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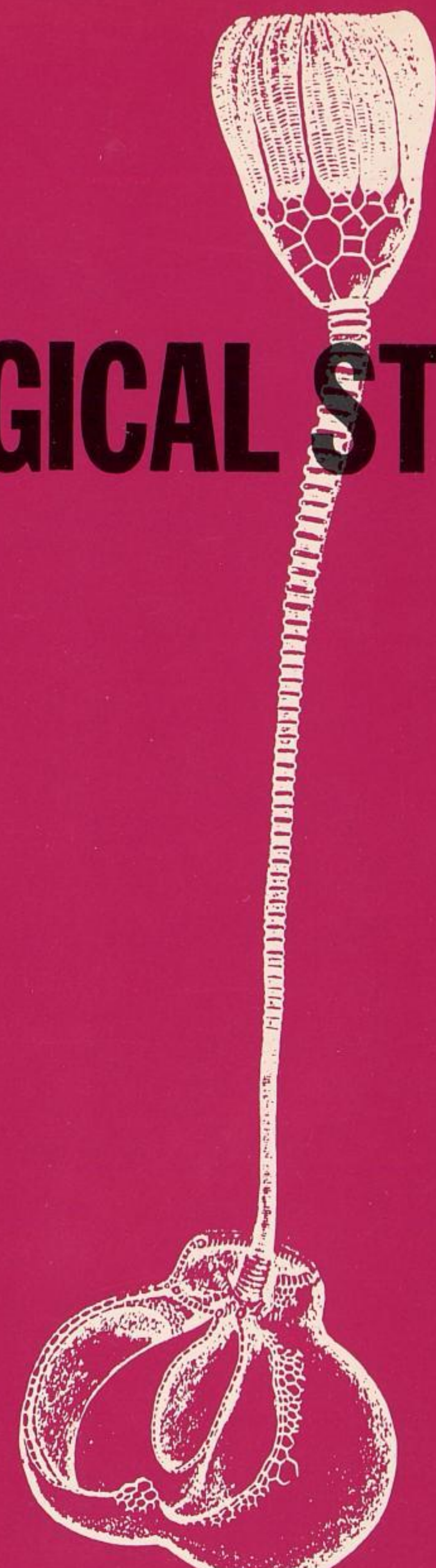

FALL 1980

Bulletin No. 39

A Study of the Crinoid Genus Camarocrinus *in the Hunton Group of Pontotoc County, Oklahoma*

BRADLEY S. RAY

Baylor Geological Studies

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Waco, Texas
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ABSTRACT

The crinoid genus *Camarocrinus* has been described as an independent class of echinoderms, cystoids, genital sacs, brood-pouches, pathologic cysts, anchoring roots, and as the floating organ of the genus *Scyphocrinus*.

It has been commonly accepted that *Camarocrinus* was connected at the distal end of its stem to the stem of *Scyphocrinus*. This study shows that the assignment of the bulb to the second genus should not be so readily accepted as fact until evidence is found to conclusively support such a hypothesis.

As opposed to the "float theory," suggested in most of the current literature, the conclusion of this study offers support to the more natural interpretation that *Camarocrinus*, an independent crinoid genus, served as enlarged roots, anchoring an unknown crinoid to the substrate.

INTRODUCTION*

PURPOSE

This study was initiated to review, clarify, and expand our understanding of the crinoid genus *Camarocrinus* and to offer scientific evidence regarding the function of the bulb and the crinoid's mode of life.

LOCATION

The area of study is located in southeastern Pontotoc County, Oklahoma, along the northern edge of the Arbuckle Mountains (Fig. 1). Three localities were selected from the known occurrences of the bulbs, and from these, specimens were collected for use in the study. *Camarocrinus* is found in the Haragan and Henryhouse Formations of the Hunton Group exposed at the localities in southern Oklahoma (Fig. 2).

*A thesis submitted in partial fulfillment of the B.S. degree in Geology, Baylor University, 1980.

PROCEDURE

In order to clarify the existing knowledge of *Camarocrinus*, a thorough literature review was done and various paleontologists who have studied echinoderms were consulted. Field work was restricted to the occurrences of the crinoids in the Hunton Group of south-central Oklahoma. Field and laboratory work included the collection and examination of over 400 bulbs.

Two-hundred bulbs, selected as representative fossils from the outcrops, were sectioned, using a rock saw, and the geopetal structure revealed in each bulb was recorded. The position of the bulbs as they occur in the outcrops was also documented. The morphology of the fossil was studied in detail, enhanced greatly by the use of HCl to clean the bulbs and a microscope to examine their intricate structures.

PREVIOUS WORKS

Many authors have included in their topics of discussion various theories regarding the function of the bul-

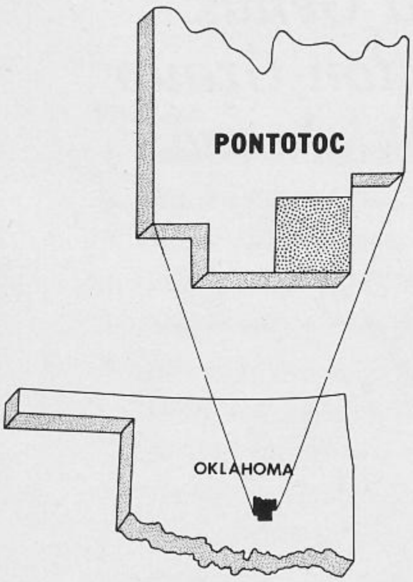

Fig. 1. Location map of study area: Southeastern Pontotoc County, Oklahoma.

