ON SILURIC AND DEVONIC CYSTIDEA AND CAMAROCRINUS

By CHARLES SCHUCHERT

Introduction

The Ontaric or Siluric system of eastern United States is terminated by the Manlius formation, above which is the Helderbergian group with its prolific fauna so unlike those of older American deposits. Heretofore the fauna of the Manlius has been regarded as a very small one and is essentially described in three places, by Hall,[1] Whitfield,[2] and Grabau.[3] It is now quite evident, however, that this formation has a much more extensive fauna than has been surmised.[4] This is true not only for New York west of the Helderberg mountains, but especially for Pennsylvania and Maryland. Along the eastern escarpments of the Helderberg mountains these deposits include only the upper half of the beds known farther west and south, and the strata consist of thin-bedded limestones with the fossils either poorly preserved or not separable from the matrix. West of the Helderberg mountains, but more particularly in Pennsylvania and Maryland, considerable beds of shale occur in the lower half of the Manlius, and locally quantities of fossils, especially of bryozoa, are here found. One of the best places in Pennsylvania exposing this formation is at Clark's Mills, near New Bloomfield; at this locality cystids are rare, but the bryozoa occur abundantly. Near the southern border of Pennsylvania *Stromatopora* is common. About Cumberland, Maryland, bryozoa and a few species of corals and brachiopods predominate, and 30 miles to the southwest, near Keyser, West Virginia, cystids, bryozoa, and some forms of brachiopods are the prevailing fossils.

Owing to extensive alterations and improvements in the road-bed of the Baltimore and Ohio railroad, much ballast has been required, and one of the quarries established for the purpose of obtaining road metal was located near the town of Keyser, West Virginia. It

[1] *Nat. Hist. N. Y., Pal.*, III, 1859 [1861].

[2] *Geol. Surv. Ohio, Geol.*, VII, 1893.

[3] *Bull. Geol. Soc. Amer.*, 11, 1900, pp. 347–376.

[4] Since this was written, Weller has added a number of new species. See *Geol. Surv. New Jersey, Pal.*, III, 1903.

is reported that this railroad has spent upward of $2,000,000 in this quarry alone during the last three years. The great amount of work thus represented has made it possible to obtain a new and unique Manlius fauna. In the quarry in question the strata stand nearly vertical; as the shaly cystid zone is deeply decomposed, most of it had to be carted away as of no value to the railroad. This material, however, proved of great interest to the paleontologist. Unfortunately all the refuse from this great quarry is thrown together; otherwise an abundance of fine cystids might be obtained from these dumps for years to come.

Soon after the quarry was opened, Messrs. Robert H. Gordon and Frank Hartley, of Cumberland, Maryland, in collecting here, began to find excellent brachiopods and some cystids. After a few *Sphærocystites* had been obtained by Mr. Hartley, he interested the foreman, Mr. Joseph Gambino, and the gang of Italian laborers by showing them the specimens and offering to purchase any material found. He little dreamed that a few weeks later he would be offered a quart of these cystids, yet on each succeeding visit during the first year he obtained a like quantity. This activity on the part of these Cumberland collectors and the quarrymen yielded more than five thousand cystids, all of which have passed through the writer's hands. Such wholesale collecting undoubtedly explains why so many species have been found. With the cystids occur about ten species of crinoids, but these are always rare and none is known to be represented by more than five specimens. Other associated fossils are bryozoa and a few species of brachiopods.

Nearly all the specimens from the cystid layers in the Keyser quarries are uninteresting when picked up, because of the firm adherence of the shale, structural details thus being obscured. Weathering does not improve these fossils, as they are not completely siliceous, and all must be cleaned with potash to reveal their beautiful detail. For the benefit of those unacquainted with this method of preparing specimens for the cabinet or for study, the following extract, taken from *Directions for Collecting and Preparing Fossils*[1] is here added:

"To remove hard clay from the calyxes of corals or the interior of shells and other objects, caustic potash is often very serviceable. Fossils cleaned in this way, however, must be solid and without cracks, for the potash will penetrate into the minutest fracture and force the parts asunder. 'Caustic potash' comes in [purified] round, slender sticks sealed in one-half and one-pound bottles. Keep the potash sealed in the bottles with paraffin and cork stoppers. Handle

[1] Schuchert, *Bull. 39, U. S. Nat. Mus.*, Pt. K, 1895.

the pieces with iron forceps, not with the fingers. In cleaning fossils have the parts to be acted on uppermost, and on these lay small pieces of solid caustic potash. After the potash has acted for a day or so wash the dirt away which rises in puffed masses, and continue the application of fresh potash until the parts are cleaned. To get rid of all potash, which if not removed will for years after come to the surface in a white film, soak the fossils in many changes of water to which has been added a few drops of muriatic acid, and brush repeatedly. Sometimes the white film is a product of decomposition and cannot be wholly removed. It can then be darkened with india ink or some suitable color."

The cystid fauna continues through about 37 feet of shale and is then suddenly terminated by a heavy-bedded impure limestone in which *Camarocrinus* abounds. In no other place have these forms been found in abundance, though occasionally a specimen is picked up at Devil's Backbone, Cash valley, and in the city of Cumberland. For the sake of completeness the detail of the Manlius formation, as exposed in the quarries near Keyser, is here presented:

SECTION OF MANLIUS FORMATION AT B. & O. R. R. BALLAST QUARRIES NEAR KEYSER, WEST VIRGINIA.[1]

	Ft.	In.
Coeymans limestone. Base of Devonic:		
6. Heavy-bedded solid blue limestone. No fossils seen....	34	6
5. A solid blue limestone, filled with a small form of *Gypidula* near *G. galeata*.....	2	
4. Heavy-bedded impure limestone, with an abundance of *Camarocrinus* and more rarely *Tentaculites gyracanthus*, *Calymmene camerata*, and *Trimerocystis peculiaris*	6	
3. Cystid beds. Thin-bedded shaly limestone and shale, deeply weathered. Throughout this zone *Sphærocystites multifasciatus*, *S. globularis*, *Pseudocrinites gordoni*, and *Jackelocystis hartleyi* abound. *Pseudocrinites stellatus*, *P. clarki*, *P. perdewi*, *Jackelocystis papillatus*, *J. avellana*, *Lepocrinites manlius*, and *Tetracystis chrysalis* occur more rarely.....	37	
2. A solid blue limestone.....	2	4
1. Thin-bedded shaly limestone like 4. Toward the base occur *Nucleospira*, *Rhynchonella* like *campbellana*, and *Spirifer octocostatus*.....	28	6
Salina formation, 1125 feet:		

[1] See also Schuchert, *Proc. U. S. Nat. Mus.*, XXVI, 1903, pp. 413–424.

Phylum *ECHINODERMA* Bather

Grade PELMATOZOA Leuckart

Class *CARPOIDEA* Jaekel

Jaekel[1] defines this class as follows:

"Carpoidea are aberrant, irregular Pelmatozoa, whose ambulacral organs had but slight connection with the thecal skeleton and on which it generally left but slight traces of its existence. Their thecæ form a closed capsule whose wall has a mouth and anus. The thecal skeleton is always apentamer, often distorted, mostly oriented dorsoventrally, and more or less symmetrical on the right and left. The ambulacra are developed in two radii. The known bearers of the ambulacral grooves are arranged in a single line. The base has four or three pieces, the stem consists mostly of two series of symmetric parts, and sometimes has metamerally ordered genital appendages. Their geological distribution is in the Cambrian and Silurian."

The range should extend from the Cambrian into the Lower Devonic, as *Anomalocystites*(?) *disparilis* Hall is found in the Upper Oriskany formation.

Family ANOMALOCYSTIDÆ Meek

This family is defined by Jaekel in the work just cited (p. 668), as follows: "Theca oval, nearly symmetrical, and both broad sides having similar skeletal plates. Ventralia only about twice as numerous as the dorsalia. Three to four marginalia on each side with angulated side margins. Base deeply impressed; the stem occupies the entire breadth of the basalia. Thecal plates ornamented with horizontal wavy lines." In *Anomalocystites* there are 2 stout and short arms composed of imbricating plates in 2 columns, having great ambulacral furrows covered by minute roofing plates. In *Placocystites* and seemingly, also, in *Anomalocystites*(?) *disparilis* the arms are replaced by long and slender, apparently non-segmented spines.

Anomalocystites Hall

Anomalocystites HALL, Amer. Jour. Sci. (2), XXV, 1858, p. 279.—HALL, Nat. Hist. N. Y., Pal., III, 1859 [1861], p. 132.—MEEK (partim), Geol. Surv. Ohio, Pal., I, 1873, p. 43.—BARRANDE (partim), Syst. Sil. du Centre de la Bohême, VII, pt. I, 1887, p. 89.

Atelecystites WOODWARD (partim), Geol. Mag., dec. II, VII, 1880, pp. 193, 194.

Anomocystis HAECKEL, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 40.

Anomalocystis BATHER, Treatise on Zoology, pt. III, Echinoderma, London, 1900, p. 51.

[1] *Zeits. Deutsch. geol. Gesellsch.*, 1900, p. 662.

Original description.—" Body semielliptical or semiovoid; sides unequal; the vertical outline oval or ovoid, plano-convex or concavo-convex; the transverse outline semielliptical, the base of which is straight or more or less concave: the two sides composed of an unequal number of plates. Basal plates three on the convex [or ventral] side, two [=medial basals] on the concave [or dorsal] side; second series, two large plates at the angles [=lateral basals], and four (or five?) [anal] on the convex side; third series, four [anals] on the convex side, one at each angle, and a large plate on the concave side; a fourth, fifth, and sixth series of anal plates on the convex side, and a fourth series on the concave side. Base oblique, with the convex side longer, and a deep concavity for the insertion of the column. Pectinated rhombs apparently none. Arms unknown. Column deeply inserted into the body, composed of large joints above, becoming smaller below." (See fig. 21.)

No species is here mentioned, but in Hall's next account of this genus the first species and the one generally accepted as the genotype is *A. cornutus* Hall.

To the above generic description should be added the following: On the convex or ventral side of both *A. cornutus* and *A.*(?) *disparilis*, between the two lowest plates of the median column, there is always seen a rather small opening. In examples of *A. cornutus* the calcareous plates are not metamorphosed, but they are usually somewhat displaced and one can not be certain that this hole is not accidental. In *A.*(?) *disparilis*, specimens of which are always preserved as delicate pseudomorphs, all have a large unmistakable opening in the same position. In a crushed example of *Placocystites forbesianus* in the National Museum, there also appears to be an aperture on the ventral side, but here it is one plate higher toward the mouth. In the writer's opinion, this opening must be the anus, but as the evidence is not conclusive, the fact can not be stated with certainty.

Arms 2, free, small, and composed of 2 ranges of alternate, imbricating, thin pieces. Ambulacral furrows very wide and deep; ambulacralia minute, about 5 to each ambulacral piece. Column short, with a great central canal, consisting of numerous, imbricating, very narrow segments, each composed of 2 pieces. The suture lines of the columnals are on the dorsal and ventral sides.

Anomalocystites has been regarded as the same as *Atelocystites* Billings and *Placocystites* de Koninck. *Atelocystites* is from the middle of the American Lower Siluric and is not well known, but appears to be distinct. *Placocystites*, so completely worked out by Woodward in the work above cited, has on the anterior side the same

number and arrangement of thecal plates as in *Anomalocystites*. The arrangement of the plates on the anal side, however, is quite different, there being 6 more or less complete columns in *Anomalocystites*, whereas *Placocystites* has only 4 series.

So far as known, *Anomalocystites* is restricted to the American Lower Devonic.

ANOMALOCYSTITES CORNUTUS Hall

(PLATE XL, FIGURES 4, 5)

Anomalocystites cornutus HALL, Nat. Hist. N. Y., Pal., III, 1859 [1861], p. 133, pl. 7A, figs. 5–7.—WOODWARD, Geol. Mag., dec. II, VII, 1880, p. 193, pl. 6, figs. 4, 5.

Anomalocystis cornuta HAECKEL, Die Amphorideen, etc., 1896, p. 41, pl. 2, figs. 8, 9.

Length of theca 12 mm.; width 9 mm.; depth about 3 mm.

Theca subovoid, with the anal side depressed convex and the anterior side slightly concave. Lower half of theca with the plates sculptured by transverse wavy lines and the upper half with widely separated depressed pustules. Plates arranged as in figure 21.

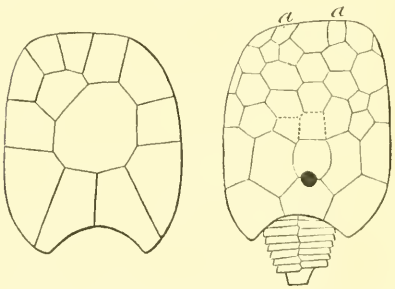

FIG. 21.—Analysis of both sides of *Anomalocystites cornutus* Hall. (*a*, *a*, Plates to which the two free arms are attached. The black spot indicates the probable position of the anus.)

Arms small, tapering rapidly, sharply angulated medially on the adambulacral side, about 6 to 7 mm. long, and composed of about 20 pieces in each column. Ambulacra very wide and deep; there appear to have been near the base of the arms about 3 or 4 ambulacralia to each arm-plate.

Column short, about 18 mm. long, and composed of about 64 narrow and 7 wide segments, each consisting of 2 pieces. The segments on each side, alternate with those of the opposite, are thin walled, imbricating, and with a great central cavity.

Formation and locality.—Not rare in the Coeymans limestone of the Lower Devonic of Litchfield township, Herkimer county, New York. The writer found one small slab having at least three fair specimens and possibly a dozen or more with the plates separated. Another slab shows a theca with the entire column.

Cat. numbers 35,078, 35,079, U. S. N. M.

ANOMALOCYSTITES (?) DISPARILIS Hall

Anomalocystites disparilis HALL, Nat. Hist. N. Y., Pal., III, 1859 [1861], p. 145, pl. 88, figs. 1–4.—WOODWARD, Geol. Mag., dec. II, VII, 1880, p. 193, pl. 6, figs. 2, 3.

Of this species the writer has seen eight specimens, six of which were collected by Mr. Hartley and two by Mr. Perdew. These permit the exact determination of the thecal plates, and the position of the two spines, all of which are shown in the diagrams in figure 22. Detail of spines and column and the surface ornamentation undetermined on account of the pseudomorphous condition of the fossils.

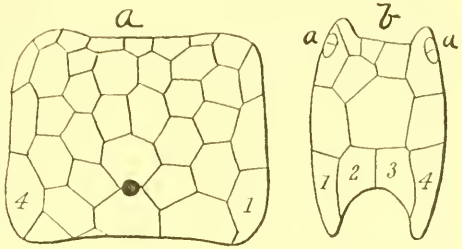

FIG. 22.—Analysis of both sides of *Anomalocystites (?) disparilis* Hall; natural size. (*a*, The ventral side with the plates projected on a plane; *b*, the dorsal side with the free arm facets shown at *a*, *a*. The black spot indicates the probable position of the anus.)

Length of largest theca 28 mm.; width 18 mm.; depth in basal region 13 mm., and in anterior region 7 mm.

Anal side convex, with more or less abrupt sides. Anterior side but slightly excavated, regularly or irregularly, with the lateral margins sharply elevated.

This species is easily separated by its larger size, more elongate and narrower theca, and the greater convexity of the anal side.

It is not yet established that *A.*(?) *disparilis* actually belongs in the genus *Anomalocystites*. In the genotype there are 2 arms with imbricating plates, while in the Oriskany species these are apparently replaced by spines of 1 piece, as in *Placocystites*. Further, in *A.*(?) *disparilis* the theca between the spines has a large, elongate-quadrate opening, which, in the best-preserved specimen, is about half closed by an inclined plate extending from the anal side over the aperture. In this specimen the longer edges of this opening are striated, suggesting a pectinirhomb. However, as all the specimens are poorly preserved siliceous pseudomorphs, one can not make out the exact nature of this opening. The differences pointed out between *A. cornutus* and *A.*(?) *disparilis* seem to indicate that the two species may not belong to the same genus.

Formation and locality.—Found in the upper half of the Oriskany sandstone associated with the *Spirifer arcuosus* fauna. It is probably

not a rare species, yet owing to the pseudomorphous, thin-shelled, hollow condition of the fossils, but few specimens hold together for the collector. All the specimens examined were found in the vicinity of Cumberland, Maryland.

Cat. number 33,661, U. S. N. M.

Class *CYSTOIDEA* Jaekel[1]

"*Definition.*—Cystoidea are Pelmatozoa whose cup or 'theca' is closed to the mouth, penetrated by pores (thecal pores), and whose ambulacral radial vessels have egress only through the mouth. The skeleton of the theca consists of non-movable polygonal plates, very rarely without a stem and by which it is anchored or free. The ambulacral radial-vessels are either restricted to the region about the mouth or they bifurcate and spread over the theca, but are always elevated distally in skeletal arm-appendages ('fingers'). The fingers [brachioles is the term used in this paper] are biserial, undivided, and have groove-plates [= ambulacralia of this paper], but are without pinnules. The mid-gut is solar, the end-gut often turned to one side, the anus is in the side of the theca, not always in interradius I:V, but is always situated outside of the bases of the fingers and generally is closed by a plated pyramid. As sexual organs the axial-sinus of the body-cavity originally functioned, opening outwardly in a pore ('parietal pore'), suborally in the interradius I:V. The position of the primary stone-canal remains fairly constant and opens outwardly near the mouth and above the parietal pore [in the following pages the writer has used the term hydropore] in the madreporite, but sometimes through regression is united with the parietal canal. The latter, the primary stone-canal, and their pores are situated in the vertical-mesenterium ('parietal septum')."

Order DICHOPORITA Jaekel

"*Definition.*—Dichoporita are Cystoidea whose thecal-pores are in pairs, each pair divided between two plates, situated vertically across the suture lines, slit or tubular-form, arranged parallel and combined into pore-rhombs [= pectinirhombs of this paper], their ambulacral radial-grooves in special skeletal elements supported by the theca." (Jaekel, p. 178.)

Suborder REGULARIA Jaekel

Dichoporita with the "theca having a base of four plates and four circles each normally made of five pieces. Pores in open adjoining

[1] *Stammesges. d. Pel.*, Berlin, 1, 1899, p. 63.

or discrete-pectinirhombs having interior calcareous folds. At least one pectinirhomb is always situated on the basal opposite to the anus [plate 1]. Anus laterally above the widest basal. Column and roots well developed; the uppermost segments alternating with collared pieces." (Jaekel, p. 194.)

Explanation of Some of the Terms Used in the Present Work

Plate formula.—The system of numbering the thecal plates in the following descriptions and diagrams is that of Bather (*Treatise on Zool.*, III, 1900). These numbers were probably first applied by Edward Forbes as early as 1848. Hall, in 1852, used a similar notation in describing *Callocystites*. The diagram of the latter genus given on page 244 has the full number of plates, and the student should familiarize himself with it.

Theca.—The cup containing the viscera and composed of a variable number of *thecal plates*. The *mouth* is at the end opposite to that attached to the *column* or stem. From the mouth radiate the *ambulacra*. Just beneath the mouth is the small porous plate known as the *madreporite,* which is connected with the stone canal. Usually in contact with the madreporite is a very minute pore, the *hydropore* or parietal pore, and in well-preserved specimens this is closed by a pyramid of plates. Still further beneath the mouth is the large aperture of the *anus* closed by the *anal pyramid*. Besides these parts the theca always has 3 *pectinirhombs* situated on 6 plates, or on plates 1 and 5, 12 and 18, and 14 and 15.

Ambulacra.—The recumbent or prostrate arms upon the theca. The lower biserial pieces are the *ambulacrals* and the roofing pieces over the radial grooves are the *ambulacralia*. On and between the ambulacrals are the 'fingers' or *brachioles*.

Pectinirhomb.—The parallel dichopores arranged across a suture between 2 plates, and combined into a rhomb. When the two halves are not separated medially by walls they are here referred to as *pectinirhombs,* but when the two halves are distinctly separated and each part is surrounded by a wall, they are termed *discrete-pectinirhombs*.

Family Callocystidæ Bernard

This family is defined by Jaekel as follows:

Regularia with the "theca closed to the mouth, plates in the circles in complete numbers. Ambulacra with paired ambulacralia and parambulacralia, projected radially over the theca and provided with numerous brachioles (fingers). Anus of medium size, generally sur-

rounded by a ring of marginal pieces. Pectinirhombs with the grooved recesses separated. Thecal plates generally sculptured with pits" (p. 266).

The family is subdivided by Jaekel into the following subfamilies:

Glyptocystinæ, the oldest and most primitive forms, with a single genus, *Glyptocystites* Billings.

Apiocystinæ, in which the ambulacra remain undivided, with widely separated brachioles. It includes *Meekocystis* Jaekel (only species *Lepocrinites moorei* Meek), *Apiocystites* Forbes, *Lepocrinites* Conrad, *Jaekelocystis* Schuchert, *Tetracystis* Schuchert, and *Hallicystis* Jaekel. The last genus is referred by Jaekel to Callocystinæ; the ambulacra, however, have not been seen, and in all the other characters *Hallicystis* agrees with *Apiocystites.*

Staurocystinæ, in which the ambulacra remain undivided, with the brachials closely crowded. It includes *Pseudocrinites* Pearce, *Trimerocystis* Schuchert, and *Staurocystis* Haeckel.

Callocystinæ has branching ambulacra, widely separated brachioles, and partial telescoping of the second and third rings of plates. It includes *Callocystites* Hall, *Cœlocystis* Schuchert, and *Sphærocystites* Hall.

Subfamily Apiocystinæ Jaekel

Callocystidæ with the 4 or 5 ambulacra, simple, and relatively with widely separated brachioles.

Apiocystites Forbes

Apiocystites Forbes, Mem. Geol. Surv. Great Britain, II, pt. II, 1848, pp. 501, 503.—Hall, Nat. Hist. N. Y., Pal., II, 1852, p. 242.—Jaekel (partim), Stammesgeschichte der Pelmatozoen, Berlin, I, 1899, p. 279.

Apiocystis Haeckel, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 132.

Lepadocrinus Bather (partim), Treatise on Zoology, pt. III, Echinoderma, London, 1900, p. 61.

Definition.—Apiocystinæ with the theca regularly oval, elongate, or slightly compressed (in the last case not strongly 4-sided), and composed of 19 plates arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 5, 6, 7, 8, 9.

Third row has plates 10, 11, 12, 13, 14.

Fourth row has plates 16, 17, 18, 19, 15.

Fifth row has deltoid 23.

Deltoid 23 is very small, placed above plate 18, with the madreporite and hydropore present. Anal area small, placed between

plates 7, 8, and 13, consisting of an outer complete circle of minute pieces and the pyramid of 5 pieces. One basal and 2 discrete-pectinirhombs, with small recesses and few dichopores.

Ambulacra 4, simple, narrow, and not prominent. These are R I, R II, R IV, R V, equally developed and generally continuing nearly or quite to the column. Brachioles few in number and more or less widely separated.

Genotype, *A. pentrematoides* Forbes (1 specimen in U. S. N. M., cat. number 35,137).

