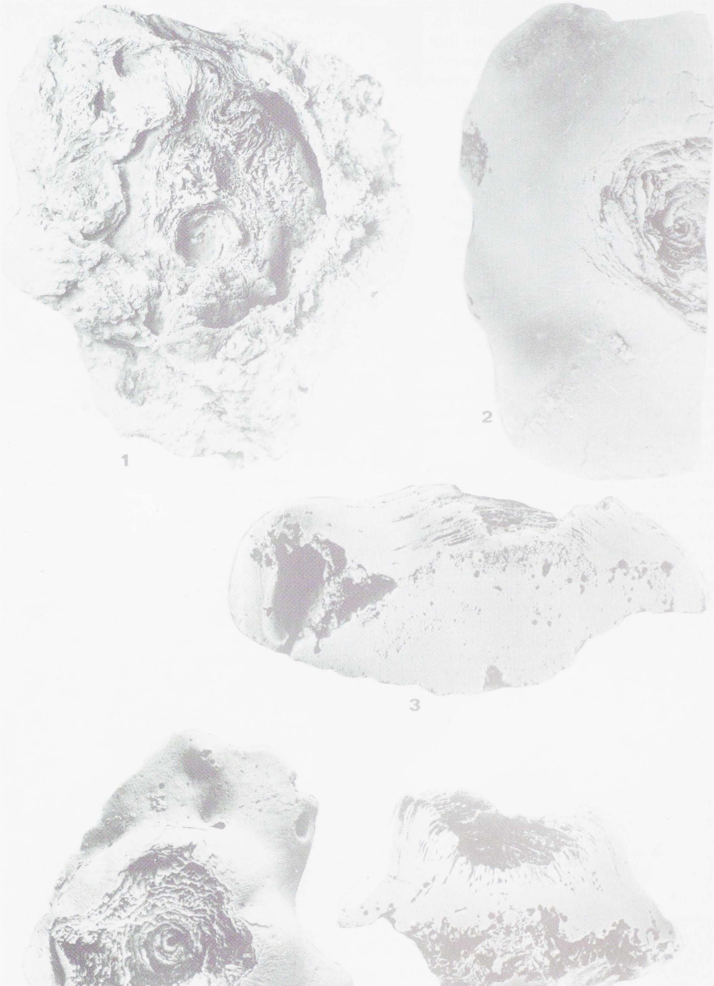

PLATE 3

to be done to further evaluate the significance of these microstructures to the taxonomy of octocorals. It is likely that fossil octocorals are not as rare as previously thought and perhaps more emphasis should be placed on their usefulness as environmental indicators.

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PLATE 4

1. Six individual holdfasts attached to a mudstone nodule. Macro-features are easily observable. (X 2.3) (Red Bluff Formation).
2. Recrystallization of the holdfasts in figure 1 has destroyed most of the microstructure. There is, however, some remnant gorgonin. (X 25) The figure represents a vertical section.

3, 4. Calcified holdfasts of Eocene age (Danville Landing Beds). (3 = X 2.9, 4 = 2.2)

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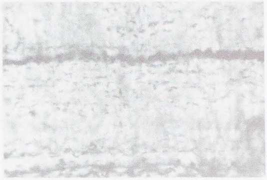

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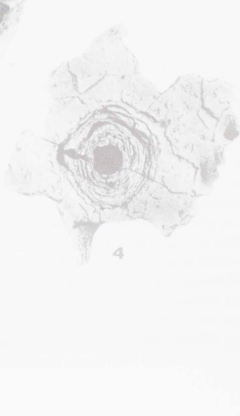

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PLATE 4