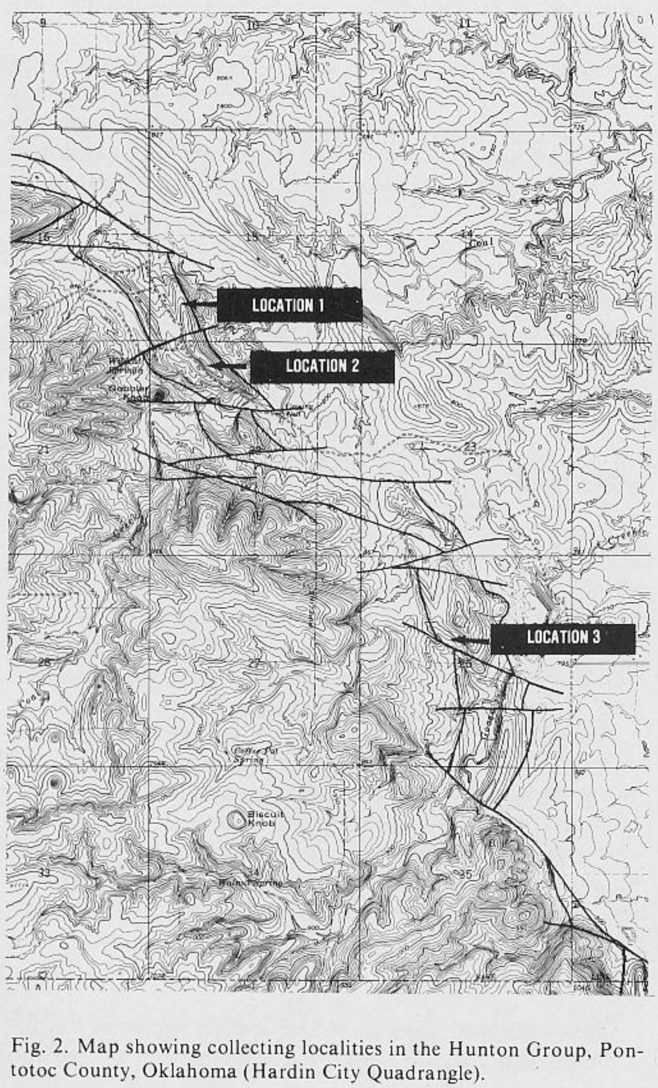

Fig. 2. Map showing collecting localities in the Hunton Group, Pontotoc County, Oklahoma (Hardin City Quadrangle).

bous growths known as *Camarocrinus*. These studies include such works as: "Notice of Some Remarkable Crinoidal Forms from the Lower Helderberg Group," Hall (1879); "Systeme Silurien du Centre de la Boheme," Barrande (1887); "Die Amphorideen and Cystoideen," Haeckel (1896); "Uber Sogenannte *Lobolithen*," Jaekel (1904); "On Siluric and Devonic Cystidea and *Camarocrinus*," Schuchert (1904); "O Nakhodke *Lobolitov* v SSSR i o Biologicheskom Znachenii ikh," Yakovlev (1953); and "O Taksonomicheskikh Priznakakh Segmentirovannykh Stebley Morskikh Liliy," Stukalina (1967).

The two most thorough works done to date are: "On the Crinoid Genus *Scyphocrinus* and its bulbous root, *Camarocrinus*," Springer (1917) and "Ban and Funktion de *Scyphocrinites-Lobolithens*," Haude (1972). Springer is credited with having proven the association of *Camarocrinus* with *Scyphocrinus*, and Haude is referred to as having scientifically proven the theorized function of the bulb known as the "float theory." This study examines these and other works and the theories they present, and objectively examines the evidences used to support the theories.

ACKNOWLEDGEMENTS

The writer thanks Dr. Gustavo A. Morales for his help, guidance, and encouragement, and Dr. Robert Grayson for the suggestion to use geopetal structures to aid in reconstructing the mode of life of *Camarocrinus*.

Special thanks are extended to Bunker Hunt for access to his ranch, the area of study, and to my grandfather, Pat Ray, Sr., who has collected several thousand bulbs from various localitites and first introduced me to this unique fossil.

Also, the writer would like to thank Bette Winter for translating Haude's study from German to English, and Muriel Mason for typing the final draft.

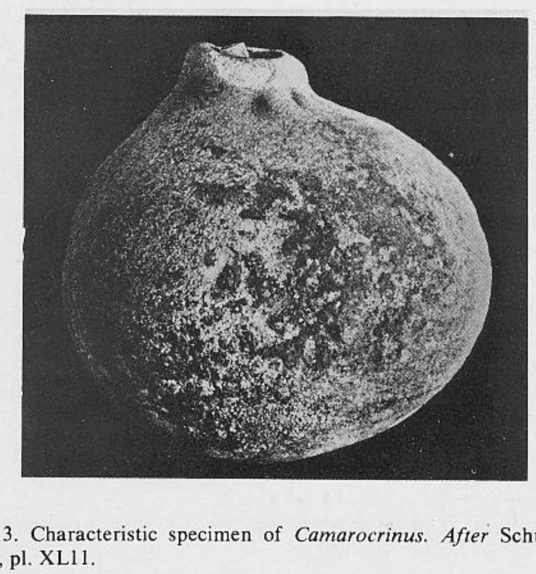

Fig. 3. Characteristic specimen of *Camarocrinus*. *After* Schuchert 1904, pl. XL11.

DESCRIPTION

Camarocrinus is a hollow, rigid, chambered body with a short collarlike projection encompassing a bilateral-symmetrical stem base of bifurcating cirri (Fig. 3). It has several internal saclike structures, which open to the exterior through large, single, channellike openings. The openings are located in the axis of each main root bifurcation.

The walls of the bulb consist of three calcareous layers. These layers are derived from the root system by repeated divisions of the main cirri. The plated cover layers (Figs. 4 and 5) are formed from thickened portions of the irregular cirri that form the middle layer.

The main cirri rest upon a flattened layer of plates originating in and formed from the lateral rootlets (Fig. 7). Some of the cirri turn upward from the floorlike layer, to form the single-layered collar (Fig. 6). Others project downward to form the walls of the saclike chambers.

Each of the main cirrus bifurcations contains an opening leading into one of the chambers (Figs. 7 and 8). There are as many chambers and related openings as there are main cirri.

The crinoidal stem rests on the primary root member as shown in Figure 9. Where the stem wedges into the primary root member (Fig. 9), the stem's axial canal branches into the system of roots, forming a neurovascular network that is spread throughout every plate in the bulb (Figs. 9 and 10).

Below, unpenetrated by the axial canal, lies the mediobasal chamber, surrounded by three to as many as 12 chambers. The medio-basal chamber is the space at the center of the bulb between the chamber walls (Fig. 11).

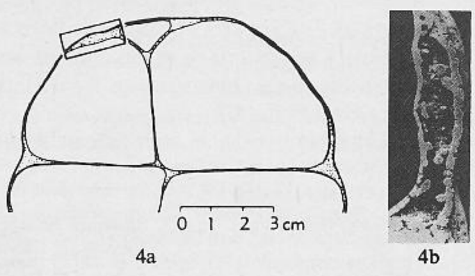

Fig. 4. (4a) Cross section of a bulb and (4b) detailed section of wall structure. *After* Haude, 1972, p. 109.