Lepocrinites gebhardii is usually referred to this genus, and although the species is closely related, it does not seem advisable to make *Lepocrinites* synonymous with *Apiocystites*. The latter undoubtedly represents an earlier stage in the development of *Lepocrinites,* but it is one that should be distinguished; it differs from the later type in having small discrete-pectinirhombs and narrower ambulacra, with the ambulacrals more elongate and narrower, causing the brachioles to become fewer in number (about 20 to 36 to an ambulacrum) and more widely separated. Moreover, the column in *Lepocrinites* is very peculiar in having 2 distinct parts—an upper consisting of about 15 segments, and a lower in which the segments are fused into a single long, swollen, leech-shaped piece. The latter is characteristic of the genus and is found abundantly in the Coeymans limestone at the base of the Devonic, while other parts of this cystid are very rarely obtained by collectors. For the differences between *Apiocystites, Tetracystis,* and *Jaekelocystis*, see the discussion under the last two genera.

The species referable to *Apiocystites* are the following: *A. pentrematoides* Forbes of the Wenlock limestone, Dudley, England; *Pseudocrinites oblongus* Forbes (partim) of the Wenlock limestone, Dudley, England; and *A. elegans* Hall of the Rochester shale at Lockport, New York, and Grimsby, Ontario.

Apiocystites canadensis Billings. The holotype of this species, which is preserved in the collections of the Geological Survey of Canada, proves to be a small or young specimen of *Callocystites*. The same form was later described by Ringueberg as *C. tripectinatus*. Further details will be found under *C. canadensis,* page 245.

Apiocystites imago Hall has been taken by Jaekel as the genotype of *Hallicystis*. It is described on page 216 in this memoir.

Apiocystites(?) *tecumseth* Billings. Through the courtesy of Professor Whiteaves the writer has seen the original "fragments of the column" described by Billings. The "detached plates" appear to be no longer in existence.

The columns are top-shaped bodies from 5 to 8 mm. long, with a large, round, central canal. The segmented central portion of the column is about 3 mm. in thickness, outside of which is a secondary non-segmented deposit, as in *Lepocrinites*, giving the stem a total diameter varying between 5 and 7 mm. The secondary deposit is ornamented with small, polygonal, shallow depressions arranged in circles.

Until the theca of *A.*(?) *tecumseth* is known, this can not be regarded as an established species.

Apiocystites(?) *huronensis* Billings. Through the courtesy of Professor Whiteaves the writer was allowed to study the holotype of this species. It certainly is not a form of *Apiocystites*, and probably represents a new genus, since the pectinirhomb of 12 and 18 rests directly on that of plates 1 and 5. In other words, plate 12 rests on plates 5 and 9—an anomalous position for the former plate, and one unknown in other American Siluric cystids. Billings's figure 28 is inverted in the text, with the column uppermost. This illustration shows all that is preserved in the holotype. The plates present are 4 and 1 of the first circle, 5 and 9 of the second, 12 of the third, and part of 18 of the fourth circle.

APIOCYSTITES ELEGANS Hall

(PLATE XXXIV, FIGURES 4, 5)

Apiocystites elegans HALL, Nat. Hist. N. Y., Pal., II, 1852, p. 243, pl. 51, figs. 1–17.

To Hall's description (based on Lockport specimens) may be added the following details seen in a very fine specimen in the collection of Dr. B. E. Walker, Toronto, Ontario. It was found by Mr. J. Pettit in the Rochester shales at Grimsby, south of Hamilton, Ontario.

Length of theca 17 mm.; diameter about 13 mm. The specimen is somewhat distorted, so that the actual diameter is not determinable.

Ambulacra extending almost to the column, the pair, one on each side of the anus, slightly converging, as does also the opposite pair. Brachioles widely separated, from 11 to 12 on each side of an ambulacrum. Ambulacralia extremely small, about 12 to each ambulacral.

Pectinirhombs equal in size, each with about 10 dichopores. Those on plates 5, 12, and 14 with strongly elevated rims, while those on plates 4, 15, and 18 are almost without elevated margins.

Anal pyramid not seen, but probably composed of 5 or 6 pieces. It is surrounded by a prominent ring of 8 pieces set between plates 7, 8, and 13.

Lepocrinites Conrad[1]

Lepocrinites Conrad, Ann. Rep. N. Y. Geol. Surv., 1840, p. 207.—Vanuxem, Nat. Hist. N. Y., Geol., III, 1842, p. 117, text-fig. 4.—Mather, ibidem, I, 1843, p. 346, text-fig. 4.

Lepocrinus or *Lepadocrinus* Hall, Nat. Hist. N. Y., Pal., III, 1859, p. 125, pl. 7, figs. 1–20.

Apiocystites Jaekel (partim), Stammesgeschichte der Pelmatozoen, Berlin, I, 1899, p. 279, fig. 59.

Lepadocrinus Bather (partim), Treatise on Zoology, pt. III, Echinoderma, London, 1900, p. 61.—Haeckel, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 134.

Conrad's original description reads as follows:

"Crinoidea. *Lepocrinites Gebhardii.* By this name I introduce a single fossil found by Mr. Gebhard. The body is composed of plates of unequal sizes, a few of which have ambulacra, connecting this fossil with the echinodermata; lower half of the column apparently solid and traversed by a pentangular canal."

This definition, as stated by Jaekel, is applicable to many Pelmatozoa, but Mather's fairly good figure, published in 1843, gave the genus and species standing among American collectors. From the standpoint of proper definition, *Lepocrinites* dates from Hall's redescription of the genus in 1859, where he changes the orthography to *Lepocrinus* or *Lepadocrinus* because "the name *Lepocrinites* was given from the resemblance to the Lepas or Barnacle, *Antifa*, and is properly *Lepadocrinus.*" Jaekel rejects Conrad's name, because the genus can not be recognized from his description; and Hall's, on the ground of priority, yet makes both synonymous with *Apiocystites* Forbes of 1848. Bather rightly goes back to the first clear usage of the name, giving the genus to Mather because of his fairly accurate figure, but accepts Hall's corrected orthography, *Lepadocrinus*. The writer prefers to adhere rigidly to the rules of nomenclature, hence makes use of the name as given by both Conrad and Mather—*Lepocrinites*.

Definition of Lepocrinites.—Apiocystinæ, with the theca oval or pyriform, the sides somewhat compressed, and composed of 20 plates arranged as follows:

Basal row has plates 4, 1, 2, 3.

[1] This name is usually written *Lepadocrinus*. The *Code of Nomenclature adopted by the American Ornithological Union*, 1892, p. 51, states: "The original orthography of a name is to be rigidly preserved, unless a typographical error is evident." As there is no evident typographical error in Conrad's proposal of the name, the writer preserves the original orthography.

Second row has plates 5, 6, 7, 8, 9.

Third row has plates 10, 11, 12, 13, 14.

Fourth row has plates 16, 17, 18, 19, 15.

Fifth row has deltoid 23.

Deltoid 23 is very small, situated on top of plate 18, or between it and 13. The hydropore and madreporite are present. Anal area small, placed between plates 7, 8, and 13, and consisting of an outer complete circle of a variable number of small pieces and the pyramid of 6 pieces. One basal and 2 upper pectinirhombs, having long, angulated, grooved, adjoining recesses, with numerous dichopores.

Ambulacra 4, not prominent, undivided, and usually not longer than one-half the length of the theca. Brachioles not abundant.

Column unlike those of all associated genera in being composed of 2 distinct parts. Beneath the theca there are about 15 segments followed by a thicker leech-shaped piece from 35 to 55 mm. in length, formed of segments anchylosed together and coated over on the outside by a nodose layer. The lower end of the fused piece seems to have articulated directly with the basal expansion.

Genotype, *L. gebhardii* Conrad.

Lepocrinites is undoubtedly closely related to *Apiocystites*, but should not be confounded with it, on account of differences pointed out in the remarks on the latter genus. The peculiarity of the column alone should distinguish *Lepocrinites* from all other associated genera. The fused piece of the column is often extremely abundant in certain crinoidal limestones of the Coeymans at the base of the Devonic in Litchfield and Schoharie counties, New York.

The earliest species is *L. manlius*, found near the top of the American Siluric; this is followed by *L. gebhardii* of the basal Devonic. *L.*(?) *angelini* Haeckel of the Upper Siluric of Gotland may also prove to belong here, and not to *Apiocystites*, on account of the large adjoining pectinirhombs, with numerous dichopores, the similar structure of the ambulacra, and the more numerous brachioles.

LEPOCRINITES MANLIUS n. sp.

(PLATE XXXVII, FIGURES 2, 3; PLATE XXXIX, FIGURES 15, 16)

Length of theca 2 cm.; greatest width 14 mm.; depth 12 mm. For general form, shape of individual plates and their ornamentation, see the figures and diagram, figure 23.

Each ambulacrum a little longer than half the length of the theca and bearing on each side about 12 brachioles (or 24 to an ambulacrum), of which none is preserved.

Basal pectinirhomb largest, with about 40 dichopores, while the 2 upper ones each have about 35.

The conspicuous valvular pyramid of the anus is composed of 6 triangular plates surrounded by a circle of about 18 very small pieces. All these parts are deeply set between plates 7, 8, and 13.

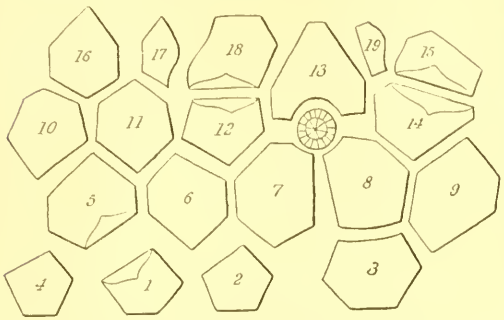

FIG. 23.—Analysis of *Lepocrinites manlius* n. sp.

Hydropore small, placed just below the conspicuous madreporite. Both are situated on plate 21, making the abutment on one side for 2 ambulacra.

Column unknown. In the cystid layer, however, occur the fused leech-shaped pieces of the column, so characteristic of *Lepocrinites*. They are smaller than in *L. gebhardii* and, as they occur in the same zone as the theca of *L. manlius*, it is probable that these pieces belong to the latter species.

Compared with *L. gebhardii* of the Coeymans, *L. manlius* is considerably smaller, in form more pyriform than subquadrate, has considerably longer ambulacra, and the plate ornamentation is far more decided.

Formation and locality.—The only specimen was found by Mr. Gordon at the Keyser quarries in the lower portion of the Manlius. The species takes its name from the Manlius formation, the horizon just beneath the Coeymans in which *L. gebhardii* occurs.

Cat. numbers 35,062, 35,073, 35,074, U. S. N. M.

LEPOCRINITES GEBHARDII Conrad

Lepocrinites gebhardii CONRAD, Fourth Ann. Rep. N. Y. Geol. Surv., 1840, p. 207.—VANUXEM, Nat. Hist. N. Y., Geol., III, 1842, p. 117, text-fig. 4.—MATHER, ibidem, I, 1843, p. 346, text-fig. 4.—HALL, ibidem, IV, 1843, tab. ill. 27, fig. 4.—OWEN, Amer. Jour. Sci. (2), 1846, p. 49, fig. 4 (fig. only).—LINCKLAEN, Fourteenth Rep. N. Y. State Cab. Nat. Hist., 1861, p. 58, pl. 9, fig. 11.

Lepadocrinus gebhardi HALL, Nat. Hist. N. Y., Pal., III, 1859 [1861], p. 127, pl. 7, figs. 1–20.—HAECKEL, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 135.

Apiocystites gebhardii JAEKEL, Stammesgeschichte der Pelmatozoen, I, Berlin, 1899, p. 282, fig. 59 on p. 280.

The writer has seen a number of specimens of this species belonging to Yale University Museum and to the U. S. National Museum,

but their preservation is such that nothing can be added to the description and illustrations given by Hall except the structure of the anal area. This is composed of 2 circles of pieces—an outer of many small plates and the pyramid.

Formation and locality.—In the upper portion of the Coeymans limestone of the Lower Devonic, at many places in eastern New York. It has not been found, to the writer's knowledge, south of New York.

Cat. numbers 10,557, 26,923, 33,202, 35,075, 35,076, U. S. N. M.

Hallicystis Jaekel

Apiocystites Hall (not Forbes nor Hall, 1852), Twentieth Rep. N. Y. State Cab. Nat. Hist., rev. ed., 1868 [1870], p. 358.

Hallicystis Jaekel, Stammesgeschichte der Pelmatozoen, Berlin, 1, 1899, p. 287.

Definition.—Apiocystinæ ? with the theca elongate balloon-shaped, base not invaginated, and with 5 rows of 4 plates arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 5, 6, 7, 8, 9.

Third row has plates 10, 11, 12, 14.

Fourth row has plates 16, 17, 18, 13, 19, 15.

Fifth row has plate 20 and deltoids 21, 22, 23 double, 24.

Anus prominent, bounded by plates 7, 8, and 13. Pyramid enclosed by a complete circle of minute plates.

Pectinirhombs normally situated, discrete, with few dichopores.

Ambulacra 4. As all the specimens are internal casts, the details of the exterior cannot be ascertained.

Genotype, *Apiocystites imago* Hall.

This genus differs from *Apiocystites* in having 5 deltoids instead of 1, but otherwise seems to be closely related. Only two species are known.

HALLICYSTIS IMAGO (Hall)

Apiocystites imago Hall, Twentieth Rep. N. Y. State Cab. Nat. Hist., rev. ed., 1868 [1870], p. 358, pl. 12, fig. 12; pl. 12A, fig. 9.

Hallicystis imago Jaekel, Stammesgeschichte der Pelmatozoen, Berlin, 1, 1899, p. 288.

Rare in the Niagaran dolomites about Chicago, Illinois.

The diagram of plates (figure 24) is based on specimen 35,060, U. S. N. M., and on material in Dr. B. E. Walker's collection.

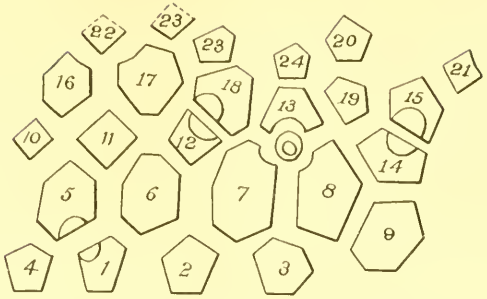

FIG. 24.—Analysis of *Hallicystis imago* Hall, based on no. 35,060, U. S. N. M., and on one of Walker's specimens.

HALLICYSTIS ELONGATA Jaekel

Hallicystis elongata JAEKEL, Stammesgeschichte der Pelmatozoen, Berlin, 1, 1899, p. 288.

The description, translated, is as follows:

"Theca greatly arched, 35 to 40 mm. high. Anus in the middle of the length, with a depression about its vicinity. Theca above the anus still convexly arched. Upper pectinirhomb on plates 14 and 15 of medium size, with 14 dichopores. Plates flat, rippled, folded toward the middle, and with concentric lines along the margins. Upper Silurian (Niagara limestone), Chicago."

Holotype in the University of Strassburg, Germany.

Tetracystis n. gen.

Definition.—Apiocystinæ with the theca elongate subquadrate, 4-sided in transverse section, and composed of 20 plates. These are arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 5, 6, 7, 8, 9.

Third row has plates 10, 11, 12, 14.

Fourth row has plates 16, 17, 18, 13, 19, 15.

Fifth row has deltoids 23 and 24. The former has a large hydropore and a small madreporite.

Anal area prominent, bounded by the thecal plates 7, 8, 13, and 14, and composed of an outer circle of many small pieces and the acutely pointed pyramid of 6 pieces. One basal and 2 large upper adjoining pectinirhombs, with numerous dichopores.

Ambulacra 4, simple, slender, and extending to the column. These are R I, R II, R IV, and R V. Brachioles very slender, widely separated, and therefore comparatively few in number.

Column unknown.

Genotype, *T. chrysalis* n. sp. The only other species is *T. fenestratus* (Troost).

As in *Staurocystis, Tetracystis* has the same arrangement of the thecal plates and of those in the anal area, but differs widely in the construction of the ambulacra. In the latter they are slender, inconspicuous, each with about 20 brachiole sockets, while in the former the ambulacra are wide, very conspicuous, heaped medially, and each bears about 40 brachioles. Moreover, deltoid 23 is a prominent plate in *Tetracystis,* while in *Staurocystis* it is probably very small, the relation of this genus being with *Pseudocrinites. Apiocystites* is also closely related to *Tetracystis,* but differs in having the 2 parts of each pectinirhomb discrete and the anal plates surrounded by thecal plates 7, 8, and 13; while in *Tetracystis* there is an additional plate, or 7, 8, 13, and 14. *Lepocrinites* differs in having but 3 thecal plates bounding the anal area instead of 4 as in the new genus. In *Jackelocystis* plate 19 is lacking, the rhombs are quite different, and the anal area has not a second circle of small pieces as in *Tetracystis.*

TETRACYSTIS CHRYSALIS n. sp.

(PLATE XXXIV, FIGURES 9, 10; PLATE XL, FIGURES 1–3)

Length of theca of holotype 23 mm.; width 17 mm.; depth 13 mm. A single paratype has a length of 24 mm.; breadth 15 mm.; depth

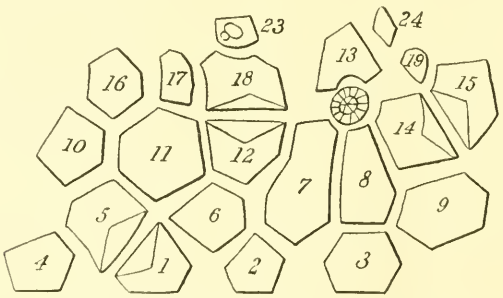

FIG. 25.—Analysis of *Tetracystis chrysalis* n. sp.

13 mm. For general form, shape of individual plates and their ornamentation, see the figures and diagram, figure 25.

Ambulacra narrow, depressed, not excavated into the thecal plates, and extending to the column. Ambulacrals very long and narrow, about 20 in a column. Ambulacralia extremely small, about 12 to 14 to each ambulacral. Brachioles very slender, about 11 on each side of an ambulacrum or about 88 to each theca; length unknown.

Pectinirhombs each with from 25 to 35 dichopores.

Hydropore on plate 23 comparatively large and easily seen; immediately behind it is a shallow pit with numerous pores, indicating the madreporite.

Anal area very prominent owing to the elevated anal margins of plates 7, 8, 13, and 14, and composed of an outer circle of 17 small pieces and a highly elevated pyramid of 7 pieces.

Column unknown.

Formation and locality.—The two specimens were found by Mr. Gordon in the cystid beds at the quarries near Keyser, West Virginia. The paratype is in Mr. Gordon's collection.

Cat. number 35,063, U. S. N. M.

TETRACYSTIS FENESTRATUS n. sp. (Troost)

(PLATE XXXIV, FIGURES 6–8)

Echinocrinites fenestratus TROOST, Amer. Jour. Sci. (2), VIII, 1849, p. 419 (nomen nudum).

Echino-encrinites fenestratus TROOST, Proc. Amer. Assoc. Adv. Sci., II, 1850, p. 60 (nomen nudum).[1]

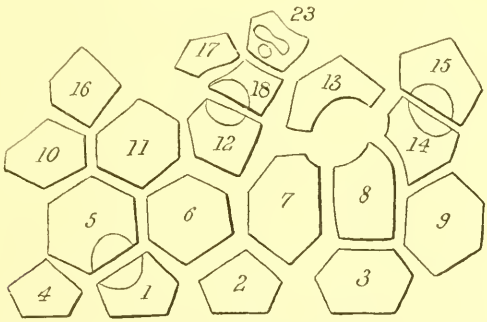

FIG. 26.—Analysis of *Tetracystis fenestratus* n. sp. (Troost).

[1] Professor Troost died August 14, 1850, about one year after his paper was read by Professor Agassiz "in the absence of the author" at the second, or Cambridge meeting, August, 1849, of the A. A. A. S. The full manuscript title of this paper, which is now in the U. S. National Museum, is "Monograph on Crinoids (?) discovered in the state of Tennessee by Dr. G. Troost." The manuscript was received by the Smithsonian Institution, July 18, 1850, and was then sent to Agassiz for revision. In Meek's letters, preserved by the Smithsonian Institution, there is one from Dr. B. F. Shumard as follows:

"New Harmony, Ind., Jan. 20, 1851.

". . . The Monograph by Troost on the Crinoids of Tennessee will probably not be published for some months yet. It is now in the hands of Agassiz and Wyman for revision."

The following is Troost's original description:

"*Echino-encrinites fenestratus,* Mihi.

"This crinoid, the summit of which is closed, and which does not possess arms, approached to the genus *Echino-encrinites* of Herman von Meyer—Cystides of von Buch, but it differs nevertheless in very important particulars from *Echino-encrinites.* The arrangement and number of plates of which it is composed are perhaps identical with those of *Echino-encrinites.* I say *perhaps,* because the five plates which form the summit, as will be seen, can not be distinguished in our fossil. The other characters by which it differs from the *Echino-encrinites* may entitle it to form a new genus.

"It has the form of a small acorn; four furrows [ambulacra] running longitudinally from the summit to the base, divide the surface into four equal parts; on three of them are poriferous rhombs and on one is an oval aperture [anus]. The poriferous rhombs are barred (these bars are not equal in number in these rhombs; some have 16, and 14 at the top, and 12 below) in the direction of the

In the Smithsonian Annual Report for 1853, p. 213, is the following:

"A paper has also been presented for publication by the executors of the late Dr. Troost, of Nashville. It consists of descriptions and drawings of a very numerous family of extinct zoophytes, to which the organic remains called the stone lily belong . . . and the paper of Professor Troost describes several hundred [only 107] species, of which two only have living representatives.

"The memoir, however, is not in a condition to be published without revision, and additions to bring it up to the state of knowledge at the present time. This labor has been gratuitously undertaken by Professor Agassiz, of Cambridge, and Professor James Hall, of Albany. The collection of specimens from which the drawings were made is now in the possession of these gentlemen, and the memoir will be published as soon as the corrections and additions are made."

After the paper had remained unrevised by Agassiz for five years, the manuscript was turned over to Hall, and on the cover the latter wrote "received from Professor Agassiz in Cambridge, August 23d, 1855, James Hall." Many years later Meek made inquiries at the Smithsonian Institution regarding this work, and received the following reply:

"Washington, D. C., July 21, 1868.

"My Dear Mr. Meek,

I can tell you nothing about present condition of Troost's paper or what Professor Hall has done or will do with it. Nor does Professor Henry remember anything of any plan or arrangement. We have published nothing and know of no publication. Sincerely yours,

"S. F. Baird.

"F. B. Meek,
"Springfield, Ill."

Troost's manuscript and fossils remained in Professor Hall's possession for more than forty years, and the matter was lost sight of by the Smithsonian authorities. After Professor Hall's death, the writer called the attention of

smaller diagonal which gives them the appearance of venetian blinds, from which its specific name.

"The pelvis is circular with four reëntering angles, composed of four [basal] plates, three of which are pentagonal, and one, having its superior angle truncated, is hexagonal. The lower part of the pelvis terminates externally in a more or less projecting edge and then the plates turning immediately inwards form the sides of a [deep] circular excavation in which the column was inserted.

"The first [second] series of plates is composed of five; four are hexagonal, and one having upon its lower margin one [i. e., one-half] of the poriferous rhombs is rendered thereby irregular. They are placed in the four reëntering angles of the pelvis; the fifth plate is quadrilateral and rests upon the hexagonal pelvic plate, the superior of which surrounding partly the oral aperture [anus] is also thereby rendered irregular.

"The second [third] series is composed of five hexagonal plates of which three are rendered irregular by two poriferous rhombs and by the oral aperture [anus]. This oral aperture is large and circular. One of the poriferous rhombs, on the quarter section on the left of the oral aperture, occupies about one-half of an hexagonal plate; above this rhomb is an elevation, running transversely and having on its summit a furrow [the madreporite], and below it a single pore [the hydropore], neither of which penetrates through or deeply into the plate. The second poriferous rhomb is on the quarter section on the right of the oral aperture; it occupies the upper part of the third hexagonal plate, which is thus also rendered irregular.

the National Museum authorities to Troost's manuscript and fossils still remaining at Albany, and finally, in the month of November, 1898, the acting administrator of the Hall estate returned to Washington 294 specimens and the manuscript and drawings for 107 species. The specimens for 17 species are still missing. In the Annual Report of the National Museum for 1899, p. 39, is the following statement:

"As a matter of historical interest, it may be noted that the Troost collection of crinoidea, which, together with the manuscript describing them and drawings for 107 species, was sent by the Smithsonian Institution to Professor James Hall in 1855, was returned last November by the administrator of the Hall estate."

With very little revision, this work could well have been published in 1850, and most of Troost's species would have been saved to him. However, as it was and still is the custom of the Smithsonian Institution to refer all manuscripts submitted for publication to a committee of specialists for advice, it is very unfortunate that the work was thus allowed to fall into neglect. Since 1850 most of the species have been described, mainly by Hall, but what are left of new species will in the near future be revived. The blastoids have recently been reworked by Hambach (*Trans. St. Louis Acad. Sci.*, 1904), and the only cystid is described in this paper.

"The summit, which has no aperture, as in other species of this genus, may have been composed of five plates. But our fossil, which is very perfect, without the least erosion, being around the summit much complicated by the [ambulacral open] furrows mentioned above, which here combine, the joints of the plates being thereby obliterated, their number and form can not be ascertained.

"I can say nothing about the column,—the place where I found my specimen contained numerous fragments of different crinoids. The place of insertion of the column is very large in proportion to the size of the body, its diameter being 4 mm., while the largest diameter of the body is 10 mm. and the length 14 mm. The column was not inserted as is generally the case with crinoids. The cavity is formed of an inclined slope or bevel of about 2 mm., having no articulating striæ.

"I found this interesting fossil in Decatur county, Tennessee, associated with *Calymene Blumenbachii* [= *C. niagarensis*], *Orthoceratites*, *Tereb. wilsoni* [= ?*Wilsonia saffordi*], etc."

Remarks.—It is interesting to find that Troost had a species of *Tetracystis* more than 50 years ago, which he then referred to *Echinocrinites*. It is closely related to the Manlius *T. chrysalis*, but differs in being smaller, more circular in transverse outline, and not flattened as is that species; the pectinirhombs, also, have far fewer dichopores. In *T. fenestratus* there are 12 to 17 pores, and in *T. chrysalis* from 25 to 35. Of brachioles the former has from 7 to 8 on each side of an ambulacrum, while the latter species has 11 in the same space. Plate 19 and deltoid 24 may not be present in *T. fenestratus;* if they are, they are now obscured by the ambulacralia. However, as Troost's species is otherwise closely related to *T. chrysalis*, it is probable that other specimens may reveal these two small plates.

Formation and locality.—The horizon in Decatur county, Tennessee, furnishing this fossil, appears to be the Brownsport limestone of Foerste, formerly a part of Safford's Meniscus limestone, in the upper portion of the Niagaran.

Cat. number 35,091, U. S. N. M.

Jackelocystis Schuchert

Jackelocystis SCHUCHERT, Amer. Geol., XXXII, 1903, p. 230.

Definition.—Apiocystinæ with the theca pyriform or globular in outline, rounded oval or 4-sided in transverse section, and composed of 18 plates, which are arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 5, 6, 7, 8, 9.

Third row has plates 10, 11, 12 (7, 8), 14.

Fourth row has plates 16, 17, 18, 13 (19 absent), 15.

Fifth row has deltoid 23.

Deltoid 23 is a very small plate situated at the top of plate 18 and between it and plate 13. It has a comparatively large hydropore, but a madreporite does not seem to be present. Plate 19 of other genera is not developed in this genus. Anal area small but conspicuous and protruding, consisting only of the pyramid of 6 pieces. The prominence of the anal area is due to the protrusion of the bounding thecal plates of which there are 4, i. e., 7, 8, 13, and 14. One basal and 2 upper very small discrete-pectinirhombs. The parts on plates 1, 12, and 14, as a rule, do not show the dichopores, since these are deeply situated each in a pit with a high margin. Dichopores few.

Ambulacra normally 4 in number. These are R I, R V, R IV, and R II. In rare cases, either R I or R II may be absent, or R V may be forked. Ambulacra depressed, more or less deeply excavated, and, in normal individuals, continuing to or near to the column. Brachioles moderately abundant, short and stout.

Column comparatively stout. Length unknown.

Genotype, *J. hartleyi* Schuchert.

Jackelocystis seems to have closest relationship with *Apiocystites* and therefore, also, with *Lepocrinites*. It is readily distinguished from these genera in that it has but 18 thecal plates, plate 19 not being developed. The same difference is found when *Jackelocystis* is compared with *Staurocystis*. Even should plate 19 be present as a very minute piece, this genus would still differ from *Apiocystites* and *Lepocrinites* in that its third row of thecal plates has but 4, while in the latter genera it has 5, plates. In other words, in these two genera plate 13 is in the third row, while in *Jackelocystis* it is in the fourth. Another difference distinguishing this genus from all other associated cystids with 4 simple ambulacra lies in the composition of the anal area, which consists only of the pyramid of 6 pieces. In the other genera there is always an additional circle of small pieces. Moreover, in *Apiocystites* and *Lepocrinites* this area is bounded by plates 7, 8, and 13, while in *Jackelocystis* there are 4 plates—7, 8, 13, and 14.

Tetracystis also has 4 ambulacra and but 4 plates in the third circle of the theca. However, it differs from *Jackelocystis* in having plate 19, and therefore has 6 plates in the fourth circle of the theca. Further, the anal area has a circle of plates around the pyramid, the

pectinirhombs are large with the halves adjoining, and the brachioles few in number and widely separated.

The genus is named for Doctor Otto Jaekel of the Geological Institute of the Friedrich-Wilhelms University, Berlin, Germany, in recognition of the great service he has rendered to paleontology by his detailed description of the *Thecoidea* and *Cystoidea*, forming volume I of his great contemplated work on the *Stammesgeschichte der Pelmatozoen*. This work has been of the greatest aid in the present studies, and in the accuracy of their results.

JAEKELOCYSTIS HARTLEYI Schuchert

(PLATE XXXVII, FIGURES 4–8)

Jackelocystis hartleyi SCHUCHERT, Amer. Geol., XXXII, 1903, p. 231.

Length of a full-grown theca 15 mm.; width and depth about 11 mm. For general form, shape of individual plates and their ornamentation, see the figures and diagram, figure 27.

Ambulacra narrow, excavated into, and but slightly elevated above, the theca, and in normal specimens extending to the column. Each pair of ambulacra, or R I and R II, R IV and R V, converging and almost touching each other near the column. In one individual, R I is but half the normal length and R II is almost aborted, having but 6 brachioles. In another individual R I is entirely undeveloped, while in a third specimen R II is absent. In a fourth specimen R V is forked, the branch developing on the left. In full-grown specimens, there are about 34 brachioles to each ambulacrum, 17 on either side. Brachioles stout and folded over each other medially; length unknown but apparently quite short. Ambulacral grooves narrow and shallow, with very minute ambulacralia.

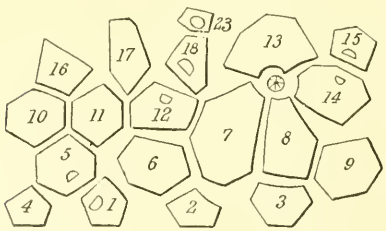

FIG. 27.—Analysis of *Jaekelocystis hartleyi* Schuchert.

Dichopores on plates 1, 12, and 14 not shown at the surface, being deeply situated within small oval pits, each with a rim highly elevated above the surface of these plates. Those on plates 5, 18, and 15 show the dichopores with the excavation deepest orally, and are here delimited by a crescentic lip. About 8 folds in each rhomb.

Hydropore conspicuous, situated on a small piece (plate 23), placed above and between plates 18 and 13. No madreporite dis-

cernible. For detail of this region and the ambulacra, see figure 6, plate XXXVII.

Anal pyramid small, not strongly elevated, composed of 6 pieces, but made quite prominent by the protrusion of the bounding margins of thecal plates 7, 8, 13, and 14.

Column comparatively stout, and, as is usual in cystids, composed of thick segments near the theca. Length unknown.

Comparisons.—This beautiful, regular, but small cystid is readily distinguished from the other species of *Jaekelocystis* by the pyriform outline, strong sculpturing, and the more prominent ambulacra. *J. papillatus* is also easily identified by the much finer papillose ornamentation.

Formation and locality.—A very common species in the quarries and elsewhere near Keyser, West Virginia, many hundred examples having been seen. The first specimen was dug up near Judge Alkire's house by Mr. Frank Hartley of Cumberland, Maryland. It is found associated with *Sphærocystites multifasciatus, S. globularis*, and *Pseudocrinites gordoni*, these four being the common species of the cystid beds of the lower Manlius formation about Keyser. It gives the writer pleasure to name this species for its discoverer, in recognition of his enthusiasm and untiring efforts in the unearthing of many new Siluric and Devonic species of western Maryland.

Cat. number 35,055, U. S. N. M.

JAEKELOCYSTIS PAPILLATUS n. sp.

(PLATE XXXVII, FIGURES 9, 10)

Length of the largest theca 15 mm.; width and depth 12 mm. For general form and sculpturing, see plate XXXVII, figures 9, 10.

Anal area less prominent than in the other species of this genus, and bounded by plates 7, 8, 13, and only a very small part of 14.

This species differs from *J. hartleyi*, to which it is closely related, in the more globular theca, fewer brachioles, absence of grooves along the suture lines of the plates and the papillose sculpturing of the plates; also in the fact that the discrete halves of the pectinirhombs are alike and not with one-half buried deeply in a pit with a high rim. Each ambulacrum has from 11 to 12 brachioles on each side, while in *J. hartleyi* there are 17 in the same length. The pectinirhombs likewise have more dichopores, there being from 12 to 15 in each, while in *J. hartleyi* there are only about 8.

Formation and locality. Only two specimens of this species are known from the quarries near Keyser, West Virginia.

Cat. number 35,057, U. S. N. M.

JAEKELOCYSTIS AVELLANA n. sp.

(PLATE XXXVII, FIGURES 11, 12)

Theca shaped like a hazelnut, the resemblance suggesting the name, about 10 mm. in length and breadth, in the largest of three known examples. Plates nearly smooth; for their individual form, see the diagram (figure 28) and plate XXXVII, figures 11, 12.

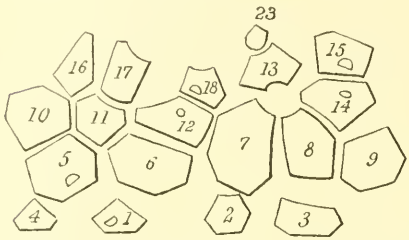

FIG. 28.—Analysis of *Jaekelocystis avellana* n. sp.

Ambulacra narrow, but appearing wide on account of their lying in rather deeply excavated thecal grooves, with sharply elevated margins, extending to the lower ends of the second or to the top of the basal circle of thecal plates. The 4 ambulacra are regularly disposed and do not converge. Nature of brachioles unknown, about 26 on each ambulacrum, or 13 on each side. Ambulacrals thick, causing the ambulacral furrow to be narrow; ambulacralia not preserved.

Hydropore conspicuous and situated as in *J. hartleyi*.

Anal pyramid not preserved. Anal area less conspicuous, but otherwise as in *J. hartleyi*.

Pectinirhombs as in the species just cited, with 1 or 2 dichopores less to each rhomb.

Column unknown.

Formation and locality.—Three specimens of this species are known from the cystid beds of the Manlius in the quarries near Keyser, West Virginia. One of these is in Mr. Hartley's collection.

Cat. number 35,056, U. S. N. M.

Subfamily STAUROCYSTINÆ Jaekel

Callocystidæ with the brachioles closely adjoining, and the ambulacra highly arched and prominent. Ambulacra 2, 3, or 4 in number, and never bifurcating.

Pseudocrinites Pearce

Pseudocrinites PEARCE, Proc. Geol. Soc. London, IV, 1843, p. 160.—FORBES, Mem. Geol. Surv. Great Britain, II, pt. II, 1848, p. 494.—JAEKEL, Stammesgeschichte der Pelmatozoen, Berlin, I, 1899, p. 283, fig. 60 on p. 284.

Pseudocrinus HAECKEL, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 135.—BATHER, Treatise on Zoology, III, Echinoderma, London, 1900, p. 62, fig. 29.

The Cystidea were not separated from other Echinoderma until 1844, by von Buch; a year earlier, however, Pearce defined the genus *Pseudocrinites* as follows:

"Mr. Pearce regards them as constituting a new genus which he proposes to name *Pseudocrinites*, including two species both having the arms [ambulacra] and fingers [brachioles] inserted in hands, which commence just above the column and pass over the plates of the head to its summit. The one form has two [now accepted as the genotype], the other four ranges of fingers [*Staurocystis*]. They resemble each other in having the columns at their superior part composed of rings, gradually increasing in size towards the head. The plates of the head are thin and broad, and marked on their outer surface by lines of growth, and radiating ridges resembling the plates of the marsupite. They are also furnished with four orifices [pectinirhombs. Seeing two on one side he concluded there were four in all, but there are only three] of a lozenge shape, most singularly inserted in the plates of the head, and their arms and fingers are exceedingly short. The fingers [brachioles] are composed of two rows of bones [plates], each bone on the one side being inserted between two of the opposite. These fingers appear to be placed in four rows [should be two rows on each ambulacrum] on each of the hands, and pass off from the head in a radiating direction, commencing at the column and uniting at the summit. Mr. Pearce names the first species *Pseudocrinites bifasciatus* [the genotype selected by Haeckel], and the second *P. quadrifasciatus* [selected by Haeckel as the genotype of *Staurocystis*]."

Emended definition of Pseudocrinites.—Staurocystinæ with the sides of the theca compressed, varying in outline from circular to elongate subquadrate, and composed of 19 plates. These are arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 5, 6, 7, 8, 9.

Third row has plates 10, 11, 12, 14.

Fourth row has plates 16, 17, 18, 13, 19, 15.

Fifth row has deltoid 23.

Deltoid 23 is very small, situated between the ambulacra on the left oral side of plate 18, with the hydropore and madreporite present. Hydropore closed by a pyramid of 5 plates. Anal area small, placed between plates 7, 8, 13, and 14, and consisting of an outer complete

or incomplete circle of from 6 to 8 pieces and the pyramid of 7 pieces. One basal and 2 upper pectinirhombs normally situated, with long, angulated, grooved, adjoining recesses, and numerous dichopores.

Ambulacra 2 in number, apparently R I and R IV (see remarks on *Trimerocystis*). These extend along the narrow periphery of the theca and in most species touch the column. Brachioles abundant. The piece with the madreporite and a depression diagonally opposite separates the 2 ambulacra.

Column stout near the theca, tapering more or less rapidly, and composed of equal-sized pieces with angulated margins. Beneath this upper section the column maintains a nearly equal diameter, and the pieces may be interspersed with larger ones, all having a rounded periphery.

Genotype, *P. bifasciatus* Pearce. The above diagnosis, however, is based on *P. gordoni*. Of the former there is a specimen in U. S. N. M.; cat. number 35,138.

Pseudocrinites is readily distinguished from the other Siluric genera of cystids by the fact that it has but 2 ambulacra, sometimes called recumbent arms. In all other associated genera there are 3 or 4 of these arms.

The number and arrangement of the thecal plates are the same in all species (except *P. abnormalis*). The specific characters are form, arrangement of anal plates, length of ambulacra, number and length of brachioles, nature of ambulacralia, and number of dichopores. On the basis of these characters, eight new species are here described. To facilitate easy reference, these forms and their specific features are tabulated as follows:

TABLE OF CHARACTERS OF AMERICAN SPECIES OF PSEUDOCRINITES. (BASED ON AVERAGE-SIZED OR FULLY ADULT SPECIMENS)

Group of *P. gordoni*

Circular in outline. Ambulacra extending to the column. Anal area composed of 1 outer complete circle of pieces and an inner pyramid.

	Length	Width	Brachioles	Folds in Pectinirhomb		
				1–5	12–18	14–15
P. gordoni.....	31 mm	29 mm	160	80	90	120
P. abnormalis....	29 "	22 "	135	65	70	70
P. claypolei.....	19 "	19 "	56	26	32	42
P. stellatus.....	25 "	23 "	72	60	80	90

Group of *P. clarki*

Elongate in outline. Ambulacra extending to the column. Anal area composed of an apparently incomplete outer circle of pieces and an inner pyramid.

	Length	Width	Brachioles	Folds in Pectinirhomb		
				1–5	12–18	14–15
P. clarki.....	30 mm	22 mm	88	42	50	68
P. subquadratus..	16 "	12 "	52	33	33	43
P. elongatus.....	40 "	23 "	84	65	75	110

Group of *P. perdewi*

Pear-shaped in outline. Ambulacra occupying less than two-thirds of the periphery of the theca. Anal area as in the *P. gordoni* group.

	Length	Width	Brachioles	Folds in Pectinirhomb		
				1–5	12–18	14–15
P. perdewi	57 mm	39 mm	90	82	114	148

Of foreign species of *Pseudocrinites*, there are but two—*P. bifasciatus* Pearce and *P. magnificus* Forbes—and these are of the *P. gordoni* group. Forbes states that the former has 12 to 16 brachioles on each ambulacrum, but this number apparently includes only those of one edge, as is shown by his figure 3 of plate XI. The total number of brachioles in this species appears, therefore, to be from 48 to 64 (Jaekel gives about 80). *P. bifasciatus* is consequently closely related to *P. claypolei* and *P. stellatus*, but in both of the latter the pectinirhombs are much more pronounced. *P. magnificus* is somewhat larger than *P. gordoni*, and has about 136 brachioles (Jaekel gives 100 to 120), but differs from American species in the smaller pectinirhombs and the different thecal ornamentation. Both these English species occur in the Siluric near Dudley; *P. bifasciatus* in the Wenlock limestone, and *P. magnificus* in the same horizon and in the Lower Ludlow.

PSEUDOCRINITES GORDONI Schuchert

(PLATE XXXVI, FIGURES 8–12; PLATE XXXIX, FIGURES 11–13)

Pseudocrinites gordoni SCHUCHERT, Amer. Geol., 1903, XXXII, p. 235.

Length of the largest theca 32 mm.; greatest width 32 mm.; depth 21 mm. For general form, shape of individual plates and their ornamentation, see the figures and diagram, figure 29.

Ambulacra angularly elevated, prominent, extending around the entire periphery of the theca, and touching the column in specimens 20 mm. or more in length. In some of these mature specimens the ambulacra, when near the column, are deflected, and one or both will pass on the same side for a short distance in front of it. In smaller specimens the ambulacra do not quite reach the column, and in one having a thecal length of 15 mm. they stop within 3 mm. of the stalk. In the largest specimen there are 40 brachioles on each side of an ambulacrum, while in one having a thecal length of 15 mm. there are about 21. Length of brachioles not definitely known; those of the apical region not less than 11 mm., stout, and with about 17 pieces in each column. Ambulacral groove wide and covered by a complex series of small and large ambulacralia arranged as shown in figure 11 of plate XXXIX.

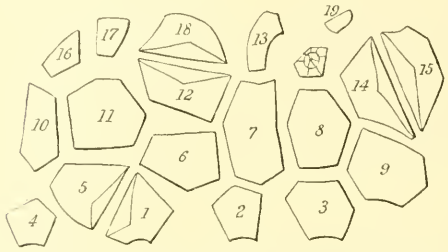

FIG. 29.—Analysis of *Pseudocrinites gordoni* Schuchert.

Basal pectinirhomb smallest, in the largest specimen having about 80 grooves; that on plates 12 and 18 has about 90, and the one on plates 14 and 15 is the largest, with about 120.

Hydropore minute, closely adjoining the madreporite.

Anal pyramid depressed, consisting of 7 somewhat ornamented plates surrounded by a circle of 8 larger plates of irregular size and definite sculpture.

Column slender. Length unknown.

Comparisons.—*P. gordoni* is the most prolific of American *Pseudocrinites*. The nearly circular outline of the theca and the greater number of brachioles distinguish this species from *P. clarki* and *P. perdevi*. Of forms with nearly circular theca *P. stellatus* differs in the very prominent sculpturing and the smaller number of brachioles, while *P. claypolei* differs in the vermiform sculpturing and fewer brachioles.

P. gordoni undergoes but little modification in form. In general the outline is circular, but occasionally a specimen is a little more elongate and in rare cases one is more transverse. Of the latter, one has a thecal length of 29 mm.; breadth 33 mm.; and depth 19 mm. There is very little abnormal material. One specimen has the ambulacrum R IV abutting against the lower pectinirhomb instead of

passing to the left of it. In another basally compressed individual, both ambulacra are bowed toward the anal side, particularly R IV, causing the opposite side of the theca to be more convex and almost angulated on the left.

Formation and locality.—Common in the Keyser quarries, where it was first collected by Robert H. Gordon of Cumberland, Maryland. The species is named for its discoverer in recognition of the very valuable services he has rendered, not only as an enthusiastic collector, but also as a careful student of the complicated geology of western Maryland.

Cat. number 35,071, U. S. N. M.

PSEUDOCRINITES ABNORMALIS n. sp.

(PLATE XXXV, FIGURES 10–12)

Length of the only specimen 29 mm.; width 22 mm.; depth 14 mm. For general form, shape of individual plates and their ornamentation, see the figures and diagram, figure 30.

Pectinirhombs about equally large and each has from 65 to 70 folds. Basal pectinirhomb on plates 5 and 6 and not, as usual in this genus, on plates 1 and 5. In other words, this pectinirhomb is confined to the second circle of plates and is not divided, one-half of the rhomb being in the basal and the other half in the second row.

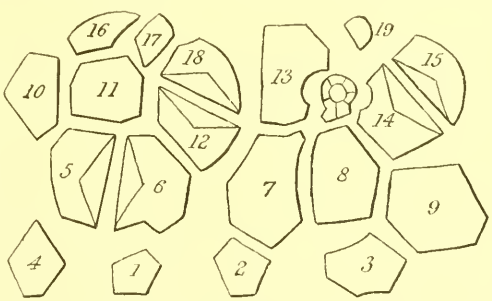

FIG. 30.—Analysis of *Pseudocrinites abnormalis* n. sp.

Ambulacra as in *P. gordoni,* with about 34 brachioles on one side of each ambulacrum.

Comparisons.—This species has the general expression of *P. gordoni,* except that the outline of the theca is regularly oval instead of nearly circular. It differs, also, in having the basal pectinirhomb on plates 5 and 6 instead of on plates 1 and 5. That the two forms are really closely related is shown by the arrangement of the anal plates. In *P. abnormalis,* as in *P. gordoni,* these are composed of 2 complete circles of plates, while in the group typified by *P. clarki* the outer circle consists of plate 13 and several small pieces restricted to the posterior half. Because of this close resemblance the writer

regards the present specimen as abnormal in development, or a monstrosity, but thinks it best to give it a name, for easy reference. Were it not for the very close identity in all specific characters save the abnormal position of the basal pectinirhomb, one would be led to distinguish *P. abnormalis* as the genotype of a new genus. That the position of the basal pectinirhomb is abnormal is shown by the shape of plate 1, but especially by plate 6, which is notched to receive all the anterior edge of plate 1.