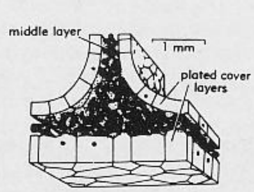

Fig. 5. Diagrammatic section showing wall structure. *After* Moore, 1978, p. 95.

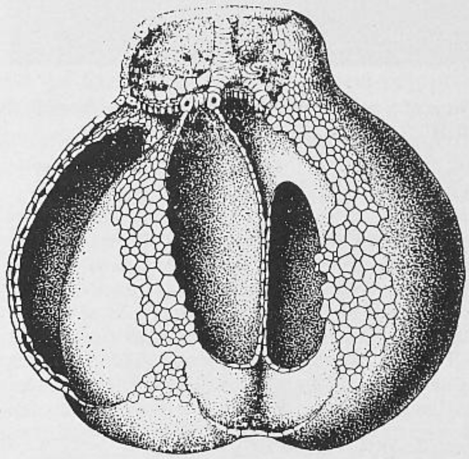

Fig. 6. Generalized section of *Camarocrinus* showing the relationship of the stem and various wall structures. *After* Springer, 1917, p. 17.

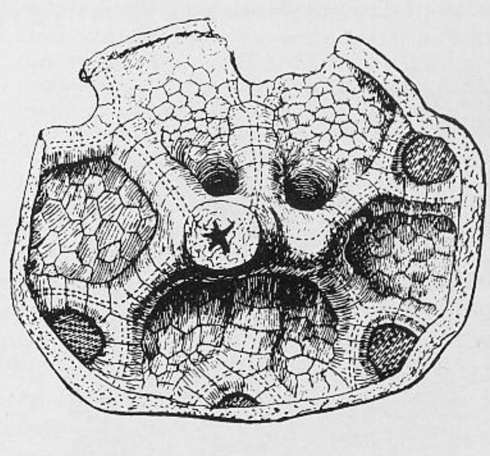

Fig. 7. Floorlike layer of plates which roots rest upon; broken lines indicate interior canals; also shown are the chamber openings. *After* Schuchert, 1904, p. 264.

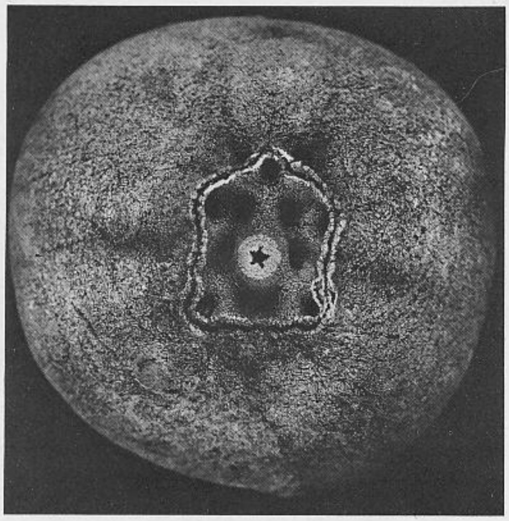

Fig. 8. Top view of a bulb from the Hunton Group showing channel openings. (x 0.7)

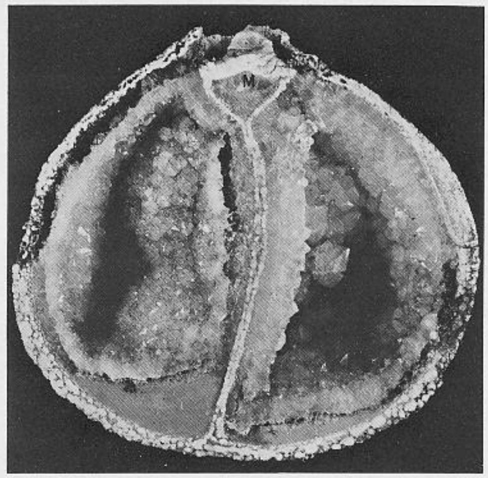

Fig. 11. Cross section of bulb showing location of medio-basal chamber (M). (x 0.5)

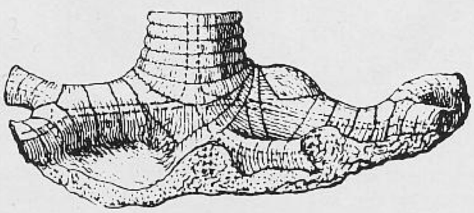

Fig. 9. Side view of base of *Camarocrinus* showing stalk wedged into roots; root canals are indicated by broken lines. *After* Schuchert, 1904, p. 265.

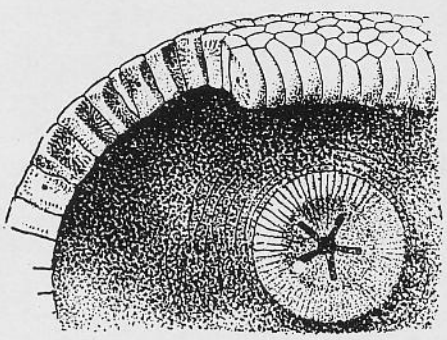

Fig. 10. Collar of *Camarocrinus* with plates removed to show perforations for nerve cords. *After* Springer, 1917, p. 17.

Table 1. Systematic Paleontology of *Camarocrinus*.

Taxonomy—Kingdom - ANIMALIA
Phylum - ECHINODERMATA
Class - CRINOIDEA Miller
Subclass - CAMERATA Wachsmuth and Springer
Order - MONOBATHRA Moore and Laudon
Family - MELOCRINITIDAE Bassler
Genus - SCYPHOCRINITES Zenker, 1833

Synonymy—*Scyphocrinites elegans* Zenker, 1833;
Scyphocrinus Roemer, 1855;
Lobolithus Barrande, 1868;
Camarocrinus Hall, 1879.

SPECIES ASSIGNED TO *SCYPHOCRINITES* (Bulbous root = *Camarocrinus*)	OCCURRENCE
Scyphocrinites elegans (Genotype) Zenker, 1833	Silurian; Bohemia Devonian; Missouri
Scyphocrinites clarkii Hall, 1879	Devonian; Tennessee
Scyphocrinites saffordi Hall, 1879	Devonian; Tennessee
Scyphocrinites stellatus Hall, 1879	Devonian; New York and West Virginia
Scyphocrinites subornatus Barrande, 1880	Silurian; Bohemia
Scyphocrinites ulrichi Schuchert, 1904	Devonian; Oklahoma
Scyphocrinites ulrichi stellifer Schuchert, 1904	Devonian; Oklahoma
Scyphocrinites quarcitarum Fritsch, 1905	Silurian; Bohemia
Scyphocrinites asiaticus Reed, 1906	Silurian; India

Genotype—*Scyphocrinites elegans* Zenker, 1833.

Geologic Range—Silurian, Devonian.

Geographic Distribution—Europe, Asia, North Africa, India, North America.

HISTORY OF DISCOVERY

Lobolithus Barrande was discovered in the Silurian System of Bohemia and is discussed in Barrande's work on Cystidea (1887). Barrande spoke of *Lobolithus* as an independent class of echinoderms differing in their composition from all others by "the absence of all regularity" (Schuchert, 1904, p. 257). He believed that the bulb was all there was to the animal and that they were therefore crinoid or cystid thecae (Barrande, 1887, p. 161).

John Gebhard, Jr., of Schoharie, New York, was the first American to find specimens of *Camarocrinus*. In a letter to Charles Schuchert dated Albany, New York, January 7, 1904, Dr. John M. Clark wrote the following interesting comments:

> Do you remember John Gebhard, Jr.—Squire John as his friends liked to call him—or had he passed on before your day in Albany? He died in 1887 at a very advanced age. Your quandary over the nature of *Camarocrinus* reminds me of his ready interpretation of it. The Squire was the most assiduous collector of fossils of his day in this country and I have no doubt was the first to discover this strange fossil. He had extensive collections and a detailed knowledge of the rocks in Schoharie county before the New York Survey came into being. When Lyell came to America (1841-42), Hall took him over to Schoharie to see the region and the Gebhard collections. In them were fine slabs of *Tentaculites gyracanthus* from the Tentaculite limestone and Lyell said to Gebhard (the Squire himself told me this) "Here you have had the spines of sea urchins, see if you cannot find the echinus itself." This Gebhard set himself to do and accomplished his purpose, finding *Camarocrinus*. To him these bodies were always sea urchins whose spines were *Tentaculites*. (Schuchert, 1904, p. 254).

In the Silurian rocks of North America, James Hall found similar bodies that he described as cystids in 1872; in 1879 he declared them to be either air-filled swimming organs used as floats or root structures used as anchors. To these bodies he gave the name *Camarocrinus*. Hall's comments on *Camarocrinus* are as follows:

> This remarkable crinoidal body is so totally unlike any previously described form, within my knowledge, that its true characters and relations are not at once evident. There is no doubt as to its crinoidal nature, but there is no apparent analogy of its parts with ordinary crinoids. Some of its characters would indicate that it is a curiously modified and enlarged summit or dome; that the visceral cavity is a small internal chamber immediately over the column-attachment; and that the lobes are an abnormal development of the interbrachial or interradial spaces. But the more probable theory in regard to this fossil, points to a functional similarity with a crinoidal root, as in *Ancyrocrinus* from the Upper Helderberg and Hamilton groups, in which there is a bulbous growth at one extremity of the column, supposed to act as a float or anchor to the body and arms. Viewing it in this respect, it may be regarded as a large chambered bulb, with an attached column, on the distal extremity of which was a calyx, having characters unknown at the present time. In this aspect, it must have been a free floating organism, similar in its habits to the recent *Medusae* and *Comatulae*. The lack of definition and symmetry which these crinoidal bodies assume would be an argument in support of this view, and find explanation in their consequent secondary functional importance, and separation from the governing center of centers (Hall, 1879, p. 205).

Haeckel (1896) interpreted the bulbs to be, without question, bladderlike swellings of crinoid columns. He disagreed with Hall's idea that they served as a swimming apparatus; he suggested that they served as brood-pouches or pathologic cysts induced by myzotomids.

In 1901 Bather concluded that *Camarocrinus* was a cystid and consulted Frank Springer about this hypothesis. Springer disagreed, commenting:

> These strange organisms are a complete puzzle to me and I never could frame any theory of their nature which was not at once swamped under a multitude of objections. I am inclined to think Hall's explanation the most probable, although from anything we know about crinoid structures it is difficult to conceive what such a chambered mass had to do with the roots. I cannot see how they can be cystids (Schuchert, 1904, p. 258).

Jaekel (1904), after examining *Camarocrinus* from various localities, was convinced that they were bladder-like developments of crinoidal roots as Haeckel had previously suggested.

In 1904 Dr. Jaroslav F. Jahn, Brünn, Austria, continued Haeckel's idea that *Lobolithus*=*Camarocrinus* was a bladderlike root structure of crinoids that probably served as brood-pouches or brood-receptacles (Schuchert, 1904, p. 258).

Several months later Springer commented on this hypothesis as follows:

> These strange bodies have always been, and still are, a complete puzzle to me. I can readily endorse the part of Jahn's statement that they are "bladder-like swellings of the roots of crinoids," but I have to halt at the "brood-receptacles," for I know nothing of them in any Pelmatozoa. The breeding organs of the living crinoids are located in the pinnules. The fertilized eggs are scattered in the water singly or in bunches and become attached by means of a glutinous substance to other objects. There is nothing in their known habits to suggest any gathering of the progeny of an individual about it like a brood. The Comatulae, when developed, swim in schools, and the crinoids generally are no doubt gregarious.
>
> I cannot see that they are calyxes, of Cystids or anything else. Hall's idea that they may have served as an anchor or float, remotely comparable to the anchor of *Ancyrocrinus*, seems to me about the most plausible of anything yet suggested. I do not believe they were expansible, but think they must have been firm growths. The condition of preservation indicates that, for if pliant or expansible we should find them generally collapsed and flattened in the fossil state (Schuchert, 1904, p. 258-260).

Charles Schuchert followed Hall's hypothesis that the bulb served as a float. Following is Schuchert's conclusion of his study on *Camarocrinus*:

> *Camarocrinus* appears to be the float of an unknown crinoid that was held together after the death of the individual by the firmly interlocked double walls of the exterior and interior, while the crown and stalk dropped away. Under this hypothesis, the float drifted with the sea currents, was finally filled with water, and the attenuated end being heavier, sank in that position to the sea bottom. The occurrence of these bulbs thus in the strata now gives one the impression that they represent the entire animal and are preserved in the original position of growth (Schuchert, 1904, p. 269).