Formation and locality.—The holotype was found by the writer, associated with *P. gordoni,* in the quarries near Keyser, West Virginia.

Cat. number 35,068, U. S. N. M.

PSEUDOCRINITES CLAYPOLEI n. sp.

(PLATE XXXVII, FIGURE 1)

Length and width of the only specimen at hand 19 mm.; thickness about 12 mm. For form and ornamentation, see figure 1, plate XXXVII.

The ambulacra extend around the entire periphery of the theca and touch the slender column. All plates of the ambulacra and the brachioles are gone, but the impressions left by the former indicate that about 14 brachioles existed on either side of each ambulacrum.

Basal pectinirhomb with 26 dichopores, that on plates 12 and 18 has 32, and on plates 14 and 15 about 42.

Comparisons.—That this species is related to *P. gordoni* and *P. stellatus* is shown by the lens-shaped theca; it differs from the former in having fewer brachioles and in the vermicular sculpturing, while the latter species has the plates marked by a few strong radiating ridges.

Formation and locality.—In the lower portion of the Manlius at Clark's Mills, near New Bloomfield, Pennsylvania, associated with *Sphærocystites bloomfieldensis.* The writer's attention was directed to this locality on reading an account of it in *Report FF* of the *Second Geological Survey of Pennsylvania* (p. 182), by the late Professor Edward W. Claypole, for whom this species is named.

Cat. number 35,066, U. S. N. M.

PSEUDOCRINITES STELLATUS Schuchert

(PLATE XXXV, FIGURES 8, 9; PLATE XXXIX, FIGURE 7)

Pseudocrinites stellatus SCHUCHERT, Amer. Geol., XXXII, 1903, p. 236.

Length of a large specimen 25 mm.; breadth 23 mm.; depth about 15 mm. Mr. Hartley has a specimen 32 mm. long and 30 mm. wide. For form of theca and its sculpturing, see figure 7, plate XXXIX.

Ambulacra well defined, flat topped, extending around the entire periphery of the theca and touching the column. Ambulacrals large. Each ambulacrum in full-grown specimens has about 36 brachioles; in a small specimen having a thecal length of 15 mm., there are but 24 brachioles. Brachioles usually not preserved. Ambulacral groove wide, roofed by a median double row of tiny angular ambulacralia arranged in short crescents, and outside of these by a single row of much larger, strongly elevated plates, each one of which is as large as two of the ambulacrals. For detailed structure, see figure 7, plate XXXIX.

Basal pectinirhomb with about 60 dichopores, that of plates 12 and 18 with 80, and of 14 and 15 with 90.

Madreporite quite large for *Pseudocrinites*, but the hydropore is exceedingly minute.

Anal area small, composed of 2 circles of plates; the outer has 7 nodose pieces and the inner depressed pyramid has the same number of plates.

Column slender, but its length is unknown.

Comparisons.—This species is readily distinguished from all other *Pseudocrinites* by the strongly stellate sculpturing of the plates. *P. gordoni* differs further in having many more brachioles.

Formation and locality.—Of this species three specimens are in the U. S. National Museum, seven in Mr. Hartley's collection, and two in Mr. Gordon's. All are from the quarries near Keyser, West Virginia.

Cat. number 35,069, U. S. N. M.

PSEUDOCRINITES CLARKI Schuchert

(PLATE XXXVI, FIGURES 4–7; PLATE XXXIX, FIGURE 14)

Pseudocrinites clarki SCHUCHERT, Amer. Geol., XXXII, 1903, p. 237.

Length of largest theca 44 mm.; greatest width 30 mm.; depth 22 mm. Length of an average specimen 30 mm.; greatest width 22 mm.; depth about 16 mm. For general form, shape of plates and their ornamentation, see figures 4–6, plate XXXVI.

Ambulacra in mature specimens very prominent, triangular in transverse section, extending around the entire periphery of the theca and touching the column. In the second largest individual each ambulacrum had about 44 brachioles, in another mature but smaller specimen there were only 32. Brachioles unknown, apparently more slender than in *P. gordoni*. Ambulacral grooves narrow, and covered by highly elevated ambulacralia of about the same nature as in *P. gordoni*, but less numerous and the larger plates more nodose.

Basal pectinirhomb in the specimen of average size above mentioned, with about 42 dichopores, that of plates 12 and 18 with about 50, and that of plates 14 and 15, which is the largest, with about 68. In the largest specimen there are as many as 120 in a rhomb.

Hydropore minute and closely adjoining the rather large and prominent madreporite, situated, as usual in *Pseudocrinites,* laterally between the ambulacra on the edge of plate 23.

Anal area well marked, consisting of 2 circles of plates. The outer circle has 4 small plates in the right posterior corner, and these are followed on the left by 3 very much smaller pieces. The latter are not readily seen, and the first impression is that the 4 pieces of the right posterior corner and plate 13 complete the circle. The prominent anal pyramid has 7 triangular pieces.

Column stout, composed of thick pieces near the theca. Length unknown.

Comparisons.—This species differs from other *Pseudocrinites* having ambulacra extending to the column, in its regularly oval outline. *P. subquadratus* is a much smaller species, subquadrate in outline, and with different thecal sculpturing. *P. elongatus* is more elongate subquadrate.

Formation and locality.—Of this species the U. S. National Museum has eleven specimens, the Geological Survey of Maryland one, Mr. Gordon two, and Mr. Hartley ten. All are from the quarries near Keyser, West Virginia. It gives the writer pleasure to name this species for Dr. William Bullock Clark, the distinguished geologist and paleontologist, and the director of the Maryland Geological Survey.

Cat. number 35,070, U. S. N. M.

PSEUDOCRINITES SUBQUADRATUS n. sp.

(PLATE XXXV, FIGURES 4, 5)

Length of the only known specimen 16 mm.; width 12 mm.; depth 9 mm. The base of the theca is comparatively large, indicating a stout column; the oral end is flattened. Between the two flattened ends the theca is slightly convex, giving it the subquadrate outline indicated by the specific name. The sculpturing of the thecal plates is decidedly vermicular, and not radiate as in most other species.

Ambulacra prominent, rounded on the top, extending to the column, composed of 26 comparatively stout basement plates bearing 13 brachioles on one side of each ambulacrum. Brachioles short, very slender, about 5 mm. long, and having about 10 plates in each column. Ambulacral groove large. Ambulacralia not preserved.

Pectinirhombs on plates 1 and 5, 12 and 18, about equally large and having about 33 dichopores, while that on plates 14 and 15 is largest and has 43.

Madreporite prominent, situated as usual on plate 18; the hydropore is very minute.

Anal area as in *P. clarki*, prominent, consisting of 2 circles of pieces, the outer one made up of 4 or 5 right posterior plates, 3 minute pieces on the left, and plate 13. The inner pyramid is not preserved in the specimen at hand.

Comparisons.—This species is most closely related to *P. elongatus*, but the greater size and elongated theca of the latter will readily distinguish it. *P. clarki* is similar, but the greater size, oval outline, and the differently sculptured plates will serve to identify it.

Formation and locality.—The only specimen known was found by Mr. Hartley at Devil's Backbone, opposite Corringansville, near Cumberland, Maryland. The horizon is in the upper portion of the Manlius or the lower half of zone "D. B. Ba." of the section described by the writer on p. 418, *Proceedings of the U. S. National Museum*, 1903.

Cat. number 35,067, U. S. N. M. Presented by Mr. Robert H. Gordon.

PSEUDOCRINITES ELONGATUS n. sp.

(PLATE XXXV, FIGURES 6, 7)

Oral end of the only specimen broken away, but the length seems to have been about 40 mm.; width 23 mm.; depth 17 mm. For general form and shape of individual plates, see figures 6, 7, plate XXXV, and text-figure 31.

Ambulacra prominent, extending around the entire periphery of the theca and touching the column. As the top of the theca is broken away, the exact number of brachioles cannot be counted, but, on the basis of brachioles preserved and the close relationship to *P. subquadratus*, the total number on each side of an ambulacrum is estimated to be between 26 and 28. Ambulacral groove large and deep; ambulacralia not preserved.

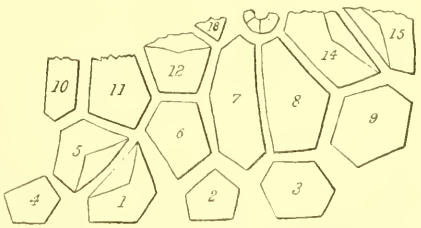

FIG. 31.—Analysis of *Pseudocrinites elongatus* n. sp.

Basal pectinirhomb has about 65 dichopores, that of plates 12 and 18 about 75, and of plates 14 and 15 about 110.

Comparisons.—As the various forms of *Pseudocrinites* are easily recognized on account of their constant characters, the writer does not hesitate to describe this broken specimen as a new species. Its greatly elongate, narrow form distinguishes it from all the others. *P. elongatus* is closely related to *P. subquadratus,* as both have the same general form, size of ambulacral plates, and sculpture, but the former is readily separated by being more elongate with the sides of the theca straighter, and more especially by the far greater size, being 2½ times larger than *P. subquadratus.*

Formation and locality.—The holotype was found by Mr. Perdew in the Manlius formation on Martin's mountain, near Lodger Perdew's farm in Pleasant valley, Bedford county, Pennsylvania.

Cat. number 35,065, U. S. N. M.

PSEUDOCRINITES PERDEWI Schuchert

(PLATE XXXVI, FIGURES 1–3; PLATE XXXIX, FIGURES 8–10)

Pseudocrinites perdewi SCHUCHERT, Amer. Geol., XXXII, 1903, p. 238.

The four following specimens represent four stages in the growth of this species:

	Length	Width	Depth	Brachioles (total)	Rhomb 1–5	Rhomb 12–18	Rhomb 14–15
Specimen 1	16 mm	11 mm	9 mm	23	20 dichop.	34 dichop.	40 dichop.
Specimen 2	24 "	17 "	12 "	48	42 "	48 "	58 "
Specimen 3	35 "	27 "	15 "	76	53 "	65 "	82 "
Specimen 4	57 "	39 "	?20 "	90	82 "	114 "	148 "

General form pear-shaped, with the sides appressed. For shape of the individual plates and their ornamentation, see the diagram and plate-figures.

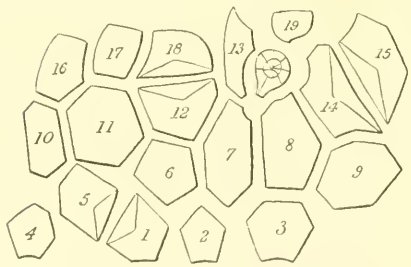

FIG. 32.—Analysis of *Pseudocrinites perdewi* Schuchert.

Ambulacra wide, very prominent, with vertical angulated sides and flat or slightly trough-shaped oral surfaces. In specimen number 1, the 2 ambulacra taper rapidly and extend along the periphery of the theca for one-third its length. In number 2, they are just one-half the length of the theca, in number 3 nearly two-thirds the length, while in number 4 they are about one-half the length. This shows that the length of mature ambulacra is somewhat vari-

able, extending from one-half to two-thirds the thecal length. The ambulacrum nearest the anal region is always somewhat shorter. Number of brachioles on one side of each ambulacrum varying with age, there being in the youngest known specimen (no. 1) about 5, in a mature individual (no. 3) about 19, and in the largest example (no. 4) about 22. Ambulacral grooves narrow in comparison with the large size of the ambulacrals, and covered by very small rectangular ambulacralia which are sharply elevated into a median ridge. There are usually from 10 to 12 ambulacralia to each ambulacral, but in different specimens the number varies. The branches going to the brachioles at the lateral ends of the plates have the ambulacralia as well developed as the median series. Brachioles slender, composed of rather large, elongate, smooth pieces. Those at the distal ends of the ambulacra have 6 pieces in a column 4 mm. long; seemingly these brachioles did not exceed 12 mm. in length.

Anal area small, not prominent, and composed of 2 circles of plates. The outer circle has from 7 to 9 pieces of unequal size, and the flat pyramid has 7 or 8 equal triangular pieces.

The madreporite is rather large for *Pseudocrinites*, but the hydropore is minute, and both are placed within a distinct hollow separating the ambulacra of one side.

Basal pectinirhomb smallest, that of plates 14 and 15 largest.

Column slender, tapering rapidly for a short distance from the theca, and composed of pieces of equal thickness. Length unknown.

Comparisons.—This splendid large and odd *Pseudocrinites* is readily distinguished from all other species of the genus by the short, high, and angulated ambulacra. The form of the theca and the plate sculpturing are also characteristic.

Formation and locality.—Of this form the National Museum has five excellent examples, the Geological Survey of Maryland one, Mr. Gordon one, and Mr. Hartley twelve. All are from the cystid beds of the Manlius in the quarries near Keyser, West Virginia. The specific name is given in recognition of the assistance rendered the writer by Mr. George M. Perdew of Cumberland, Maryland.

Cat. number 35,072, U. S. N. M.

Trimerocystis n. gen.[1]

Generic characters.—Staurocystinæ having the general structure of *Pseudocrinites*, but differing in having 3 ambulacra instead of 2; these are as long as the theca, and are R I, R IV, and R V. Another

[1] The generic name has reference to the tripartite divisions of the ambulacra in this cystid.

difference is that whereas plates 10 and 16 in *Pseudocrinites* are situated in the third and fourth rows, in *Trimerocystis* they have passed one circle lower, being, respectively, in the second and third rows. In tabular form the 4 rows of 19 thecal plates in these genera are arranged as follows:

	Basal Circle	Circle 2	Circle 3	Circle 4
Pseudocrinites	4–1–2–3	5–6–7–8–9	10–11–12–14	16–17–18–13–19–15
Trimerocystis	4–1–2–3	10–5–6–7–8–9	16–11–12–14	17–18–13–19–15

Madreporite and hydropore as in *Pseudocrinites*.

Genotype, *T. peculiaris* n. sp.

Comparisons.—The 3 long ambulacra readily distinguish *Trimerocystis* from all other related genera, as they have either 2 or 4 simple, or 4 variously branched ambulacra.

In determining what 3 ambulacra of the 5 of a primitive cystid are present in *Trimerocystis*, the writer has relied on the assumption that R III is always absent in forms having 4 ambulacra, as *Tetracystis*, *Lepocrinites*, etc. This view seems to be correct, since in all 4-armed cystids described in this paper, there is no ray directly opposite the anus. In *Pseudocrinites* Jaekel identifies the 2 ambulacra as R II and R V; Bather does the same, except that he names them "apparently right posterior and left anterior." If this interpretation is correct, then the third ambulacrum, or the one just to the right of the anal area, in *Trimerocystis* should be R IV or the right anterior ray, thus placing the anal area between R V and R IV, which is of course anomalous and highly improbable. It is certain that the ambulacrum to the left of the anal area in *Trimerocystis* is the same as R II in *Pseudocrinites;* also that the one passing anteriorly in the former genus is equal to R V of the latter—an interpretation also made by both Jaekel and Bather. This is further shown in the specimen of *Trimerocystis* in which the 2 corresponding ambulacra are continuous, and directly in line and opposite to each other as in *Pseudocrinites*. Not only so, but the madreporite, and pectinirhombs 1 and 5, and 12 and 18, are to the left of these ambulacra, while the anal area and pectinirhombs 14 and 15 are to the right in both genera. The third ambulacrum in *Trimerocystis* is also to the right. If this third ambulacrum is not altogether anomalous, then it may be stated that the 2 ambulacra placed one on either side of the anus represent the bivium or rays I and V. As the anterior ray does not hold the central line opposite the bivium, one is seemingly forced to conclude that it represents R IV. With this interpretation the 2 ambu-

lacra in *Pseudocrinites* should represent R I and R IV. Moreover, the madreporite, hydropore, and pectinirhombs 1 and 5, and 12 and 18, in *Trimerocystis* will then lie between R I and R IV, and pectinirhombs 14 and 15 between R V and R IV. The three following diagrams will make this correlation more clear:

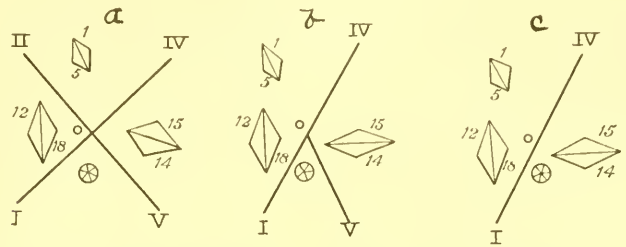

FIG. 33.—Diagram showing relation of ambulacra in (*a*) *Tetracystis*, (*b*) *Trimerocystis*, and (*c*) *Pseudocrinites*.

For these reasons the writer has changed the nomenclature of the rays in *Pseudocrinites* from R II and R V to R I and R IV.

Though *Trimerocystis* is based on a single specimen, having obvious relations to *Pseudocrinites clarki*, it cannot be regarded as a monstrosity of that species, because the two forms do not occur in the same bed. *Trimerocystis peculiaris* was not found in the cystid horizon at Keyser, but above it (probably less than 10 feet), in association with *Camarocrinus*, and is the only known cystid in this zone. Under these circumstances, and in order that the generic definition of *Pseudocrinites* may stand, the writer has deemed it advisable to erect a new genus for this 3-rayed type.

TRIMEROCYSTIS PECULIARIS n. sp.

(PLATE XXXV, FIGURES 1–3)

Length of theca 35 mm.; width 26 mm.; depth 20 mm. Base of theca deeply excavated and occupied by a stout column. For general form, shape of individual plates and their ornamentation, see figures 1–3, plate XXXV, and text-figure 34.

Ambulacra prominent, rounded, extending along three sides, bent around the excavated base of the theca, and touching the column. Each ambulacrum has on one side about 30 brachioles, or 60 to each ray, and about 180 on the entire theca. Brachioles apparently not very stout nor long, and composed of rather large pieces. Ambulacral grooves narrow, but deep, and covered by a series of small ambulacralia arranged much as in *Pseudocrinites perdewi*, with the pieces somewhat larger.

Basal pectinirhomb and that on plates 12 and 18, each with about 75 dichopores, and that on plates 14 and 15 with about 110.

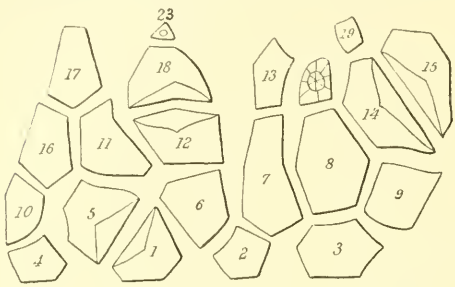

FIG. 34.—Analysis of *Trimerocystis peculiaris* n. sp.

Madreporite large and the hydropore immediately in front of it somewhat larger than in *Pseudocrinites*. Both are situated on plate 23.

Anal pyramid composed of 7 pieces, and surrounded by another circle of larger pieces of which there appear to be 7 or 8. The anal area lies between plates 7, 8, 13, and 14.

Column very stout. Length unknown.

Formation and locality.—From bed 4 (see page 203) of the Manlius formation in the Keyser quarries, associated with *Camarocrinus, Tentaculites gyracanthus*, and *Calymmene camerata*. The holotype was found by Mr. Joseph Gambino, foreman in the quarries.

Cat. number 35,064, U. S. N. M.

Staurocystis Haeckel

Pseudocrinites FORBES (partim), Mem. Geol. Surv. Great Britain, II, pt. II, 1848, p. 498, pl. xiii, figs. 1–13.

Staurocystis HAECKEL, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 134.—JAEKEL, Stammesgeschichte der Pelmatozoen, Berlin, I, 1899, p. 285.

Lepadocrinus BATHER (partim), Treatise on Zoology, III, Echinoderma, London, 1900, p. 61.

Haeckel's definition, translated, is as follows: "Callocystida with 4 simple, equal ambulacra, which form a regular rectangular cross, and extend along the 4 edges of the theca to the column. Theca 4-sided prismatic, and quadrate in transverse section. Three pectinirhombs (3 paired adanals and an unpaired baso-frontal)."

Genotype, *Pseudocrinites quadrifasciatus* Pearce.

This definition does not point out any essential characters of the genus further than that it has 4 ambulacra. As other genera of this family have the same number, the genotype must furnish the detailed generic characters.

Jaekel's definition, translated, reads as follows: "Theca oval, with 4 ambulacra having numerous crowded brachioles. Anal area small, between plates 7, 8, 13, and 14; one basal and 2 upper pectinirhombs

normally situated, with long angulated rhombs and numerous single pores."

His remarks are as follows: "The theca on account of the 4 ambulacra is 8-sided in transverse section; the free sides are slightly domed and in the middle are nearly twice as wide as the ambulacra. Plate 14 abuts but very little against the anal area. The 4 ambulacra are the same as those of the Apiocystids, namely R I, R II, R IV, R V. They are equally developed and without exception continue to the base of the column. The number of brachioles is about 40 to each ambulacrum. The anus and the pectinirhombs, built and situated as in *Pseudocrinites,* are equally divided on the thecal sides between the ambulacra, so that the anus lies between R IV and R V, the basal rhomb between R I and R II, and the upper rhombs, one in each of the other two areas." For reasons mentioned in discussing *Trimerocystis,* the present writer regards the anus as between R I and R V.

The description and figures show clearly that *Staurocystis* is very closely related to *Pseudocrinites,* the plate structure being precisely the same in both; this is also true of the structural detail in the ambulacra. The former genus differs from the latter only in being 8-sided (essentially 4-sided) and in having 4 full-length ambulacra, *Pseudocrinites* being 2-sided and having but 2 ambulacra. Though *Trimerocystis,* also, is closely related, it differs from the other two, not only in being 6-sided (essentially 3-sided) and in having 3 ambulacra, but also in the arrangement of the thecal plates. These 3 genera agree in this, that the anal area consists of 2 circles of pieces and is placed between plates 7, 8, 13, and 14. *Pseudocrinites* and *Staurocystis* further agree in having the plates of the theca arranged alike, but in *Trimerocystis* they are disposed differently. This difference may best be expressed in tabular form, thus:

	Basal Circle	Circle 2	Circle 3	Circle 4
Pseudocrinites	4-1-2-3	5-6-7-8-9	10-11-12-14	16-17-18-13-19-15
Staurocystis	4-1-2-3	5-6-7-8-9	10-11-12-14	16-17-18-13-19-15
Trimerocystis	4-1-2-3	10-5-6-7-8-9	16-11-12-14	17-18-13-19-15

Forbes's figure 7 shows the anal area surrounded by plates 7, 8, 13, 19, and 14, but in his description he adds that "there is not sufficient material to make out the arrangement of the plates completely" (p. 499). Jaekel's diagram of this region, however, shows that plate 19 of Forbes is a part of plate 13, and that the arrangement of the thecal plates around the anal area is as stated above, i. e., 7, 8, 13, and 14.

In the *Treatise on Zoology*, Bather makes *Staurocystis* a synonym of *Lepocrinites* (*Lepadocrinus*), without, as the writer believes, sufficient reason. In the latter genus the ambulacra are more depressed and excavated into the thecal plates, are only half the length of the theca, and have relatively fewer brachioles. In *Pseudocrinites*, *Staurocystis*, and *Trimerocystis* the ambulacra are very conspicuous, highly arched, as long as the theca (with one exception), and have numerous brachioles. Added to these differences, the anal area in *Lepocrinites* is bounded only by plates 7, 8, and 13, yet in the other two genera these and plate 14 delimit this area. In *Lepocrinites*, furthermore, plates 7 and 8 are shorter than in the other genera, allowing plate 14 to enter the third circle, while in the others this plate is a member of the fourth circle.