Schuchert's assumption about the bulbs' position (stem down) in the rocks was the basis for his conclusion that they could not have been roots. Later, in 1917, Springer showed this assumption to be in error, due to inaccurate observations of the bulbs *in situ*. He thereby discredited support given to the float theory.

Springer then concluded that the bulbs served as holdfasts for various species of *Scyphocrinites*. The stems and crowns, after the death of an individual, theoretically were carried away by any moderate current, leaving the segregated bulbs imbedded in the mud in which they grew.

ASSOCIATION WITH *SCYPHOCRINITES*

It has been commonly accepted in the literature to date that *Camarocrinus* is connected, at the distal end of its stem, to the stem of *Scyphocrinites*. It is generally accepted to belong to the species *Scyphocrinites elegans* Zenker, 1833. As one examines the basic assumptions used to establish this relationship, the accepted association is not so convincing and demands scientific evidence to support such a conclusion.

The Treatise on Invertebrate Paleontology appears to acknowledge the uncertainty with which *Camarocrinus* is assigned to the second crinoid genus: "Hall recognized their (*Camarocrinus*) real nature as holdfasts of a crinoid, which is now determined almost certainly to belong to the camarate *Scyphocrinites*" (Moore, 1978, p. 91).

Strimple (1963, p. 18) refers to the question of whether *Camarocrinus* and *Scyphocrinus* are two parts of one animal, suggesting that "Springer (1917) established the relationship between the two forms beyond the shadow of a doubt." Strimple states, however, that the "bulbs in the Henryhouse Formation have nowhere been found in association with calices or crowns, so assignment to *Scyphocrinites cinctus* is made with reservation" (ibid, p. 102).

Springer's conclusion, referred to by Strimple, was based upon his observations of quarried slabs from the Bailey Limestone near Cape Girardeau, Missouri, in which *Camarocrinus* and *Scyphocrinus* are found within the same bed of limestone (Fig. 12). Frederick Braun quarried this rock while collecting for Springer in 1912 along the bluffs of the Mississippi River.

Upon examination of the slab, which at first seemed to confirm that the two were one animal, Springer stated: "In no case can the stem be traced to the distal end; all of them at a short distance from the crown either pass under other crowns, or become enveloped in the general mass of remains . . . in no case are the stems directly traceable from the bulb in situ" (Springer, 1917, p. 1-10).

Schuchert, 1904, had observed a similar occurrence in Bohemia, in a horizon correlated with the American Rochester Shale, where *Lobolithus* or *Camarocrinus* and thecae of *Scyphocrinus* are preserved. One *Scyphocrinus* theca at this locality had a column over 3 feet long, which extended and terminated upon a *Camarocrinus*. This seemed to leave no doubt that the two belonged together.

After further examination, however, it was observed that the long column of *Scyphocrinus* lying on the *Camarocrinus* was at least twice as thick as any *Camarocrinus* column ever found. Schuchert also showed that its axial canal was large and quinquelobate as opposed to the small, stellate axial canal of *Camarocrinus* (Fig. 13). These observations led Schuchert to the conclusion that the two parts could not belong to the same animal (Schuchert, 1904, p. 262).

Then, in 1917, Frank Springer showed that a *Scyphocrinus* stem could possibly have tapered from the calyx to the bulb, diminishing in diameter to about half its size, and that its axial canal could become modified from quinquelobate to sharply stellate at the distal end of the bulb (Fig. 14).

Fig. 12. *Scyphocrinus* and *Camarocrinus* (G and H) associated on the same bed of limestone. *From* Springer, 1917, p. 58, pl. 1.

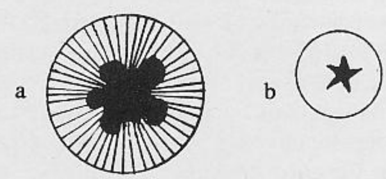

Fig. 13. Transverse sections through the stalks of *Scyphocrinus* (a) and *Camarocrinus* (b). *After* Schuchert, 1904, p. 262.

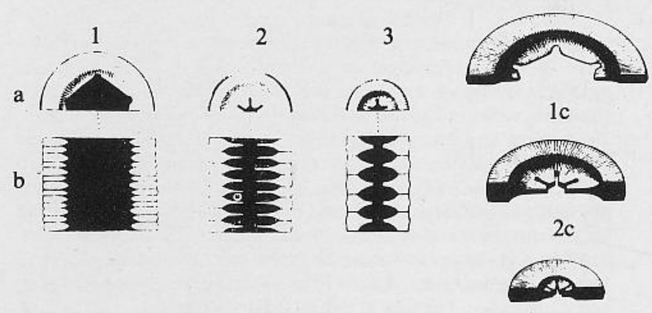

Fig. 14. Stem characteristics of *Scyphocrinus*:
1. a. Joint face of column near caylx.
   b. Cross section.
   c. Enlarged, oblique view showing characteristic shape of axial canal near caylx.
2. a, b, and c—Similar views of mid-column section.
3. a, b, and c—Section of column near the distal end, modified to small, sharply stellate axial canal (Springer, 1917, p. 67, pl. 5).

This idea and the occurrences of the two crinoids in the same bed of limestone are what give the strongest support for Springer's assumption that the two parts "without a doubt" belong to the same animal.

Springer has been cited in the current literature as having settled the issue. Springer refers to LaTouche (Mem. Geological Survey of India, 1913, v. 39, Pt. 2) whom he credits as having "definitely proved" the theory of association (Springer, 1917, p. 3) and states in his work on *Scyphocrinus:*

> As a rule, we do not know positively to which form of calyx any one of the bulbs in the different localities belongs. Nevertheless, it is fair to assume that a given bulb of *Camarocrinus* belongs to the calyx found in the same bed (ibid, p. 27).

OCCURRENCE IN THE ROCKS

In Bohemia *Camarocrinus* has been found in a limestone that has been correlated with the American Rochester Shale. One Bohemian locality, an abandoned quarry in the Schwartze Schlucht near Kuchelbad, has *Camarocrinus* and *Scyphocrinus* in the same bed. The *Camarocrinus* is flattened, and the thecae of *Scyphocrinus* are poorly preserved. The occurrence of these two genera in the same stratum is the reason for belief that the two are one organism.

Near Keyser, West Virginia, in ballast quarries of the B & O Railroad, *Camarocrinus* has been found in great numbers near the middle of the Manlius Formation. There are no other traces of crinoids associated with these bulbs. Hundreds of bulbs have been collected by various paleontologists, but no other crinoids have been found. The only other echinoderm found was a single specimen of *Irimerocystis preculiaris* (Schuchert, 1904, p. 260).