Of *Staurocystis* but a single species is known, *S. quadrifasciatus* (Pearce). This occurs in the Wenlock limestone and Lower Ludlow of England.

Subfamily CALLOCYSTINÆ Jaekel

Callocystidæ in which the ambulacra bifurcate. Brachioles widely separated. Thecal plates variously arranged, owing to the plates of the higher rings shoving into the lower ones.

Callocystites Hall

Callocystites HALL, Nat. Hist. New York, Pal., II, 1852, pp. 238, 248.—HALL, ibidem, III, 1859, p. 151.—JAEKEL, Stammesgeschichte der Pelmatozoen, I, Thecoidea und Cystoidea, 1899, p. 289.—GRABAU, Bull. N. Y. State Mus., IX, 1901, p. 151.—GRABAU, Bull. Buffalo Soc. Nat. Sci., VII, 1901, p. 151.

Callocystis BATHER, Treatise on Zoology, III, Echinoderma, London, 1900, p. 62, text-fig. 31.

Anthocystis HAECKEL, Amphorideen und Cystoideen, Festschrift Carl Gegenbaur, Leipzig, 1896, p. 132, pl. 3, figs. 23, 24.

Emended definition.—Callocystinæ with the theca olive-shaped, the oral end being more attenuated and bluntly pointed, while the base is flat or truncated. Theca with 25 plates arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 5, (11), 6, 12, 8, 14, 9, 10.

Third row has plates 16, (11), 17, 18, 13, 19, 15.

Fourth row has deltoids 20, 21, 22, 23 double, and 24. Hydropore and madreporite on the 2 parts of plate 23. The former is closed by a pyramid. (See text-figure 35.)

Anal area bounded by thecal plates 7, 8, and 13. Anal pyramid composed of 5 or 6 plates and surrounded by a ring of many minute pieces.

One basal and 2 upper generally discrete and rarely closely adjoining pectinirhombs, each discrete-rhomb being generally completely bounded by a highly elevated thickened margin.

Ambulacra wide and prominent, consisting of 5 simple ones or one or all of the rays may divide once, so that there may be from 5 to 10 ambulacra near the base of the theca. Brachioles widely separated, slender, and very long.

Genotype, *C. jewettii* Hall.

Jaekel gives 24 plates in his diagram of *Callocystites*, but it is certain that 25 are present. Bather, basing his diagram on Hall's work, also gives 25. The difference lies in the fact that plates 24 and half of 23, which are separate in the present specimens, are united by Jaekel.

The irregular variation in the branching of the ambulacra led the latter author to state that it "gives one the impression of a degeneration process." To the present writer it appears just the opposite, for if *Callocystites* is descended from a form having throughout life 5 simple rays, then the bifurcation of the rays beginning in *Callocystites* and developing to an extreme in *Sphærocystites* (apparently a descendant of the former) shows the course of development to be a progressive one. The degree of arm bifurcation in *Callocystites* is evidently not of specific value, and only occasionally is the primitive character of 5 simple rays maintained throughout growth in *C. jewettii*. It is to the latter type, illustrated by Hall in 1852, that Haeckel restricted the present genus, the specimens with bifurcated ambulacra being placed by him in a distinct genus under the name *Anthocystis*. In the opinion of the writer, Haeckel's generic distinction has not even the justification of a variety.

Callocystites is an American genus, of which only two species, *C. jewettii* and *C. canadensis*, are known.

CALLOCYSTITES JEWETTII Hall

(Plate XXXIV, figures 1, 2)

Callocystites jewettii Hall, Nat. Hist. New York, Pal., II, 1852, p. 239, pl. 50, figs. 1–18.—Jaekel, Stammesgeschichte der Pelmatozoen, I, Thecoidea und Cystoidea, 1899, p. 290, text-fig. 64 on p. 291, pl. 15, figs. 1–1c.—Grabau, Bull. N. Y. State Mus., IX, 1901, p. 151, text-fig. 47.—Grabau, Bull. Buffalo Soc. Nat. Sci., VII, 1901, p. 151, text-fig. 47.

Callocystis jewetti Zittel, Handbuch der Palæontologie, I, 1879, p. 410, text-fig. 290; p. 421, text-fig. 297.—Haeckel, Amphorideen und Cystoideen, etc., 1896, p. 131, pl. 3, figs. 21, 22.—Bather, Treatise on Zoology, III, Echinoderma, 1900, p. 62, text-fig. 31.

Anthocystis halliana Haeckel, Amphorideen und Cystoideen, etc., 1896, p. 132, pl. 3, figs. 23, 24.

Length of largest theca seen nearly 35 mm., while the average length for a matured specimen is about 28 mm.

Ambulacra prominent and wide, extending to near the base of the theca. In some mature individuals the 5 primary ambulacra remain simple; in others all bifurcate once, making 10 ambulacra near the base of the theca; in others still, all branch except the ray to the left

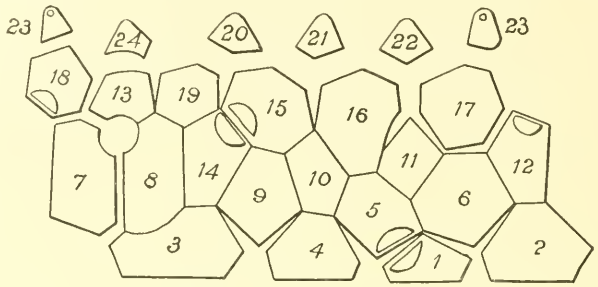

FIG. 35.—Analysis of *Callocystites jewettii* Hall, somewhat altered after Jaekel.

of the anus and the one to the left of the lower pectinirhomb. In *C. canadensis* further types of bifurcation occur, thus making it probable that any 1 or 2 of the rays may remain simple while the others divide. There is also no regularity in the period of branching, but as a rule it takes place before half the size of the theca is attained. On mature examples each simple or branched ambulacrum has on one of the outer sides about 11 brachioles; on the inner side of the branches about 6 or 7. Brachioles very long and slender, from 11 to 12 mm. in length, and composed of about 30 to 32 pieces in each range. Ambulacral grooves wide, not very deep, and covered by a series of very minute quadrangular ambulacralia of which there are in one range about 14 to 16 between each brachiole.

Basal pectinirhomb with about 17 pores, the upper ones varying between 12 and 15. Each rhomb usually is completely surrounded by a high, thickened wall. The walls are most prominent on plates 5, 12, and 14.

Madeporite ∞ -shaped and situated on the 2 parts of plate 23. Hydropore immediately beneath the madreporite, very small, and closed by a pyramid of 4 pieces.

Anal area not prominent, the pyramid composed of 5 or 6 pieces, and surrounded by a complete ring of 13 minute plates of variable size.

Column very stout, with thick joints near the theca, tapering rapidly in the upper half and more slowly beneath. Total length

unknown but exceeding 6 cm. The upper half is composed of about 22 stout, highly carinated segments, the lower ones having the periphery more and more crenated. The lower half of the column is composed of high and slender, longitudinally striate segments.

The form with divided ambulacra, which Hall described and illustrated as the typical form of *C. jewettii*, was taken by Haeckel as the genotype for his genus *Anthocystis*, and named *A. halliana*. Jaekel considers the form with 5 unbranched ambulacra as possibly worthy of specific distinction, but with justice adds "in no case can one make it, as Haeckel has done, displace the type of *Callocystites*." In the present instance it is not regarded as worthy even of a varietal name.

Formation and locality.—When the Erie canal was dug, Colonel Jewett obtained quite a number of specimens in the Rochester shales about Lockport, New York, but the species is now a very rare one. In recent years Mr. J. Pettit found a number of excellent examples at Grimsby, Ontario, in the same geological horizon. These are now in the collection of Dr. B. E. Walker, Toronto, Canada, and were kindly lent to the writer for study.

Cat. number 35,136, U. S. N. M. Presented by Dr. Walker.

CALLOCYSTITES CANADENSIS (Billings)

(Plate XXXIV, figure 3)

Apiocystites canadensis Billings, Geol. Surv. Canada, Cat. Sil. Foss. Anticosti, 1866, p. 90.

Callocystites tripectinatus Ringueberg, Bull. Buffalo Soc. Nat. Sci., v, 1886, p. 12, pl. 1, fig. 10.

This species is distinguished by the fact that the 2 halves of each pectinirhomb closely adjoin, there being no high, separating walls between them as in *C. jewettii*. When this feature is well preserved, as in a not fully mature specimen in Dr. Walker's collection and in the types of *C. tripectinatus* and *Apiocystites canadensis*, it is very striking. That the ambulacra in this species more often remain simple has no marked value, because some specimens have bifurcated arms, and in *C. jewettii* fully mature examples are also seen to have but 5 simple ambulacra. In a small but very fine, typical example of *C. canadensis*, all the ambulacra bifurcate once except the one to the right of the anus. In a larger but less typical specimen 4 of the ambulacra divide, but in this case the simple one is to the left of the anus.

Billings distinguishes his *Apiocystites canadensis* from *A. elegans* Hall by the 5 arms and the rhombs "not double, but single, i. e., the two triangles, of which each is composed, have their bases in contact,

the elongated pores being continuous across the suture between the two plates on which each rhomb is situated." He also calls attention to the fact that one arm is shorter than the others. The holotype, now preserved in the collections of the Geological Survey of Canada, and kindly loaned to the writer by Professor Whiteaves, shows that the character of the rhombs and the number of arms are those of *Callocystites* and not of *Apiocystites*. Moreover, the other Canadian specimens studied by the writer come from the identical locality that furnished Billings's type. Both were collected by Mr. J. Pettit.

Ringueberg's *C. tripectinatus* is also a 5-armed individual, the rays having unequal length. Two of the rays are "slightly bifid at their lower extremity." His differential specific character is the "paired hydrospires" in contradistinction to the separated ones in *C. jewettii*. As he does not mention Billings's species *Apiocystites canadensis*, he was probably unaware of the identical type of pectinirhomb in that form.

Formation and locality.—Rochester shales at Grimsby, Ontario. Three specimens, collected by Mr. J. Pettit and now in Dr. Walker's collection. Another specimen was found near Lockport, New York, by Mr. Ringueberg.

Cat. number 35,135, U. S. N. M. Presented by Dr. Walker.

Cœlocystis Schuchert

Hemicosmites HALL (not von Buch), Twentieth Rep. N. Y. State Cab. Nat. Hist., rev. ed., 1868 [1870], p. 359.

Sphærocystites JAEKEL (not Hall), Stammesgeschichte der Pelmatozoen, Berlin, I, 1899, p. 289, fig. 63; also p. 307.

Cœlocystis SCHUCHERT, Amer. Geol., XXXII, 1903, p. 234.

Until recently, *Sphærocystites* seems to have been based on a single example—the holotype of *S. multifasciatus*. As this specimen did not permit Hall to make out the thecal structure, Jaekel gave the plate formula for the genus, basing it on *S. dolomiticus* Jaekel = *Hemicosmites subglobosus* Hall. In the present work the plate formula for *Sphærocystites* is based on the genotype *S. multifasciatus*, and this study has shown that Jaekel's type belongs to another and more primitive genus. For this reason the Niagaran form is here distinguished under the genus *Cœlocystis*, the name having reference to the deeply invaginated base of the theca.

Hemicosmites is a quite different form, as the plate formula is $4 + 6 + 9 + 9$, anal area 7, 8, and 13 (see Bather, *Treatise on Zoology*, III, *Echinoderma*, London, 1900, p. 68, fig. 3).

Definition.—Callocystinæ? having a depressed globular theca with a deeply invaginated base, and normally composed of 24 plates arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 10, 5, 6, 12, 7, 8, 14, 9.

Third row has plates 16, 11, 17, 18, 13, 19, 15.

Fourth row has deltoids 20, 21, 22, 23 double, and 24.

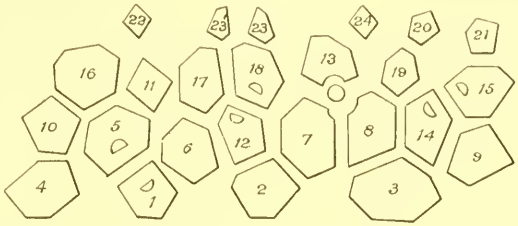

FIG. 36.—Analysis of *Calocystis subglobosus* (Hall).

Anal area bounded by plates 7, 8, and 13. The anal pyramid is apparently not surrounded by a circle of small plates as in *Sphærocystites*.

Pectinirhombs normally situated, small, discrete, and with but few dichopores.

As all the specimens are internal casts of the theca, the nature of the ambulacra, anal area, sculpture, and the column cannot be stated.

Genotype, *Hemicosmites subglobosus* Hall.

The foregoing definition and the diagrams here given show that *Calocystis* differs widely from *Sphærocystites* in that it has 6 additional plates and these have a quite different arrangement. The second row of the former genus has all the plates of the latter and in addition plates 10, 12, and 14; the third row has 7 plates and includes all the plates of the fourth row in *Sphærocystites,* while the deltoids of the fourth row in *Calocystis,* 5 in number, are not present (except 23 which is not double) in *Sphærocystites*.

A comparison of this diagram with that of *Sphærocystites* Jaekel (not Hall), in the work cited, shows that that author omitted plate 10 in the second row. Jaekel's diagram therefore has 24 plates, while that here represented has 25, counting the parts of plate 23 as separate pieces. The writer's material is excellent, and while considerable variation in the shape of the plates exists in different specimens, there seems to be little chance for error in the interpretation of their arrangement as given in text-figure 36.

Dr. B. E. Walker, of Toronto, Canada, has presented to the National Museum a very well-preserved specimen of *C. subglobosus*, which differs from all others in shape and in the number of plates. It is more globose, higher, and somewhat more drawn out posteriorly. The anal tube also protrudes more than is usual. This specimen, instead of having 25 plates, the normal number, has 29, as shown in the following diagram. An analysis based on normal specimens leads

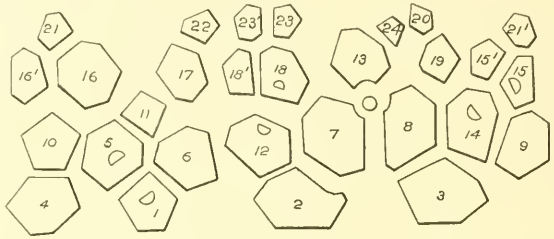

FIG. 37.—Analysis of an abnormal specimen of *Cœlocystis subglobosus* (Hall).

to the conclusion that plates 15, 16, 18, and 21 are divided, thus producing the 4 additional plates. It seems rather odd that division in these plates takes place so irregularly; 2 of the plates bear pectinirhombs, one being a simple thecal plate, and the other a deltoid.

The only species of this genus is *C. subglobosus* (Hall).

CŒLOCYSTIS SUBGLOBOSUS (Hall)

Hemicosmites subglobosus HALL, Twentieth Rep. N. Y. State Cab. Nat. Hist., rev. ed., 1868 [1870], p. 359, pl. 12, fig. 13.

Sphærocystites dolomiticus JAEKEL, Stammesgeschichte der Pelmatozoen, Berlin, I, 1899, p. 289, fig. 63.

Cœlocystis subglobosus SCHUCHERT, Amer. Geol., XXXII, 1903, p. 235.

Rare in the Niagaran limestone about Chicago, Illinois. See text-figures 36 and 37 for the analysis of two specimens of this species.

Cat. numbers 35,061 and 35,155, U. S. N. M.

Sphærocystites Hall

Sphærocystites HALL, Amer. Jour. Sci. (2), XXV, 1858, p. 279.—HALL, Nat. Hist. N. Y., Pal., III, 1859, p. 130.—SCHUCHERT, Amer. Geol., XXXII, 1903, p. 232.

Sphærocystis HAECKEL, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 133.—BATHER, Treatise on Zoology, III, Echinoderma, London, 1900, p. 63.

Original definition.—"Body spheroidal, wider than high. Arms in two principal pairs, with numerous bifurcations. Brachial sulci obliquely lobed. Mouth longitudinal ? apical: anus [=madreporite] subapical: ovarian [=anus] opening upon the summit.

Basal plates four; those of the series above not determined. Base depressed. The species have the general aspect of *Callocystites* or *Lepadocrinus*. Column unknown."

Jaekel's[1] definition of *Sphærocystites* cannot be accepted, as it is not based on the genotype *S. multifasciatus*, but on *S. dolomiticus* Jaekel (= *Hemicosmites subglobosus* Hall) of the Niagaran dolomites of Chicago, Illinois. The latter species, having a greater number and a different arrangement of thecal plates, has been made the type of *Cælocystis*.

Emended definition.—Callocystinæ with the theca varying between depressed echinus-shape with a deeply excavated base to elongate-globular form with almost no excavated base. Theca with 18 plates arranged as follows:

Basal row has plates 4, 1, 2, 3.

Second row has plates 5, 6 (sometimes part of 12), 7, 8, 9.

Third row has plates 10, 11, 12, (7, 8), 14.

Fourth row has plates 16 (17 absent), 18, 13 (19 absent), 15.

Fifth row has deltoid 23, with madreporite and hydropore.

Anal area not prominent, bounded by thecal plates 7, 8, and 13. It is composed of 2 circles of plates, an outer of from 10 to 14 pieces of variable size, and the pyramid with 6 or 8 pieces.

One basal and 2 upper discrete-pectinirhombs, with numerous dichopores.

Ambulacra not much elevated above, and but slightly excavated into, the theca, beginning with 4 rays and bifurcating variously in different specimens of the same species, until 27 branchlets result. Brachioles widely separated, slender, short and club-shaped.

Madreporite large, with a small hydropore immediately below. The latter is closed by a pyramid of 4 or 5 pieces.

Column stout, tapering rapidly for a short distance and then hardly at all throughout the remainder of its length. Total length about 95 mm. Base of attachment terminating in a few roots.

Genotype, *S. multifasciatus* Hall.

To the foregoing description should be added the fact that in *S. multifasciatus* plate 12 enters the second row and rests partly on plate 6 and directly on plate 2 of the basal row. This is due to the depressed form of the theca. In *S. globularis* the case is different, as plate 12 rests directly on plate 6.

The feature distinguishing *Sphærocystites* from all the associated genera is that the theca has but 18 plates. Plates 17 and 19 of other

[1] Stammesgeschichte, etc., 1, 1899, pp. 288–9.

genera are here absent. Another marked feature is that the 4 primary ambulacra are abundantly branched.

SPHÆROCYSTITES MULTIFASCIATUS Hall

(PLATE XXXVIII, FIGURES 1, 2; PLATE XXXIX, FIGURES 1–4)

Sphærocystites multifasciatus HALL, Nat. Hist. N. Y., Pal., III, 1859, p. 130, pl. 7A, figs. 1–4.—JAEKEL, Stammesgeschichte der Pelmatozoen, Berlin, I, 1899, p. 289.—SCHUCHERT, Amer. Geol., XXXII, 1903, p. 233.
Sphærocystis multifasciatus HAECKEL, Die Amphorideen und Cystoideen, Beitr. Morph. u. Phyl. d. Echinodermen, Leipzig, 1896, p. 133.

Length of one of the largest theca 19 mm.; transverse diameter in both directions 24 mm. Another large theca has a length of 19 mm.; diameter in the direction of the two upper pectinirhombs 20 mm., and in the opposite direction through the anus 22 mm. A greatly depressed specimen has a length of 13 mm., and a diameter of 20 mm. A young theca has a length and diameter of 9 mm. Base of theca more or less excavated, greatest in the depressed specimens. Plate 12 rests on basal plate 2. For general form, shape of individual plates and their ornamentation, see the plate-figures and diagram.

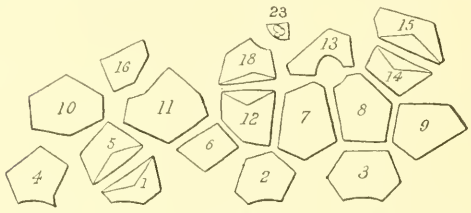

FIG. 38.—Analysis of *Sphærocystites multifasciatus* Hall.

Ambulacra 4, branching rapidly and with no apparent regularity, the branches varying between 14 in the youngest to 27 in the largest

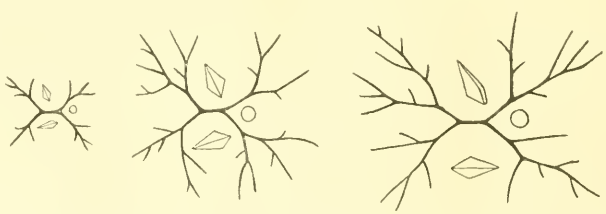

FIG. 39.—Diagrams showing the manner and number of ambulacral branches in a young, adult, and old specimen of *S. multifasciatus* Hall.

theca. These spread between and around the anus and pectinirhombs until the greater portion of thecal surface is occupied by them, obscuring the suture lines between the thecal plates. Brach-

ioles widely separated, about 3 in 5 mm.; club-shaped, tapering to a point, and about 3 mm. long. Ambulacrals large, to each of which there are about 5 ambulacralia.

Dichopores in sharply delimited, low, angulated, discrete pits; in other words, the grooves of the 2 parts of the pectinirhombs do not meet each other at the suture lines of the plates of which they are a part, but are restricted to the prominent pits. From 40 to 45 grooves in each pit.

Anal pyramid depressed, composed of 6 pieces and surrounded by a ring of 3 large aboral and 7 small oral pieces.

Hydropore minute, closed by a pyramid of 4 pieces, and situated immediately in front of the large madreporite occupying the greater portion of plate 18.

Column slender, with about 16 stout and equally large segments beneath the theca, followed by others of unequal size of which the larger segments are widely separated.

Formation and locality.—Hall states that his specimen came from "the limestones of the Lower Helderberg group, Cumberland, Maryland." This usage of "Lower Helderberg" is the old one, now obsolete, including the Tentaculite limestone or Manlius formation. About Cumberland, this species is very rare, probably not more than four specimens are known, but in the quarries near Keyser, West Virginia, more than 4,000 specimens have been picked up during the last three years. Here they range through the middle layers for about 37 feet, associated with the other common cystids, *S. globularis, Pseudocrinites gordoni, Jaekelocystis hartleyi,* and several species of crinoids.

Cat. numbers 35,052, 35,058, U. S. N. M.

SPHÆROCYSTITES BLOOMFIELDENSIS n. sp.

Length of theca 14 mm.; diameter 15 to 16 mm. Depressed globular, with the base not excavated.

Thecal plates arranged as in *S. globularis;* otherwise this species is closely related to *S. multifasciatus.*

Of this form, the two known thecæ were greatly exfoliated in breaking them from the shaly limestone, so that most of the specific characters are not determinable. However, the shape allies the species with *S. multifasciatus* from which it differs in having no excavated base and in plate 12 not resting on plate 2 of the basal row, but upon plate 6 of the second row as in *S. globularis.* It probably differs further, not only in the smaller and more spheroidal theca, but also in having the ambulacra less branched. From *S. globularis* it is distinguished

by the more depressed theca and more strongly sculptured plates. In *S. bloomfieldensis,* plate 18 is much larger than in the other two species, and the madreporite is therefore comparatively more conspicuous.

Formation and locality.—The writer found this species at the base of the Manlius, at Clark's Mill, near New Bloomfield, Pennsylvania. It appears to have been a common form, as the separated thecal plates occur abundantly. It is associated with *Pseudocrinites claypolei.*

Cat. number 35,059, U. S. N. M.

SPHÆROCYSTITES GLOBULARIS Schuchert

(PLATE XXXVIII, FIGURES 3–5; PLATE XXXIX, FIGURES 5, 6)

Sphærocystites globularis SCHUCHERT, Amer. Geol., XXXII, 1903, p. 233.

Length of a large and regular theca 22 mm.; transverse diameter 20–21 mm. Base not excavated. Plate 12 resting on plate 6 of the second circle.

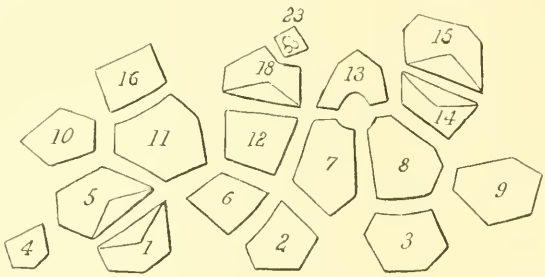

FIG. 40.—Analysis of *Sphærocystites globularis* Schuchert.

Ambulacra branching with no apparent regularity, the branches in adults varying between 9 and 14. Ambulacralia about 7 to each ambulacral.

Anal pyramid depressed, composed of 8 pieces, and surrounded by a ring of 4 large and 10 small plates.

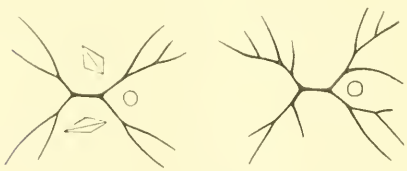

FIG. 41.—Diagrams showing the number of ambulacral branches in two specimens of *S. globularis* Schuchert.

Hydropore minute, closed by a pyramid of 5 pieces, and situated immediately in front of the elongate dumb-bell-shaped madreporite on plate 21.

Column tapering rapidly for a very short distance and then hardly at all throughout the remainder of its length. Total length

about 95 mm., with the root end about 7 mm. high. First 11 segments beneath the theca thinnest, with angulated peripheries, followed by about 65 segments of nearly equal size and rounded edges.

This species is readily distinguished from the associated *S. multifasciatus* by the globular form of the theca, the non-excavated base, the smaller number of ambulacral branches, thus causing the surface to appear smoother; finally, by the higher position of plate 12, which does not attain the basal row as in that species.

Formation and locality.—Not rare in the cystid beds of the Manlius in the quarries near Keyser, West Virginia.

A specimen with the entire column was found by Mr. Gordon in the bryozoa beds of the Manlius, at Devil's Backbone, near Cumberland, Maryland.

Cat. numbers 35,053, 35,077, U. S. N. M.

S. GLOBULARIS OVALIS n. var.

(PLATE XXXVIII, FIGURE 6)

Associated with *S. globularis* are specimens that attract attention on account of their more elongate and regularly ovate thecæ. These specimens never attain the size of that species, however, and they commonly retain a portion of the column, a feature much more rare than in the variety *ovalis*. In addition to the smaller size, and the rounded-ovate outline of the theca, the variety is further distinguishable in always having the 4 ambulacra less bifurcate. The number of branchlets varies between 5 and 10, the average being 6 or 7. In 13 specimens, the ambulacra divided as follows: 1 with 5 branchlets, 4 with 6, 4 with 7, 2 with 8, 1 with 9, and 1 with 10. In *S. globularis* the average number of branchlets is between 10 and 12.

Cat. number 35,054, U. S. N. M.

Class *CRINOIDEA*

? Order MONOCYCLICA CAMERATA

Family CAMAROCRINIDÆ Barrande (emend.)

Camarocrinus Hall

Camarocrinus HALL, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., Mus. ed., 1879, pp. 205–6; extract, 4°, with additions, 1880, pp. 3–5.—ZITTEL, Grundzüge der Palæontologie, 1895, p. 154.—ZITTEL and EASTMAN, Text-book of Palæontology, 1896, p. 183.—HAECKEL, Die Amphorideen und Cystoideen, Leipzig, 1896, pp. 168–169.—BARRANDE and WAAGEN, Syst. Sil. du Centre de la Bohême, VII, pt. 1, 1897, p. 1.—BATHER, Treatise on Zoology, III, Echinoderma, 1900, pp. 77, 136, 161.

This imperfectly understood echinoderm has been variously regarded as the float or the inflated root end of a crinoid or the theca of a cystid. These bodies have recently been found in considerable numbers in such widely separated localities as Maryland, Tennessee, and Indian Territory. The material from the last region is best preserved and permits of the determination of every detail.

The writer has been enabled to work out much that is new regarding the minute structure of these objects as well as their occurrence in the strata. Before proceeding to their description, however, it is deemed advisable to give a rather full account of what others have said about them, followed by a statement as to their occurrence in the various geological formations.

History of the Genus

The first American to find *Camarocrinus* appears to have been John Gebhard, Jr., of Schoharie, New York. Dr. John M. Clarke, in a letter to the writer dated Albany, New York, January 7, 1904, furnished the following interesting statement: "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 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*."

Hall describes *Camarocrinus* as follows:

"Body large, externally lobed, chambered within, varying from transversely or longitudinally oblate-spheroidal to subspherical, and frequently assuming an unsymmetrical form from the unequal development of the lobes corresponding to the internal chambers. The cavity of the body or dome is divided into two or more large compartments, with usually several smaller accessory chambers, by vertical and horizontal partitions which are extensions of the substance of the inner walls of the dome.

"The basal portion occupies a subcircular area, which is placed in a central position with regard to the disposition of the lobes of the body, and is surrounded by an elevated projection or extension of the walls. In structure this area is composed of spreading, radiciform, bifurcating rays, connected by irregular polygonal plates. The basal rays are composed of joints similar to those of an ordinary crinoidal column, and vary in number from five to twelve or more, and are arranged symmetrically with respect to two axes at right angles; they bifurcate at the third or fourth segment from their origin, and enclose ambulacral openings which penetrate into the interior cavities of the body.

"The external wall of the dome is composed of two distinct layers, of which the infolding and extension of the inner one forms the partitions dividing the chambers. No traces of free arms have been observed. Column cylindrical, smooth near the body; the segments regular. The interior canal is five lobed, and is divided and continued through the basal rays and their ramifications; not opening into any interior cavity of the body, so far as observed."

Hall's remarks on this fossil 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 *Medusæ* and *Comatulæ*. 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 or centers."

Barrande in Waagen states the following:

"The family of Lobolithes is known only by the publication of Prof. J. Hall under the name of *Camarocrinus*.

"Indeed for more than forty years we have shown visiting savants these remarkable specimens in our collection, which, however, we do not suppose have made a deep impression on their minds. We announced these under the new name, Lobolithes, but have not called attention to them by a proper publication. The time has been lacking.

"We now show the very diverse forms of this family on 13 plates numbered 67 to 79 [not yet published].

"At this time we will not make comparisons between Lobolithes and related families as the Cystidea and Crinoidea. A cursory examination of the 13 plates by an intelligent student will at once show him that our new echinoderms are distinguished by the absence of all regularity in their structure."

Zittel's description, as translated by Eastman, is as follows:

"Family 3. Camarocystidae. Barrande.

"Calyx globose or discoid, composed of numerous polygonal plates, and sometimes fixed by the ventral surface [this seems to refer only to *Lichenocrinus* as will be seen later]. Interior of calyx divided into four to six compartments by partitions corresponding in position to lobes on the exterior. Stem long and slender. Silurian.

"This family embraces two genera whose systematic position is still doubtful. The larger, *Camarocrinus*, Hall (= *Lobolithes*, Barrande), occurs in the middle and upper members of the Silurian in North America and Bohemia, and attains considerable size. The smaller, *Lichenocrinus*, Hall, is more or less crateriform, has a very long, tapering stem, and is invariably attached by its flattened ventral surface. It is found in the Ordovician (Hudson River Group) of North America."

It should be stated that *Lichenocrinus* has no direct relationship with *Camarocrinus*, as it is a sessile body with a long column; the base is composed of an upper series of small porous plates beneath which is a very thin chamber with the basal layer finely striate radially. There are no camaræ like those in *Camarocrinus*. The latter, on the other hand, is a free body, and is never sessile nor cemented to foreign objects as is *Lichenocrinus*.

Haeckel's remarks, translated, are as follows:

"In the Silurian System of Bohemia Barrande discovered quite 50 years ago the remains of large Echinoderma to which, in the 'Programme Generale' of his large work on Cystidea, he has applied the name *Lobolithus* (Syst. Sil. du Centre de la Bohême, VII, 1887,

p. 1). He regarded them as the type of a new and peculiar class of Echinoderma, differing in their composition from all others 'by the absence of all regularity.' These remarkable, irregularly rounded, bladder-like bodies, attaining a diameter of several (up to 18) centimeters, have been figured by Barrande on 13 plates, not yet published, of his work (provisionally designated as plates 67 to 79).

"Similar bodies were found later in the Silurian of North America by James Hall; at first (1872) he described them as Cystids [this is an error, as the citation given seems to have reference to a paper on *Cyclocystoides*]. Later (1879) he declared them to be modified, bladder-like, swelled roots of true crinoids, an air-filled swimming apparatus. This view is also held, as I have learned through correspondence, by the Vienna geologists, Professor Waagen and Dr. Jahn, who have carefully studied the Bohemian Lobolithes and who will publish the plates of Barrande with descriptions. . . .

"In a letter from Zittel I learn that he also is now of the same opinion as Hall, Waagen, and Jahn.

"The 13 lithographed plates of Barrande, which I have seen, have figures of many Lobolithes of natural size: they are globular, or irregularly rounded cysts or bulbs, with thick walls consisting of small polygonal plates. Most of the capsules have the size of a child's head; the largest attain a diameter of 0.2 meter and over. The plates, with their peculiar structure, when magnified, show that we are here dealing with Echinoderma. A first inspection of many figures might lead one to regard them as irregular mailed-capsules of simple Amphorids, similar to *Aristocystis, Deutocystis*, etc. Against this determination, however, there are two decided facts: I. The mailed-capsules show no openings [they have many large openings] but are completely closed. On one end they rested directly on the sea bottom (they are as the description states 'cemented by the flattened crown') [this is never the case in either *Camarocrinus* or *Lobolithus*]; on the opposite side there arises a slender column, which may attain a length of several meters. II. The column is five-sided, prismatic, segmented, and has wholly the structure of an ordinary crinoid column; the single segments show on the articulating surfaces a central opening (stone canal) and a regular five-rayed stellate figure. This characteristic structure is entirely restricted to the class Crinoidea, and occurs in no other Echinoderma; it is absent in the true Cystoidea and in the Amphoridea as well. This fact indicates that in the Crinoidea alone the 'chambered organ', or the five-chambered tube, extends from the base of the cup through the hollow segmented column. In the Cystoidea, on the other hand, the pentaradial structure is restricted to the theca.

"A personal examination of well-preserved Lobolithes has enabled me to convince myself that the view of Dr. Jahn is correct; they are without doubt bladder-like swellings of large Crinoid columns. However, I do not regard them as 'swimming apparatus' but rather as brood-pouches or (probably) pathologic cysts caused by parasites. Similar structures have been described by Ludwig von Graff both in fossil and living crinoids, and he has furnished the proof that they are produced by the same parasites, Annelida of the genus *Myzostoma;* he compares them correctly with 'plant-galls' (Ueber einige Deformitäten an fossilen Crinoideen, Palæontolographica, Bd. 31, 1885)."

Bather, in the work cited, states:

"*Camarocrinus,* Hall (syn. *Lobolithus,* Barr.), root of a Crinoid (*Scyphocrinus,* apud Jaekel)" (p. 77).

"Another curious modification [of crinoids], perhaps connected with a free-floating existence, was presented by the root of *Scyphocrinus.* This swelled out into a hollow, chambered, balloon-like body, referred by Barrande to an independent class of Echinoderms under the name *Lobolithus,* and described by Hall as a float, which he called *Camarocrinus*" (p. 135).

Under *Scyphocrinus* Bather states "root a large hollow spheroid strengthened by internal septa, regarded as a float (= *Camarocrinus*) by Hall, as a cystid (= *Lobolithus*) by Barrande" (p. 161).

After having collected a large number of *Camarocrinus* in Maryland during 1901, the writer concluded they must be cystids, using this term in the old sense. This idea was communicated to Mr. Frank Springer, and on December 31, 1901, he wrote as follows:

"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 still 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."

Dr. Jaroslav F. Jahn, Brünn, Austria, who is preparing a monograph of Barrande's material of *Lobolithus,* writes me as follows:

"You probably know through Professor Jaekel that I regard *Lobolithus* as bladder-like root structures of crinoids that probably have served as brood-pouches [or brood-receptacles, Brutsbehälter]. I don't think these bodies are swimming apparatus, because they are too heavy."

Later the writer sent Professor Jahn a collection of *Camarocrinus*, to illustrate his own views as to the nature of these bodies. In reply was received the following comment, under date of April 3, 1904:

"After having seen the *Camarocrinus* you sent me I am convinced that *Camarocrinus* and *Lobolithus* are identical. I have never regarded *Lobolithus* as brood-sacks but as brood-receptacles [his word is Brutsbehälter]. Because I do not regard *Lobolithus* as the entire animal but as isolated skeletal parts, I prefer the older name *Lobolithus* [older only as a *nomen nudum*]. This name in itself says nothing (as *Entrochus* for columns) while *Camarocrinus* indicates an independent genus of crinoids. By *Lobolithus*, therefore, I understand, in part, crinoid-roots modified into brood-receptacles. In other words, of morphological significance I regard the Loboliths as bladder-like transformed crinoid roots, whose physiological significance is not yet entirely clear as brood-receptacles, etc. That all of these bodies do not belong to *Scyphocrinus* has always been clear to me because Loboliths also occur in Bohemia in beds where no *Scyphocrinus* has ever been found. That certain Loboliths belong to *Scyphocrinus* is proven by the circumstance that I have observed at Kuchelbad [the writer also saw one at this locality to which reference will be made later] on the exposed surfaces of the strata Loboliths connected by long columns to *Scyphocrinus* calices. The drawing of this I will publish. Of *Scyphocrinus* we know but few with attached columns; most of the columns occur isolated and these may belong to other genera. The dimensions and the form of the central canal in *Scyphocrinus* are variable. I know of Loboliths that have as thick a column as *Scyphocrinus*. Which forms of Loboliths belong to *Scyphocrinus* and which to other genera cannot of course be determined. It is remarkable that *Lobolithus* is found only in e 1β and in e 2. In f 2 they have not yet been found and it is therefore all the more remarkable that in America *Camarocrinus* (= *Lobolithus*) is restricted to beds the equivalent to our étage F, and also that *Scyphocrinus* has not yet been found in America."

The idea that *Camarocrinus* physiologically represents brood-sacks or brood-receptacles, first suggested by Haeckel and now provisionally accepted by Jahn, is so foreign to any known crinoid structure, that it was submitted to Springer for further comment. Under date of April 18, 1904, he writes:

"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 Comatulæ, 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."

Another collection was sent to Professor Jaekel, Berlin, who, under date of March 10, 1904, comments as follows:

"Hearty thanks for your sending of *Camarocrinus* which of course are very much like those of Bohemia. As both belong to very different horizons I am all the more convinced that they are bladder-like developments of roots. These at all times had an indifferent character and under similar local conditions did develop similar forms at very diverse places in the Pelmatozoa."

Mode of Occurrence of Camarocrinus in the Rocks

West Virginia.—In the ballast quarries of the B. & O. R. R. near Keyser, West Virginia, *Camarocrinus* occurs in considerable numbers in the shaly partings between thick beds of a compact, dark-blue limestone, near the middle of the Manlius formation. As the quarrymen do not care for dimension stone, and as the strata stand nearly vertically, they drill holes as deep as 15 feet for dynamite charges and throw down with one blast hundreds of tons of rock. On one of these occasions, in the summer of 1901, the writer examined the upper side of a slab of limestone many square yards in extent, and saw on it, partially buried in the rock, at least 10 *Camarocrinus*, nearly all of which presented their upper or unstalked end; apparently not more than two of the ten specimens had the stalked end uppermost. On this great slab there was not a trace of other fossils, not even a segment of the column of an echinoderm. This fact led at once to the hypothesis that *Camarocrinus* had no long stalk, and also that it did not represent the root end of a crinoid. Four good collectors, as well as the quarry foreman, have watched this layer at sundry times during the last three years, and, while hundreds of

Camarocrinus have been gathered, no crinoids have been seen. The only other Echinoderma from these layers is a single specimen of *Trimerocystis peculiaris*.

Indian Territory and Oklahoma.—In 1901 Dr. E. O. Ulrich, while engaged on stratigraphic work in Indian Territory, also found *Camarocrinus* very plentifully. Letters to the writer dated September 8 and October 1, 1901, state:

"Of Helderbergian fossils perhaps my principal find is the discovery of a well-marked *Camarocrinus* bed, which I have traced over 50 miles [later he extended its range to 100 miles] and from which I have procured something like 400 select specimens—ranging in diameter from 1 to 5 or 6 inches. Without much trouble I might have collected a thousand. To show their abundance will say that I took about one of every ten seen.

"You ask about other crinoids associated with *Camarocrinus*. 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*."

To show the mode of occurrence and abundance, Mr. Ulrich procured a small slab measuring 25 × 13 cm. On the upper surface (see plate XLIII) it shows 5 specimens having diameters ranging between 3.5 and 10 cm. Not one of these has the stalk end turned upward, there are no stalk fragments in the matrix, and but few scattered plates of crinoid brachia. The latter may belong to *Edriocrinus*, as the basal portion of this crinoid is often found attached to *Camarocrinus ulrichi*. It is noteworthy, also, that this slab was collected at one of the two localities in which a few fragments of other Crinoidea were found in association with *Camarocrinus*.

Tennessee.—In southwestern Tennessee, in the valley of Tennessee river, Mr. Foerste found many specimens of *Camarocrinus saffordi* ranging through the lower 50 feet of the Linden formation. This geologic horizon is about the equivalent of the New Scotland of the New York Helderbergian. The species was found at several places, and the present writer found three specimens considerably farther northwest, in Benton county. Nowhere in this region, in the strata here referred to, are the thecæ of crinoids found, nor does Mr. Foerste mention finding crinoidal limestone or fragments of crinoid columns. The writer saw only crushed *Camarocrinus* in Benton county and no crinoidal fragments.

It should be noted that the southwestern occurrences of *Camarocrinus* (i. e., in Tennessee and Indian Territory), are in the New

Scotland zone of the Helderbergian, which is regarded by most paleontologists as near the base of the Lower Devonic. The other American occurrences are in the lower portion of the Manlius, the last stage of the Siluric.

Bohemia.—In the summer of 1903 the writer visited one of the localities in Bohemia furnishing *Camarocrinus* and *Scyphocrinus* in association, on the same bed of limestone. This locality is an abandoned quarry in the Schwartze Schlucht near Kuchelbad, a few miles up the Moldau river from Prague. It is the locality referred to by Dr. Jahn in his letter quoted above. Here is exposed a very extensive, nearly vertical wall of black limestone, with a thin shale surface. This limestone forms a horizon near the top of E eβ of Barrande's section and is regarded as the transitional zone to E e2. The horizon is to be correlated with the American Rochester shale. On the wall are seen many flattened globular bodies, some of which are *Lobolithus*, or rather *Camarocrinus*, and poorly preserved thecæ of *Scyphocrinus*. One of the latter preserved a long column probably not less than 3 feet in length, extending toward and terminating upon a *Camarocrinus*. The evidence then appeared to the writer so convincing that he told Dr. Perner, who had guided him to the locality, that there seemed to be no longer any doubt of *Scyphocrinus* and *Camarocrinus* belonging to one species. The proof, however, was decidedly at variance with the American occurrence of *Camarocrinus*, as crinoids are never found associated with it. Finally, the writer observed that the long column of *Scyphocrinus* lying across the *Camarocrinus* was at least twice as thick as any column of the latter he had seen. Since then he has determined that the central canal in the column of *Camarocrinus* is different in shape and very much smaller in size than in the associated *Scyphocrinus* columns. These differences are illustrated in the accompanying figure 42.

FIG. 42.—Transverse sections through the stalks, *a*, of *Scyphocrinus elegans* Zenker, near theca; *b*, a thick stalk of *Camarocrinus ulrichi*, near roots.

These figures of the central canal in the column of *Scyphocrinus* are from close to the theca, but what the shape and size of this canal are near the other extremity of the column can not now be stated. Granting, for the present, that the canal near the root end has the size and shape of that in *Camarocrinus*, the size of the column in the latter is still considerably smaller than the column of *Scyphocrinus* which the writer saw lying across the bulb in the abandoned quarry near Kuchelbad. It therefore does not appear that the two parts can belong to one animal.

Camarocrinus Hall (emend.)

(PLATES XL–XLIV)

Pyriform, spheroidal or depressed spheroidal chambered bodies, composed of a great number of small plates to one end of which are attached roots and a short stalk of the same nature as those of crinoids. There is no evidence of ambulacra, mouth, or anus. Immediately inside the base of the bulb is a large, more or less pentagonal medio-basal chamber, around which are usually arranged 5 or 6, and more rarely as many as 11 variously shaped chambers. The walls of the camaræ have their origin in bifurcations of the roots beneath the stalk. The walls of the chambers are double and are made up of small, irregularly shaped plates, the walls for the greater part closely adjoining and parallel, and united to one another by many short, stout, blunt processes. Along the periphery of the theca these walls bend over quickly and unite with one another in such a manner that from 5 to 11 interradial, large hollow lobes or water chambers are formed. Each lobe has a large opening in the base of the theca immediately inside the lateral basal extension or basal rim of the outer wall. The inner walls are surrounded by an outer integument of innumerable small plates devoid of regular arrangement. The origin of this outer wall is independent of the roots. Communicating pores, irregularly distributed, exist between the plates of both the outer and inner walls, except those of the base beneath the medio-basal chamber.

In very young specimens, nearly all of the outer integument has irregularly distributed functional pores between the plates, but in older examples a more or less thick, amorphous secondary coating occurs over about one-third of that end of the bulb to which the stalk is attached, closing all the pores of this region. Very often in old specimens of *C. ulrichi*, encrusting animals are found upon this secondary coating, as *Edriocrinus*, bryozoa, and brachiopoda (*Leptænisca*). By this condition of preservation it is natural to infer that the pores between the outer plates were functional (for the oxygenation of the blood?) and that no parasitic animals attached themselves to any part of the bulb until the secondary coating was deposited.

In many of the Indian Territory specimens the lower part of the bulb is prolonged into a high, thick-walled collar 10 to 15 mm. high, and in such there is always about the same length of stalk preserved.

The shape and size of the medio-basal chamber are very variable. In some it is large and regularly pentagonal in transverse section, gradually tapering upward between the walls of the surrounding

camaræ. In others, one or more of the interior walls crowd upon this area, and this cavity then becomes very irregular in shape and much reduced in size. However, in all specimens there is more or less of a chamber just beneath the stalk and between the walls of the camaræ.

The camaræ occupy by far the larger part of the bulb and are very variable in shape, size, and number. The usual number is 5 or 6 (rarely 11), and additional chambers are introduced by bifurcation of the roots beneath the stalk. In *C. ulrichi* they often occur in pairs, and in some individuals there are 4 of these small chambers in pairs situated on opposite sides. Such specimens will have 8 or 9 chambers surrounding the medio-basal cavity. The greatest number observed is 11. Usually the number of camaræ is indicated on the outside of the theca by constrictions over the walls of the interior.