In southwestern Tennessee, *Camarocrinus* has been found in the lower 50 feet of the Linden Group, which is equivalent to the New Scotland Limestone of the New York Helderbergian Group. The geographic extent of the bulbs is about 50 miles. There are no crinoid thecae, crinoid columns, or crinoidal limestone found in the formations containing *Camarocrinus*. The age of the New Scotland Limestone is thought to be earliest Devonian. The Manlius Formation of Tennessee, however, is believed to be of upper Silurian age.

In 1901, while doing stratigraphic work in Indian Territory (Oklahoma), Dr. E. O. Ulrich found *Camarocrinus* in Helderbergian rocks (Fig. 2 and Table 2) and traced a bed containing *Camarocrinus* for more than 100 miles. When asked about other crinoids associated with the bulbs, he said:

> Only at two localities did I find anything of that kind in that bed. I am fully satisfied that what you call the 'bulb' is all there is, or ever was, to the fossil. There is absolutely not a sign of other crinoidal matter in most of the deposit containing *Camarocrinus*. (Schuchert, 1904, p. 261-264).

Crinoid calices have since been found in the Hunton Group of Oklahoma, but these occurrences are rare and are not found in any definite association with *Camarocrinus*. Figures 15, 16, and 17 show *Camarocrinus* as found at several localities.

Table 2. Hunton Group of Oklahoma.

GROUP AND FORMATION		AGE
Woodford Shale		Early Mississippian-Late Devonian
	Frisco Formation Haragan - Bois d'Arc Formation	Early Devonian
	Kirkidium Biofacies Henryhouse Formation	Late Silurian
	Chimneyhill Subgroup	Late Silurian-Late Ordovician
	Sylvan Shale	Late Ordovician

Amsden, 1975, Plate 10.

Fig. 15. Location 1. Colony of bulbs found in the Haragan Formation of the Hunton Group.

Fig. 16. Location 2. Group of bulbs showing upward orientation of stems.

Fig. 17. Location 3. Stem orientation of bulbs revealed showing two down, two up, and one sideways.

DISCUSSION OF PROBABLE FUNCTIONS

Camarocrinus has been interpreted as an independent class of echinoderms (Barrande, 1887); cystoids (Bather, 1901); genital sacs (Jaekel, 1904); brood-pouches or pathologic cysts induced by parasites (Haeckel, 1896); inflated roots, which served to attach the crinoid to the substrate (Springer, 1917); and floating organs (Hall, 1879; Schuchert, 1904; Yakovlev, 1953; Stukalina, 1967; Haude, 1972).

Hall (1879) interpreted the bulb as a crinoidal root. He regarded it as a large chambered body, with an attached column and unknown calyx believed to have been attached to the distal extremity of the bulb's column. Hall suggested that it served as a float, functioning similarly to the recent Medusae and Comatulae (Hall, 1879, p. 206).

Schuchert (1904) concluded that *Camarocrinus* was a float of an unknown crinoid, possibly held together after the death of the organism by its sturdy construction, while the stalk and crown dropped off. He suggests that the floats drifted with the sea currents and, after being filled with water, sank stem down, to the bottom (Schuchert, 1904, p. 269). Schuchert had observed some quarried limestone containing *Camarocrinus* in which the apparent orientation of the stalked end was downward. This observation contributed greatly to his assumption that the bulbs served as floats.

As previously stated, Springer showed Schuchert's suggested orientation of the stalked end to be incorrect. Springer states: "These bulbs when in their original position occur with the stalked end upward and not downward as before supposed" (Springer, 1917, p. 3).

The upward orientation of the stalked end of the bulbs *in situ* gave support to Springer's conclusion that the bulbs served as anchoring roots: "It is obvious that, with the foregoing fact established as to the position of these bulbs, the theory that they served as a float loses much of its force" (Springer, 1917, p. 19). He suggested that the upright position of the bulbs is consistent with the theory that they functioned as enlarged roots, anchoring the crinoid to the substrate, and that the forced supposition of the float theory is therefore not necessary. Figure 18 shows a limestone slab collected in Oklahoma from the Haragan Formation (Fig. 2).

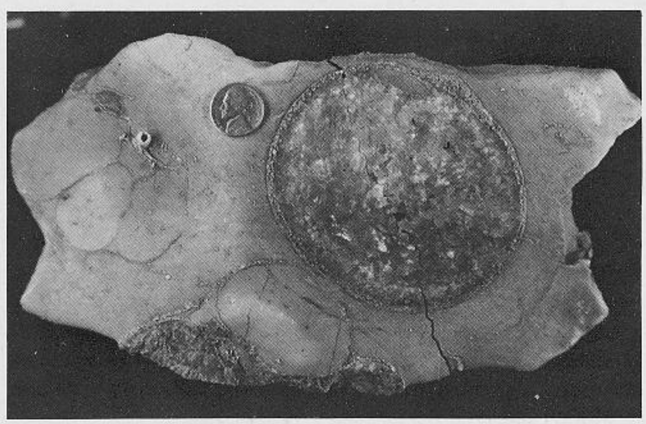

Fig. 18. Limestone slab showing position of bulb *in situ*, stalked end uppermost. Haragan Formation, Oklahoma.

The roundness and smoothness of the bulbs, Springer points out, is analogous to the bulbous root of the living Alcyonarian polyps, the pennatulids (Springer, 1917, p. 19).

Strimple, however, disagreed with the idea that the orientation of the stem supported the root theory. He believed that a drastic turbulence must have separated the bulb from the main organism allowing the floats to drift off and sink to the bottom with the stalked end uppermost (Strimple, 1963, p. 19).

Kirk (1911), in his work on Eleutherozoic Pelmatozoa, also considered the bulbs to have been floating organisms and thought that the crown must have floated in an inverted position with its arms spread downward. He attributes the segregation of the bulbs to current and wind action, which theoretically pocketed the bulbs into an area of comparatively quiet water (Kirk, 1911, p. 55).

Strimple considered the appearance of small crinoidal roots attached to mature bulbs as "further evidence of a vagrant habit." Referring to Springer's observations of similar rootlets, he states:

> Under his concept [Springer], the bulbs were buried in the muck of the ocean bottom, and in such a condition, the roots could not have attached themselves. It seems to me that the young specimens were "hitch-hiking" on the floating bulbs while they were attaining growth and that later they became free and formed their own bulbous bases. (Strimple, 1963, p. 20).