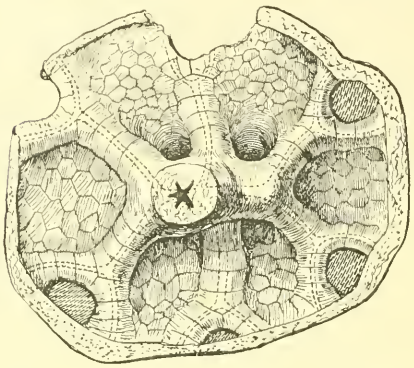

FIG. 43.—View of the base of *Camarocrinus ulrichi*; the interior canals of the roots are indicated by broken lines. × 2.

The base of the bulb inside of the more or less high collar is composed of 2 sets of plates—one series consisting of larger pieces, fairly regularly arranged, and restricted to the roots that radiate from the stalk; the other of irregularly shaped smaller plates that fill in the spaces between the root radii. The stalk is generally placed a little eccentrically to the high, most prominent or primary root member. This member usually bifurcates at each end and each division branches once more; from the lower sides of this medial member are given off from 1 to 3 other secondary branches, each of which again bifurcates distally (see text-figure 43). There are, therefore, around the inner side of the collar, from 12 to 18 and even as many as 22 branchlets, between each 2 of which is situated a more or less large opening to the chambers, there being as many of these openings, 4 to 11, as there are chambers. The roots between each bifurcation consist of from 3 to 5 plates, the place of division of the primary root member being occupied by a single wedge-shaped piece, while those on the sides usually have a double plate occupying the same position. The axial canal of the stalk does not pass through the base of the bulb and into the medio-basal chamber, but ends in the primary

root member, where it branches and connects with the canals of all the roots. The latter canals pass through all the bifurcations and continue into the outer wall communicating with the open space between the two parts of the walls. In this way vascular and nervous connection is maintained between all parts of the bulb.

The stalk is inserted into the root as a wedge (see figure 44). The length of the stalk is unknown, as the bulbs never preserve a piece longer than 15 mm. This part has thin segments, with the articular surfaces radially striate, as in crinoids, and is penetrated by a small round or pentagonal axial canal, with 5 short linear radii.

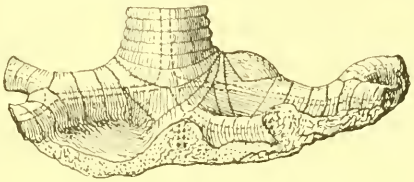

FIG. 44.—Side view of the base of *C. ulrichi,* showing how the stalk is wedged into the roots; the interior canals of the roots are indicated by broken lines. × 2.

Attached to *Camarocrinus* are sometimes found roots like those of many crinoids, as, for instance, *Eucalyptocrinus,* and these at one time were supposed also to belong to this genus, the bulb of course then being regarded as the theca of the animal. These roots, however, belong to another crinoid, as the sutures between the plates are not wavy as in *Camarocrinus.*

Genotype, *C. stellatus* Hall. The above definition, however, is based largely on *C. ulrichi.*

Conclusions.—It has been seen from the remarks of Dr. Jahn that he does not regard all the specimens of *Lobolithus* as belonging to *Scyphocrinus,* but thinks that some may belong to other genera, and that at times the former are found where the latter are unknown. On the other hand, in America, no crinoids except *Edriocrinus,* which is a stalkless form directly attached by the theca to foreign bodies, are ever found associated with *Camarocrinus,* while no *Scyphocrinus,* as defined by Zenker, are known on this side of the Atlantic. *Scyphocrinus* Hall is a different genus and was proposed by that author without knowledge of Zenker's previous use of the same name. Then again, the widely differing geological horizons of occurrence between Bohemia and the Appalachians, and between the latter and Tennessee and Indian Territory, make it certain that these bodies, if they are root appendages, can not all belong to *Scyphocrinus.* In Bohemia the fossils in question occur in the transition zone between Barrande's division E e1 and E e2, which in the American geological sequence means about the Rochester shale. The next horizon in which *Camarocrinus* is found is the Manlius, which is at the

top of the Siluric. In other words, between the Bohemian occurrence and the first American record there are the Lockport, Guelph, Salina, and Bertie formations. No occurrence of this genus is known in the highest Manlius and all of the Coeymans, but it reappears in greatest abundance in the lower New Scotland in Tennessee and Indian Territory.

The geologic occurrence of these bodies—their gregarious habit, with the great majority of the bulbs having their stalked end downward—leads naturally to the conclusion that *Lobolithus* or *Camarocrinus,* as found, represents nearly all of the animal, and that these bulbs must be thecæ either of cystids or crinoids. This was the view set forth by the great paleontologist Barrande, and was also independently reached by Ulrich and the writer. That *Camarocrinus* is, however, not a cystid theca nor crinoid calyx is clearly indicated by the absence of ambulacra, mouth, and anus. Further, the axial canal of the stalk does not pass directly into the medio-basal chamber; otherwise this cavity could be interpreted as the visceral cavity. On the other hand, the insertion of the stalk into the root complex, all of which divisions have a central canal, and the fact that the walls of the camaræ are nothing more than modified root-branches connecting with the second series of roots, seem to furnish conclusive evidence that *Camarocrinus* can be nothing more than the highly specialized root of a crinoid.

If this view apparently explains the true nature of *Camarocrinus,* the question naturally arises, How can the vertical position of these fossils in the strata be harmonized with the conclusion? The objection has been made that *Camarocrinus* is too heavy for the float of a crinoid, and while this appears to be true of the fossilized condition, it does not apply to the living state. The writer has noted the weight of the basal portion of a siliceous specimen of average size (estimated to be 3½ inches in diameter, see plate XLII, figure 4), and cleaned of all adhering calcareous matter by etching in hydrochloric acid. The siliceous matter in such a specimen, it is estimated, will not exceed 4 ounces—a weight certainly not too great for a float of this size.[1]

[1] This paragraph was shown to a critical friend and he holds that the deductions as stated are in error for the following reasons: (1) A siliceous pseudomorph, after it has been etched, is lighter than the original calcareous structure, because the acid honeycombs the walls and also because siliceous pseudomorphs are often mere skeletons of the outer and inner sides of the walls, leaving the greater central space free of material. *Answer:* In the specimen selected for ascertaining its original weight, the walls are nearly solid, though there is some honeycombing due to etching. Further, the fragment weighed is the basal portion, therefore the heaviest part of the bulb.

Moreover, if *Camarocrinus* is a float, why is it that the great majority of the bulbs are found in the strata with the stalk end downward? Assuming for the present that these bodies are the air-filled floats of some crinoid, it must be granted, on the basis of the wide dissemination of other shelled organisms with hollow cavities (as the shells of *Spirula*, *Nautilus*, and *Ammonites*) that the bulbs of *Camarocrinus* would continue to float for some time (possibly for hundreds of miles) after the crown and stalk had decayed. The latter portions would be dropped over one part of the sea bottom, while the bulb would sink later in another region. On account of its double and interlocked walls and interior braces, the dead bulb would continue to drift with the currents, as in the living condition, i. e., with the stalk downward, because the weightiest part is at this

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The weight of this specimen was multiplied by the number of equal fragments estimated to make a bulb 3½ inches in diameter. It therefore seems to the writer that the weight is considerably overestimated.

The weight of the calcareous skeleton in a dry specimen of *Echinus esculentus* L., nearly 4 inches in diameter and without spines and jaws, is 2 ounces. Another dry echinus, *E. gracilis*, with spines, jaws, and the dried remainder of the soft parts, nearly 3½ inches in diameter, weighs but 1 $\frac{5}{16}$ ounces. These figures indicate that a dry *Camarocrinus* before mineralization probably did not weigh 4 ounces.

(2) A specimen of *Camarocrinus* 3½ inches in diameter, he estimates, would contain about 8 cubic inches of air, and therefore lacked the capacity necessary to float as large and heavy a crinoid as *Scyphocrinus*. This estimate is in error, as the contents of such a bulb is about 22 cubic inches.

(3) A specimen of the crown and stem of a living *Isocrinus decorus* (Havana) 16 inches long, also in the dry state, weighs but three-sixteenths of an ounce. If *Scyphocrinus* is 4 times as large and 8 times as heavy as the *Isocrinus*, then the dry skeleton of the former would weigh only 1½ ounces.

The writer realizes that these estimates may not be the real weight in the living organisms, and also that the weight of the soft parts is not considered (these, however, need hardly be considered, as the specific gravity of the soft parts is but one-tenth heavier than water). The only point he wishes to emphasize is the relative weights of the parts in relation to the floating capacity of the bulb. A sphere 3½ inches in diameter has a cubical content of a little more than 22 inches. A cubic inch of water weighs 252.45 gr. A 3½-inch sphere will therefore displace or float above the water (distilled) a weight equal to nearly 13 ounces. In sea water it will be nearly twice as much, and if *suspension* in sea water alone is considered, it will be nearly two and a half times that of floating it in distilled water. A dry skeleton of a *Scyphocrinus* with a crown about 1 foot in length and a stalk 3 feet long, with a 3½-inch bulb, is estimated to weigh not over 6 ounces. When one considers that these bulbs attain a diameter of 5 inches, and even larger in Bohemia, while the *Scyphocrinus* crown used in the above estimates is one of the largest, it is seen that these bulbs are abundantly able to suspend a stalk and crown of so ponderous a species as *Scyphocrinus elegans*.

end. As the outer integument of the bulb decayed, the chambers would fill with water, thus causing it to sink gradually to the bottom in its natural position. This mode of segregation would also explain, not only why these bulbs are generally found with the stalk end downward, but also why no crinoid calyxes or crinoidal fragments are found (at least very rarely) associated. This hypothesis assumes that the crowns and stalks must in some other area be as plentiful as are the bulbs which make beds replete with them, in Indian Territory extending for 100 miles. In Tennessee, these bulbs are also abundant, and their geographic extent is probably not less than 50 miles. In the Appalachian region *Camarocrinus* is known plentifully only at one locality. Yet in no place throughout the formations in which these bulbs occur are there corresponding beds replete with crowns, stalks, or even accumulations of the separated ossicles. This is the one weak point in the argument that *Camarocrinus* is the float or specialized root of a crinoid.

To assume that these bodies were anchored in the mud with the stalk directed upward seems to be at variance, not only with their position in the rocks (the great majority are found in a reversed position), but also with their structure. The rounded end of the bulb is full of pores, and what purpose could these have served buried in the mud? In old examples, where all that portion which could have protruded above the mud has the pores covered over by a secondary amorphous coating, this is especially difficult to understand. On the other hand, if these bulbs were anchored in the mud during the life of the crinoid, some calyxes or a great mass of crinoidal fragments should have been found with them, yet this is not the case.

If, as the writer believes, *Camarocrinus* is the float of a crinoid, it appears to be the only one known either in the fossil or living state. It is a well-known fact, however, that crinoids "present a constant tendency to relinquish the attached mode of life and to lose that typical organ, the stem."[1] In Mesozoic times several genera of crinoids are known to have been devoid of columns and some are thought to have been pelagic.

Lichenocrinus represents the nearest approach of a modified crinoid root to *Camarocrinus*. It, too, is camerate, the radiating striæ seen on weathered examples being vertical plates extending upward from the attached base to the inner side of the surface plates. Dr. E. O. Ulrich has also demonstrated their existence for himself by means of thin sections, and has illustrated these features for Mr. S. A. Miller

[1] Bather, op. cit., p. 134.

in *L. tuberculatus*.[1] However, this form when compared with *Camarocrinus* is wholly different, as the base of *Lichenocrinus* is attached to foreign bodies, while to the upper side is attached a long, slender, and complicated stem, 3 to 4 inches in length. Many excellent specimens are known with the stalk attached, but none has a crown.

Even though no other example of root modification similar to *Camarocrinus* is known, this fact alone can not be taken as disproving Bather's statement[2] in regard to these bulbs that "another curious modification, perhaps connected with a free-floating existence, was presented by the root of *Scyphocrinus* [= *Lobolithus* = *Camarocrinus*]."

The suggestion of two writers that these bulbs may have functioned as receptacles in which the young were developed finds no support in other crinoid structures. The fertilized eggs of crinoids pass from the pinnules into the water singly or in bunches, but are not known to enter a special receptacle for further development (See Springer, ante, page 259).

Summary.—*Camarocrinus* thus 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.

The writer realizes that the last word has not been said in regard to *Camarocrinus*, and the present work is offered with the hope that some paleontologist will attack the problem from another point of view. The supposition that *Camarocrinus* is a degenerate crinoid in which the roots represent cirri, the medio-basal chamber the calyx, and the double walls of the camaræ the equivalent of the arms, seems to find no support in the detailed structure of these bulbs.

CAMAROCRINUS STELLATUS Hall

(Plate XLIV, figures 1–5)

Camarocrinus stellatus Hall, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., Mus. ed., 1879, p. 207, pl. 35, figs. 1–8. Extract, 4°, 1880, p. 5, pl. 35, figs. 1–8.

[1] Op. cit., p. 135.

[2] *Jour. Cincinnati Soc. Nat. Hist.*, v, 1882, p. 229, pl. 9, figs. 6, 6a.

This species is readily separated from *C. saffordi* by its more depressed form, larger and more open basal area, and the finely granular nature of the plates of the outer integument. These granules flow variously together and the plates are more or less stellate. In some individuals this character is more marked than in others, so that the degree of stellation is variable and individual, but it never takes place so prominently as in some examples of *C. ulrichi stellifer*.

Formation and locality.—Not common in the Tentaculite limestone of the upper Manlius at Schoharie, New York. Rare in the lower portion of the same formation at Devil's Backbone, near Cumberland, Maryland, and very common near the middle of the Manlius in the quarries of the B. & O. R. R. near Keyser, West Virginia. The largest specimen has a diameter of 12.5 cm.

Cat. numbers 35,080, 35,081, U. S. N. M.

CAMAROCRINUS SAFFORDI Hall

(PLATE XL, FIGURE 10)

Camarocrinus saffordi HALL, Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., Mus. ed., 1879, p. 208, pl. 36, figs. 1–6; pl. 37, figs. 1, 2. Extract, 4°, 1880, p. 6, pl. 36, figs. 1–6; pl. 37, figs. 1, 2.

Camarocrinus clarkii HALL, ibidem, p. 209, pl. 36, figs. 7, 8; pl. 37, fig. 3. Extract, p. 7, pl. 36, figs. 7, 8; pl. 37, fig. 3.

This species is distinguished from *C. stellatus* by the more elevated or balloon-shaped theca, as well as by the serrated suture lines of the plates and the few scattered openings between the latter. *C. clarkii* is not a good species, as large collections show considerable variation in the form, but more particularly in the number of camaræ in all the species. It is simply an unusually lobate specimen having 11 chambers. *C. ulrichi* is still more balloon-shaped, with the outer integument basally extended into a high collar, and with numerous minute pores at most of the angles of the thecal plates.

Formation and locality.—In western Tennessee there appears to be no zone equivalent to the New York Manlius, as the Meniscus, or, rather, Foerste's Brownsport limestone, is immediately followed by the Linden or Helderbergian of about the age of the New York Uppermost Coeymans or basal New Scotland. In 1897 the writer found three specimens of *C. saffordi* at Allen's Mill, on the Birdsong, in Benton county, but the exact equivalent for the horizon of these fossils in the New York section remains undetermined. During the year 1903 Mr. Foerste collected many specimens of this species in unmistakable Helderbergian strata of the age of the New Scotland. These were collected in the lower 50 feet of the Linden formation

(= New Scotland), on Horse creek, near Chalybeate spring, and on Tennessee river, near Pyburn landing, or opposite White Sulphur spring.[1] Hall's material is from Hardin county, Tennessee. Recently Mr. R. S. Bassler found this species in beds of New Scotland age, just below the Clear Creek chert along the Mississippi, north of Cape Girardeau, Missouri.

Cat. number 27,760, U. S. N. M.

CAMAROCRINUS ULRICHI Schuchert

(PLATE XL, FIGURES 6–8; PLATES XLI–XLIII)

Camarocrinus ulrichi SCHUCHERT, Amer. Geol., XXXII, 1903, p. 239.

This species is more pyriform or balloon-shaped than *C. saffordi*, and the theca is usually considerably pinched and prolonged basally into a high collar, evidently for the greater protection of the basal openings. The plates are very much as in *C. saffordi*, and where stellation has not set in, they adjoin with very finely serrated sutures, but the pores between the plates are much smaller and are far more abundant than in the latter species. In some individuals stellation begins by the insertion of small, spicular pieces between and around the pore openings, and above the larger plates over the dome of the theca. In different individuals is found nearly every stage of progression from the non-stellate form to the prominently stellate *C. ulrichi stellifer*. This detail is more clearly shown in the illustrations on plate XL.

Young or small specimens of *C. ulrichi* have the depressed form, with the large and not sharply delimited basal area of *C. stellatus*, showing progressive development toward a more balloon-shaped theca, with a pinched and restricted basal termination. The largest known specimen has a diameter of 12 cm.

Formation and locality.—Very common in the lower portion of the Helderbergian (Hunton formation) of Indian Territory, where Dr. Ulrich found them at many localities for a distance of 100 miles. Some of the best localities are 3 miles northeast and 4 miles south of Daugherty, and 1⅛ miles and 2 miles south of Franks.

It gives the writer great pleasure to name this species for its discoverer, Dr. E. O. Ulrich, one of America's most distinguished paleontologists, and an indefatigable collector.

Cat. numbers 35,082–35,085, U. S. N. M.

[1] See Foerste, *Jour. Geol.*, XI, 1903, pp. 683–685, 714.

C. ULRICHI STELLIFER n. var.

(PLATE XL, FIGURE 9; PLATE XLI, FIGURE 6)

This variety is distinguished by the great prominence of the star ornamentation of the theca, caused by the fusing together of many smaller pieces into large plates, where the pores appear to pass through the plates and not between them. In this condition the pores may remain as simple, round perforations, or 2 of adjoining angles may be drawn out into a narrow slit, giving the impression of true dichopores. In other individuals the stellation seems to leave very large openings, much like those in the calcareous skeleton of the common starfish, *Asterias forbesii*. The size of some of these openings is undoubtedly increased by weathering, but they were originally very much larger than those in *C. ulrichi*.

Formation and locality.—This variety is always found very poorly preserved, and distorted by rock pressure. The extremely loose structure of the calcareous skeleton may have been the cause of the smashed condition of these individuals, and their consequent fragmentary nature when weathered out on the surface. Found associated with *C. ulrichi*.

Cat. numbers 35,086–35,088, U. S. N. M.

Explanation of Plate XXXIV

(Photographs retouched by Miss Frances Wieser and Dr. E. O. Ulrich.)

Figs. 1, 2. *Callocystites jewettii* Hall.....p. 243

Fig. 1. The antanal side, showing many brachioles.

Fig. 2. The anal side of same specimen, showing the anal pyramid.

Rochester shales, Grimsby, Ontario. Collection of Dr. B. E. Walker, Toronto.

Fig. 3. *Callocystites canadensis* (Billings).....p. 245

The side, with the anal pyramid to the right. × 2.

Rochester shales, Grimsby, Ontario. Collection of Dr. B. E. Walker.

Figs. 4, 5. *Apiocystites elegans* Hall.....p. 212

Fig. 4. The anal side. × 2.

Fig. 5. Same specimen, from the antanal side. × 2.

Rochester shales, Grimsby, Ontario. Collection of Dr. B. E. Walker.

Figs. 6–8. *Tetracystis fenestratus* (Troost ms.).....p. 219

Fig. 6. View showing the upper left-hand pectinirhomb, with the anus to the right. × 2. Holotype, 35,091.

Fig. 7. Same, from the anal side. × 2.

Fig. 8. Same, from the antanal side. × 2.

Brownsport limestone, Decatur county, Tennessee.

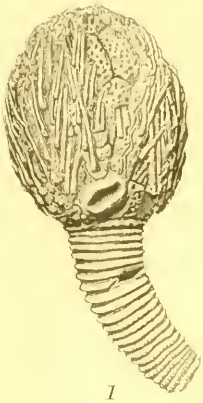
Figs. 9, 10. *Tetracystis chrysalis* n. sp.....p. 218

(See also Plate XL, figures 1–3.)

Fig. 9. View showing upper left-hand pectinirhomb. × 2.

Fig. 10. Same specimen from the antanal side. × 2. Holotype, 35,063.

Manlius formation, near Keyser, West Virginia.



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SILURIC CYSTIDS

HELIOTYPE CO., BOSTON.

Explanation of Plate XXXV

(Photographs retouched by Miss Frances Wieser. Unless otherwise stated, the specimens figured are from the Manlius formation, near Keyser, West Virginia.)

Figs. 1–3. *Trimerocystis peculiaris* n. sp. ..... p. 239

Fig. 1. View of the holotype (35,064) from the anal side.

Figs. 2, 3. Same specimen seen from the sides.

Figs. 4, 5. *Pseudocrinites subquadratus* n. sp. ..... p. 234

Two views of the holotype. × 2. 35,067.

From Devil's Backbone, near Cumberland, Maryland.

Figs. 6, 7. *Pseudocrinites elongatus* n. sp. ..... p. 235

Two views of the holotype, 35,065.

From Martin's mountain, Bedford county, Pennsylvania.

Figs. 8, 9. *Pseudocrinites stellatus* Schuchert ..... p. 232

Two side views of the holotype, 35,069.

(See also Plate XXXIX, figure 7.)

Figs. 10–12. *Pseudocrinites abnormalis* n. sp. ..... p. 231

Fig. 10. View of the sides having the abnormal position of the lower pectinirhomb.

Fig. 11. Opposite side of same specimen.

Fig. 12. End view of same. Holotype, 35,068.

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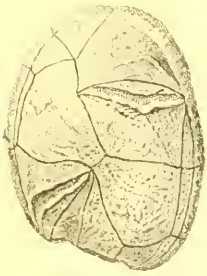

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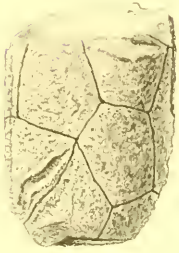

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SILURIC CYSTIDS

FELIX MPE. DEL. BOSTON.

Explanation of Plate XXXVI

(Photographs retouched by Miss Frances Wieser. The specimens figured are from the Manlius formation, near Keyser, West Virginia.)

Figs. 1–3. *Pseudocrinites perdewi* Schuchert.....p. 236

(See also Plate XXXIX, figures 8–10.)

Fig. 1. Side view of a young specimen. × 2. Paratype, 35,072.

Figs. 2, 3. Two views of the holotype. Natural size. 35,072.

Figs. 4–7. *Pseudocrinites clarki* Schuchert.....p. 233

(See also Plate XXXIX, figure 14.)

Figs. 4–6. Three views of the holotype, an average adult individual. 35,070.

Fig. 7. A very large specimen of this species. The plates around the pectinirhomb are somewhat broken. 35,070.

Figs. 8–12. *Pseudocrinites gordoni* Schuchert.....p. 229

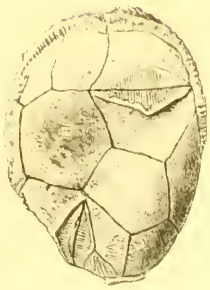
(See also Plate XXXIX, figures 11–13.)

Figs. 8, 9. Two views of the holotype, a specimen somewhat larger than usual. 35,071.

Fig. 10. Another specimen. 35,071.