Springer suggested that the young roots were *Scyphocrinites*, which would gradually form their own bulbous bases (roots); he also noted that these occurrences are very rare (Springer, 1917, p. 18). Figure 19 shows his illustrations of these growths, and Figure 20 shows an example of young roots on a bulb collected from the Henryhouse Formation in Oklahoma.

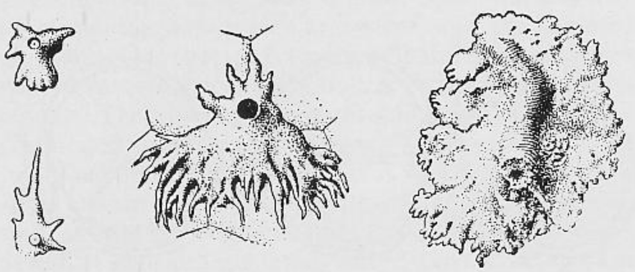

Fig. 19. Roots of young crinoids attached to *Camarocrinus* as illustrated by Frank Springer, 1917, p. 19.

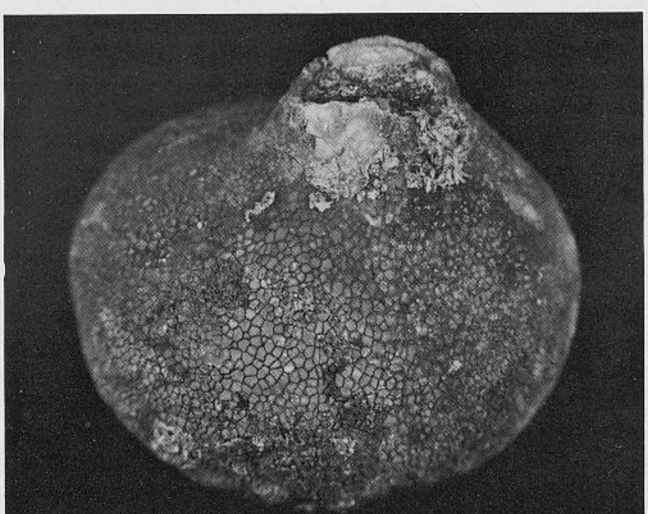

Fig. 20. Young crinoid roots attached to mature bulbs from the Henryhouse Formation, Oklahoma.

Schuchert was the first to take note of these young rootlets. He had drawn the same conclusion about *Eucalyptocrinus* roots attached to the bulbs as Springer had later drawn about young "*Scyphocrinus*" roots. The roots of *Eucalyptocrinus* proved, however, to belong to an unrelated crinoid having different interplate suture patterns than those of *Camarocrinus* (Schuchert, 1904, p. 265).

The most recent study that supports the float theory is by Haude (1972) who states that it is scientifically proven that *Camarocrinus* could have floated *Scyphocrinites*. Schuchert had also offered some scientific data as proof of *Camarocrinus*' floating potential. He showed that a dry bulb before mineralization weighed less than 4 ounces and that a bulb 3½ inches in diameter would contain about 22 cubic inches of air and/or soft parts. One cubic inch of distilled water weighs 252.45 grams, and a 3½-inch sphere would displace enough distilled water to float a weight up to 13 ounces. A dried crown and stalk of *Scyphocrinites*, 1 foot and 3 feet long respectively, with a 3½-inch bulb is estimated to weigh less than 6 ounces.

Haude and Schuchert both showed that it is scientifically possible for a bulbous growth filled with air or soft parts (less dense than the surrounding water) to have functioned as a float for *Scyphocrinus*.

Although some Mesozoic crinoids are columnless genera and some are believed to be pelagic, there are no other crinoidal floating organs found in the fossil record or the recent (Morales, 1977, p. 198). If *Camarocrinus* were a float, which after dying dropped its crown and stalk, we should find beds of the latter in as great an abundance as we do the bulbs. Nowhere in the formations containing *Camarocrinus* have such beds been found.

It is equally justifiable to conclude that there should be abundant crinoidal fragments associated with the bulbs if they served as holdfasts anchored in the mud. The absence of such remains suggests that as the crinoids died, their stems and crowns were swept away by currents, leaving the bulbs anchored on, or imbedded in the substrate. The chambers then became filled with carbonate and silicious mineral solutions, becoming solidified in their position of growth, as we find them today.

Some bulbs, however, have obviously been dislodged by burrowing organisms or by other mechanical means, as suggested by the geopetal structure in the top and sides of some 20 percent and 7 percent respectively. The dislodged bulbs were allowed to move about on the sea floor before becoming covered by sediment.

The occurrence of attached organisms, including the roots of various other crinoids, also confirms the disturbance. If the bulbs served as floats, we should find them completely covered by attaching organisms. This is not the case, however, as the vast majority (90 percent) of the bulbs do not have organisms attached to the lower half of the bulb, suggesting that the bulbs were at least partially inbedded in the mud, leaving the exposed upper half to be colonized by encrusting and attaching organisms.

The float theory suggests that the interlocked walls held the float together after its death and that it continued to drift with the sea currents, dropping off its stem and crown. Gradually the bulbs filled with water and were pocketed in an area of relatively quiet water. This theory suggests that the bulbs should be found with no consistent order in the orientation of the stalked end, which being heavier, should no doubt be oriented downward. The distribution of the bulbs should also be random and cosmopolitan.

Only 20 percent of the bulbs observed in this study were found with their stems oriented downward (Fig. 21), and 7 percent appear to have been on their sides (Fig. 22). These exceptions are evidence of burrowing organisms that, as previously suggested, dislodged the former from their original positions of growth. Wave and current action also served to dislodge the bulbs. Most (65 percent) of the bulbs have their stems oriented straight up (Fig. 23), which is consistent with the idea that they were attached to or partially embedded in the mud, and not floating as is commonly accepted (Fig. 24).

The idea that they were floats also suggests that we should find them collapsed and flattened. Very few, however, are flattened or broken, confirming the fact that they were at least partially imbedded in the soft mud, which served to protect them from the weight of the thickening, overlying sediment.

Fig. 21. Geopetal structure showing downward orientation of the stem of *Camarocrinus.*

Fig. 23. Geopetal structures indicating the preferred orientation of the holdfast. Notice geopetal structure at the base. (x 0.3)

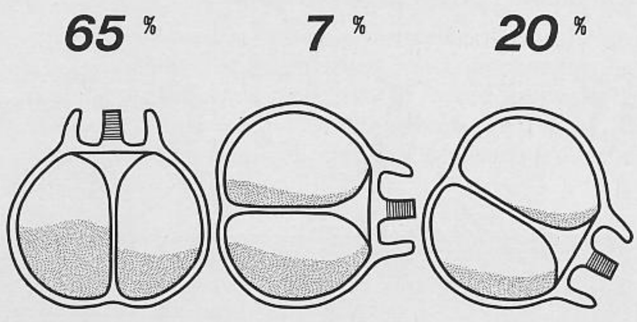

Fig. 24. Geopetal diagram representing the stem orientation of the holdfast *Camarocrinus*; 65 percent are preserved in the original position of growth, 7 percent on their sides, 20 percent resting stem down, and 8 percent are indistinguishable.

Fig. 22. Geopetal structures indicating a sideways orientation. (x 0.3)

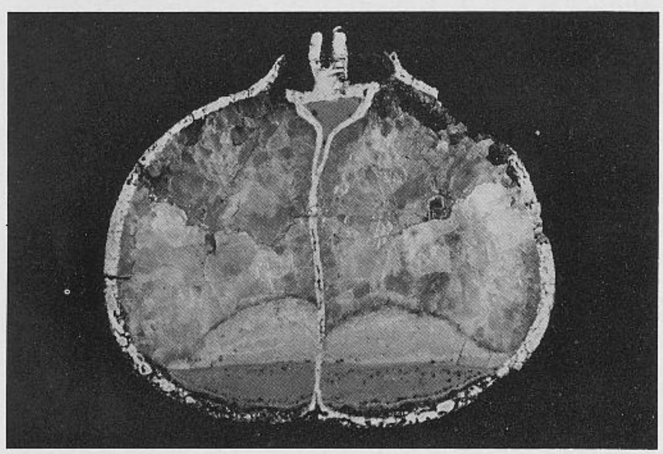

Fig. 25. Stem orientation (upward) as found in outcrops of the Hunton Group in Oklahoma. (x 0.3)

CONCLUSION

Camarocrinus is an extremely precise age indicator and serves to correlate remotely separate marine deposits. Groups of bulbs, resting on and imbedded in the soft sea bottom, seem to have been quickly killed by a change in water conditions or content. The conditions that brought about the death of the groups in Oklahoma appear to be responsible for the deaths of those found throughout all known geologic occurrences observed to date.

During mineralization its sturdy construction served to keep the bulb intact under the increasing pressure of the thickening overlying sediment and the added weight of new bulbs in the colony, which rested on top of the dead holdfasts.

The bulb functioned similarly to the holdfast known as *Ancyrocrinus*, which served as an anchor to a presently unknown crinoid. It is, as Springer (1917) suggested, analogous to Alcyonarian polyps, the pennatulids, which parallel crinoids in having three modes of attachment: branching roots, flat disks, and bulbs.

The insertion of the stalk into the root complex, with its branching neurovascular system, and the repeated divisions of the roots to form the bulb walls and plates are conclusive evidence that the bulb is a specialized crinoidal root. The absence of mouth and anus show that it functioned as a secondary organ.

The accepted suggestion that it was connected at its distal end to the column of *Scyphocrinus* is in fact suggestion, has not been documented, and awaits actual observation of such an association before it can be accepted as scientific fact. The uncertainty with which *Camarocrinus* is assigned to *Scyphocrinus* gives support to the bulbs' distinction as an independent crinoid genus as first suggested by Hall in 1879.

The stems' upward orientation in the outcrops (Fig. 25), the geopetal structures that indicate an upward-oriented majority (Fig. 24), and the unsorted sizes of bulbs found in the outcrops, unlike sorted floating organisms pocketed together after death, are several facts that are consistent with the "anchoring root" conclusion of this study.

In summary, the crinoid genus *Camarocrinus* appears to be the bulbous holdfast of an unknown crinoid whose stalk and crown were swept away by current and wave action upon the death of the individual (Fig. 26). The segregated bulbs, left behind in the muddy bottom, gradually became mineralized, most in their original position of growth.

The holdfasts are thus found today in the Haragan and Henryhouse Formations of the Hunton Group.

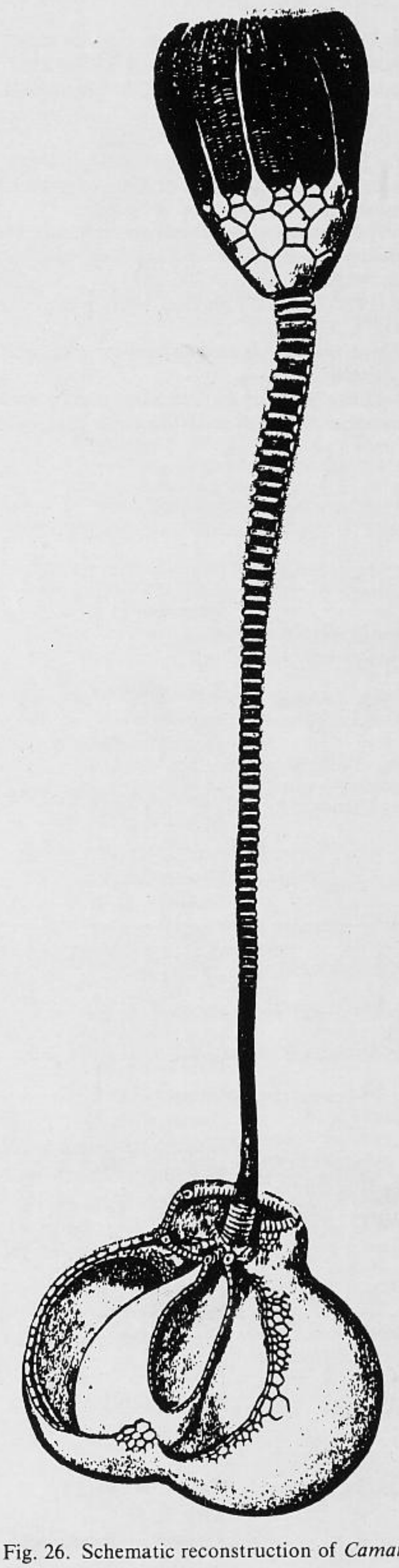

Fig. 26. Schematic reconstruction of *Camarocrinus*.

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