Fig. 11. A smaller but adult individual of the rounder variety. 35,071.

Fig. 12. An elongate individual, somewhat abnormal in having the ambulacra drawn over on the anal side more than is usual. 35,071.



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SILURIC CYSTIDS

HELIOTYPE CO., BOSTON

Explanation of Plate XXXVII

(Photographs retouched by Wieser and pen and ink camera-lucida drawings by McConnell. The specimens figured are from the Manlius formation, and unless otherwise stated are from near Keyser, West Virginia.)

Fig. 1. *Pseudocrinites claypolei* n. sp. ..... p. 232

Fig. 1. The holotype; the ambulacral plates are exfoliated. × 2. 35,066.

From Clark's Mills, near New Bloomfield, Pennsylvania.

Figs. 2, 3. *Lepocrinites manlius* n. sp. ..... p. 214

(See also Plate XXXIX, figures 15, 16.)

Figs. 2, 3. Two views of the holotype. × 2. 35,062.

Figs. 4–8. *Jackelocystis hartleyi* Schuchert ..... p. 224

Fig. 4. View of the holotype; a large specimen. Anal opening to the right. × 2.

Fig. 5. A smaller specimen with the anal opening to the left. × 2.

Fig. 6. Camera-lucida drawing of the oral end to show the arrangement of the ambulacral plates, the ambulacralia (somewhat restored), brachiole attachments, and the plate with the madreporite; the latter lies in the depression of the large plate on the left of the figure. × 8.

Fig. 7. The anal pyramid; the positions of the bounding plates, 13, 14, 7, 8, are indicated. × 8.

Fig. 8. Plates 14 and 15, with the discrete-pectinirhombs; the dichopores on plate 14 are deeply situated and do not show on the surface. × 8.

Figs. 9, 10. *Jackelocystis papillatus* n. sp. ..... p. 225

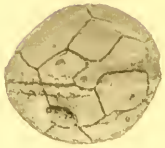
Fig. 9. Anal aspect of the paratype. × 2.

Fig. 10. Antanal view of the holotype; pectinirhomb 14–15 is faintly indicated on the left. × 2.

Figs. 11, 12. *Jackelocystis avellana* n. sp. ..... p. 226

Fig. 11. View of the holotype, with the anal opening to the left and pectinirhomb of plates 14–15 to the right. × 3. 35,056.

Fig. 12. Same specimen seen from the top, showing the 2 small discrete-pectinirhombs, the central madreporite, and the large anal opening. × 3.



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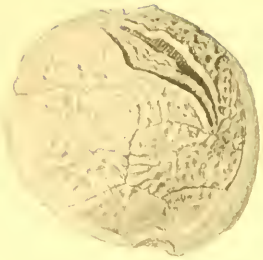

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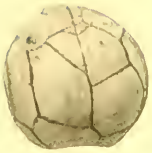

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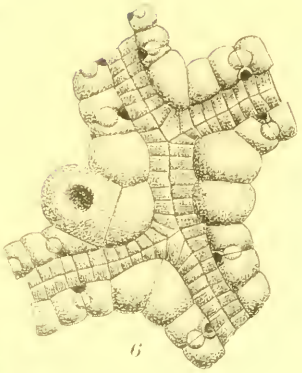

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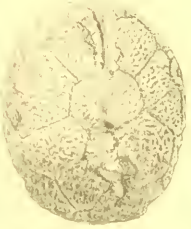

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SILURIC CYSTIDS

HELIOTYPE CO., BOSTON.

Explanation of Plate XXXVIII

(Photographs retouched by Miss Frances Wieser. The specimens figured are from the Manlius formation.)

Figs. 1, 2. *Sphærocystites multifasciatus* Hall.....p. 250
(See also Plate XXXIX, figures 1–4.)

Fig. 1. A large specimen, seen from the anal side; most of the sculpturing consists of the ambulacral branches. × 2. 35,058.

Fig. 2. The same individual, seen from the top. × 2.
Cash valley, near Cumberland, Maryland.

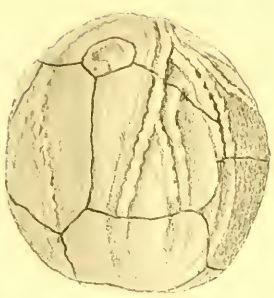
Figs. 3–5. *Sphærocystites globularis* Schuchert.....p. 252
(See also Plate XXXIX, figures 5, 6.)

Figs. 3, 4. The holotype, seen from the anal side and the top. × 2. 35,053.
Near Keyser, West Virginia.

Fig. 5. The entire stalk, terminating in the roots at one end, and at the other preserving a few of the thecal plates, seen from the interior. Natural size. 35,077.
Devil's Backbone, near Cumberland, Maryland.

Fig. 6. *Sphærocystites globularis ovalis* n. var.....p. 253

Fig. 6. The holotype, seen from the side. × 2. 35,054.
Near Keyser, West Virginia.



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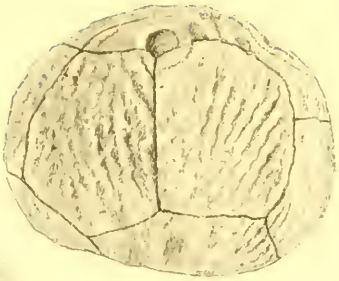

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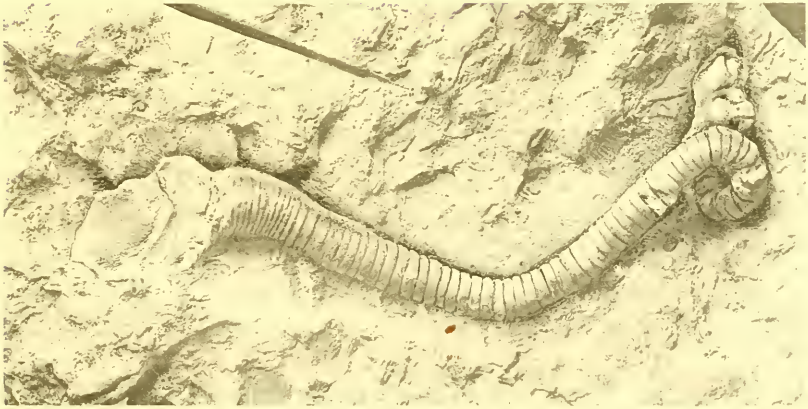

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SILURIC CYSTIDS

HELIOTYPE CO., BOSTON.

Explanation of Plate XXXIX

(Pen and ink drawings, after the camera-lucida, by J. C. McConnell.)

Figs. 1–4. *Sphærocystites multifasciatus* Hall.....p. 250

(See also Plate XXXVIII, figures 1, 2.)

Fig. 1. The two circles of plates composing the anal pyramid; the numbers indicate the bounding thecal plates. About × 5.

Fig. 2. Part of an ambulacrum, showing one row of ambulacral plates, the ambulacralia, and remnants of brachioles. About × 10.

Fig. 3. An incomplete brachiole. About × 10.

Fig. 4. Deltoid 23, with the madreporite and hydropore closed by its pyramid. About × 10. All 35,052.

Figs. 5, 6. *Sphærocystites globularis* Schuchert.....p. 252

(See also Plate XXXVIII, figures 3–5.)

Fig. 5. The anal pyramid and the bounding thecal plates indicated by numbers. About × 5.

Fig. 6. Part of an ambulacrum, showing the ambulacral and ambulacralia plates, and the points of attachment for the brachioles. About × 5. Both 35,053.

Fig. 7. *Pseudocrinites stellatus* Schuchert.....p. 232

(See also Plate XXXV, figures 8, 9.)

Fig. 7. Part of an ambulacrum, showing one row of ambulacral plates, the brachiole facets, and the ambulacralia with their intermediate large plates. About × 5. 35,069.

Figs. 8–10. *Pseudocrinites perdewi* Schuchert.....p. 236

(See also Plate XXXVI, figures 1 to 3.)

Fig. 8. Deltoid 23, with the madreporite and the small hydropore; the double row of small plates and the ambulacralia. About × 5.

Fig. 9. Portion of an ambulacrum in a young specimen. About × 5.

Fig. 10. Same as fig. 9; seen from the side to show the high elevation of ambulacralia. About × 5. All 35,072.

Figs. 11–13. *Pseudocrinites gordoni* Schuchert.....p. 229

(See also Plate XXXVI, figures 8–12.)

Fig. 11. Portion of an ambulacrum. About × 5.

Fig. 12. A nearly complete brachiole. About × 5.

Fig. 13. Deltoid 23 crowded into the ambulacral plates, showing the madreporite and hydropore. About × 5. All 35,071.

Fig. 14. *Pseudocrinites clarki* Schuchert.....p. 233

(See also Plate XXXVI, figures 4–7.)

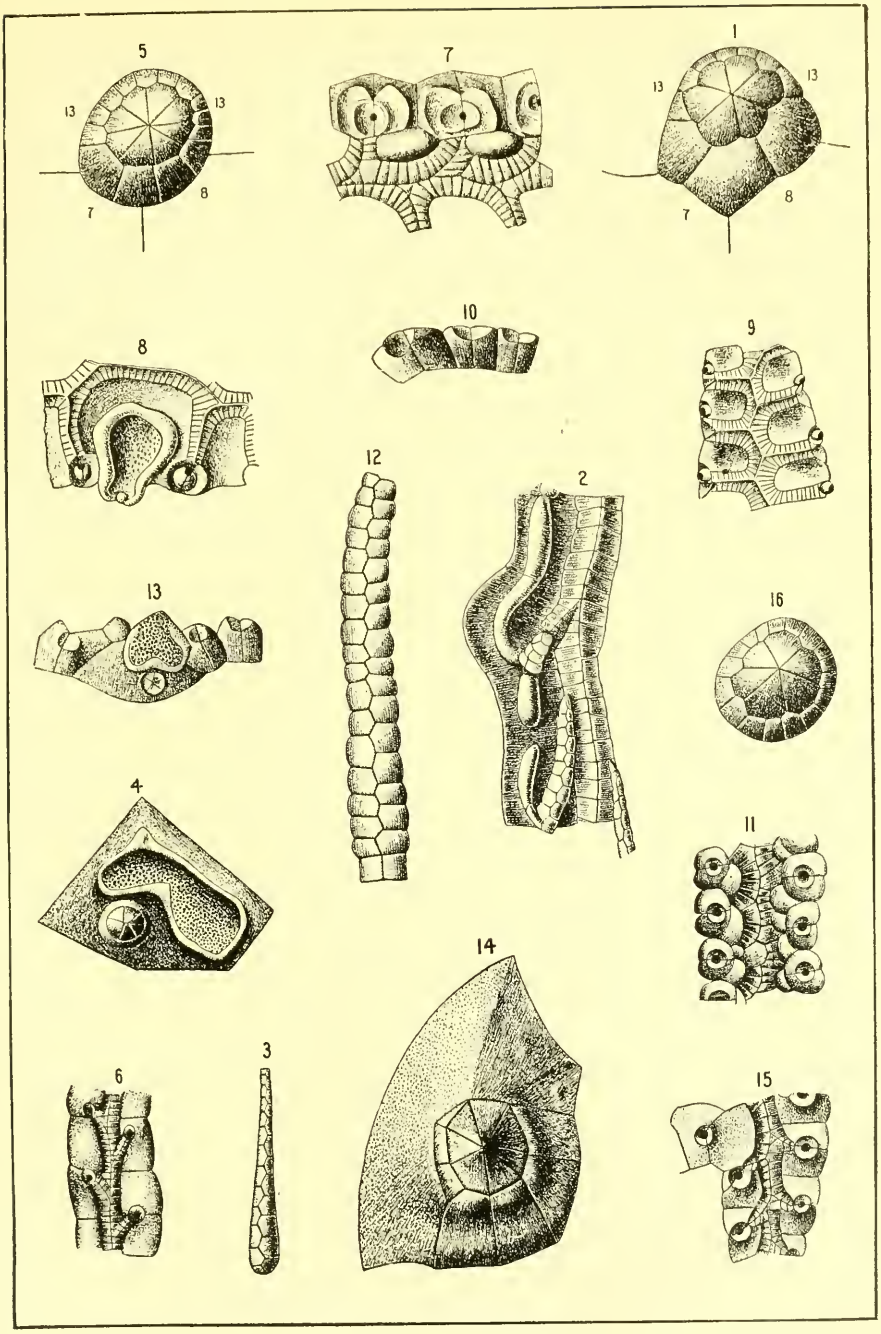
Fig. 14. Plate 13 on the left and the incomplete circle of 7 small plates bounding the anal pyramid of 7 pieces. About × 5. 35,070.

Figs. 15–16. *Lepocrinites manlius* n. sp.....p. 214

(See also Plate XXXVII, figures 2, 3.)

Fig. 15. An ambulacrum near the oral opening. About × 5.

Fig. 16. The 2 circles of pieces composing the anal pyramid. About × 5. Both 35,062.



SILURIC CYSTIDS

Explanation of Plate XL

(Pen and ink camera-lucida drawings by J. C. McConnell.)

Figs. 1–3. *Tetracystis chrysalis* n. sp. ..... p. 218

(See also Plate XXXIV, figures 9, 10.)

Fig. 1. Portion of an ambulacrum; the transverse markings in the ambulacral groove indicate the position of the ambulacralia, but not the plates themselves. About × 5.

Fig. 2. The anal pyramid and the boundary thecal plates 13, 14, 7, 8. About × 5.

Fig. 3. Deltoid 23, with the madreporite and hydropore. About × 5.

Figs. 4, 5. *Anomalocystites cornutus* Hall. ..... p. 206

(See also text-figures.)

Fig. 4. The complete stalk. Somewhat less than × 3.

Fig. 5. One of the free arms seen from the adambulacral side. About × 5.

Coeymans limestone, Litchfield, Herkimer county, New York.

Figs. 6–8. *Camarocrinus ulrichi* Schuchert ..... p. 271

(See also Plates XLI–XLIII.)

Fig. 6. The plates of the bulb, as seen on the top or rounded side of a small specimen. About × 5.

Fig. 7. More convex plates in another specimen in the same position as fig. 6. About × 5.

Fig. 8. Similar plates in a small specimen, indicating the beginning of stellation. About × 5.

Helderbergian, 3 miles northeast of Daugherty, Indian Territory.

Fig. 9. *Camarocrinus ulrichi stellifer* n. var. ..... p. 271

(See also Plate XLI, figure 6.)

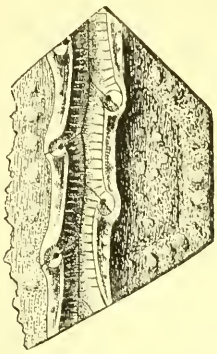
Fig. 9. The stellate surface of this variety, also showing the slit-like openings through the test. About × 5. 35,086.

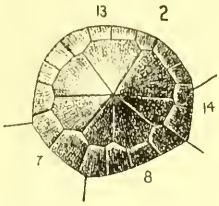
Helderbergian, S. W. ¼ sec. 15, T.2S., R.2E., Tishomingo quadrangle, Indian Territory.

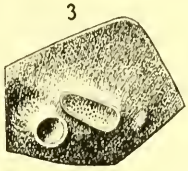
Fig. 10. *Camarocrinus saffordi* Hall. ..... p. 270

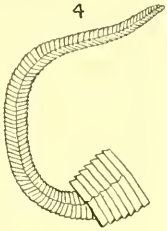
Fig. 10. The surface on the rounded end of a large bulb. About × 5. 27,760.

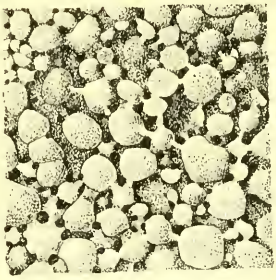
Helderbergian, Allen's Mills on the Birdsong, Benton county, Tennessee.

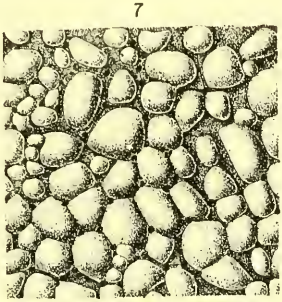


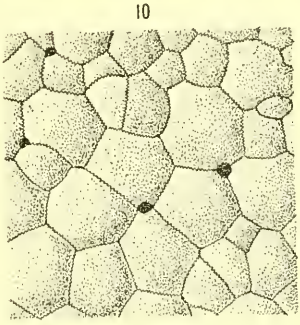


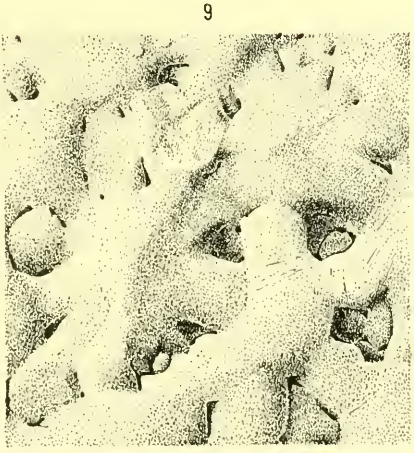


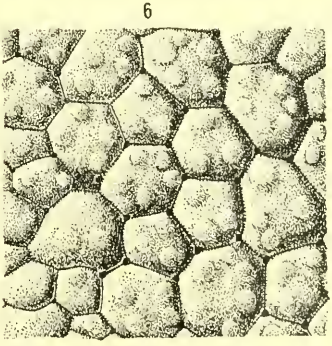












CAMAROCRINUS AND CYSTIDS

Explanation of Plate XLI

(Photographs retouched by Miss Frances Wieser. The illustrations on this plate are one-third smaller than the specimens.)

Figs. 1–5. *Camarocrinus ulrichi* Schuchert.....p. 271

(See also Plates XL–XLIII.)

Fig. 1. A small, somewhat elongate specimen, with the high collar so characteristic of this species. 35,085.

Fig. 2. A depressed, decidedly lobate specimen. 35,084.

Fig. 3. Another specimen like Fig. 2, to show the primary root and its branches; also the camaræ openings between the final bifurcations; there are 9 of these openings. 35,085.

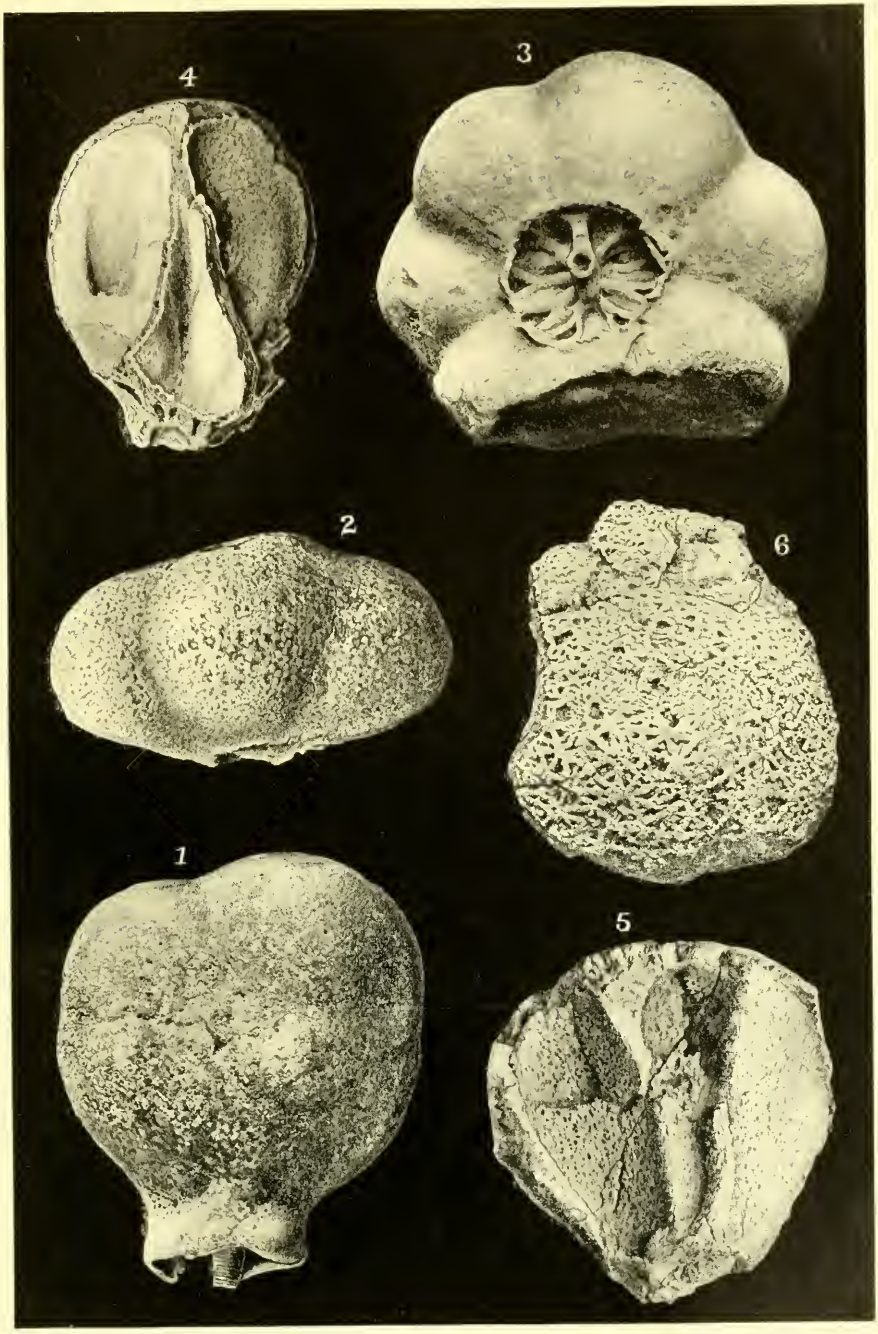
Fig. 4. A siliceous specimen broken open, showing the medio-basal chamber and 2 camaræ. 35,084.

Fig. 5. A weathered specimen, showing the porous nature of the interior walls. 35,085.

Fig. 6. *Camarocrinus ulrichi stellifer* n. var.....p. 271

(See also Plate XL.)

The surface of a crushed specimen; the holotype, 35,088.



CAMAROCRINUS

Explanation of Plate XLII

(Photographs retouched by Miss Frances Wieser. The illustrations on this plate are one-third smaller than the specimens. From the Helderbergian of Indian Territory.)

Figs. 1–4. *Camarocrinus ulrichi* Schuchert.....p. 271

(See also Plates XL, XLI, and XLIII.)

Fig. 1. A large and characteristic specimen of this species; holotype, 35,085.

Fig. 2. Another large and old specimen in which the lower half of the bulb is covered with a secondary deposit of calcareous matter through which pass large and modified openings.

Fig. 3. A small specimen illustrated to show the four small lobations or camaræ situated on the right and left of the figure; this figure also shows how the root branches terminate in the camaræ walls. 35,085.

Fig. 4. A siliceous etched base of a medium-sized bulb, showing the medio-basal chamber surrounded by 5 camaræ, each of which has a large opening through the test. 35,084.

CAMAROCRINUS

Explanation of Plate XLIII

(Untouched photograph.)

Camarocrinus ulrichi Schuchert.....p. 271

(See also Plates XL–XLII.)

A slab 9¾ inches long, showing 4 specimens with the rounded end upward and 1 lying on its side; the photograph is of the upper side of the slab in situ. 35,085.

Helderbergian, 3 miles northeast of Daugherty, Indian Territory.

CAMAROCRINUS

Explanation of Plate XLIV

(The illustrations on this plate are one-third smaller than the specimens.)

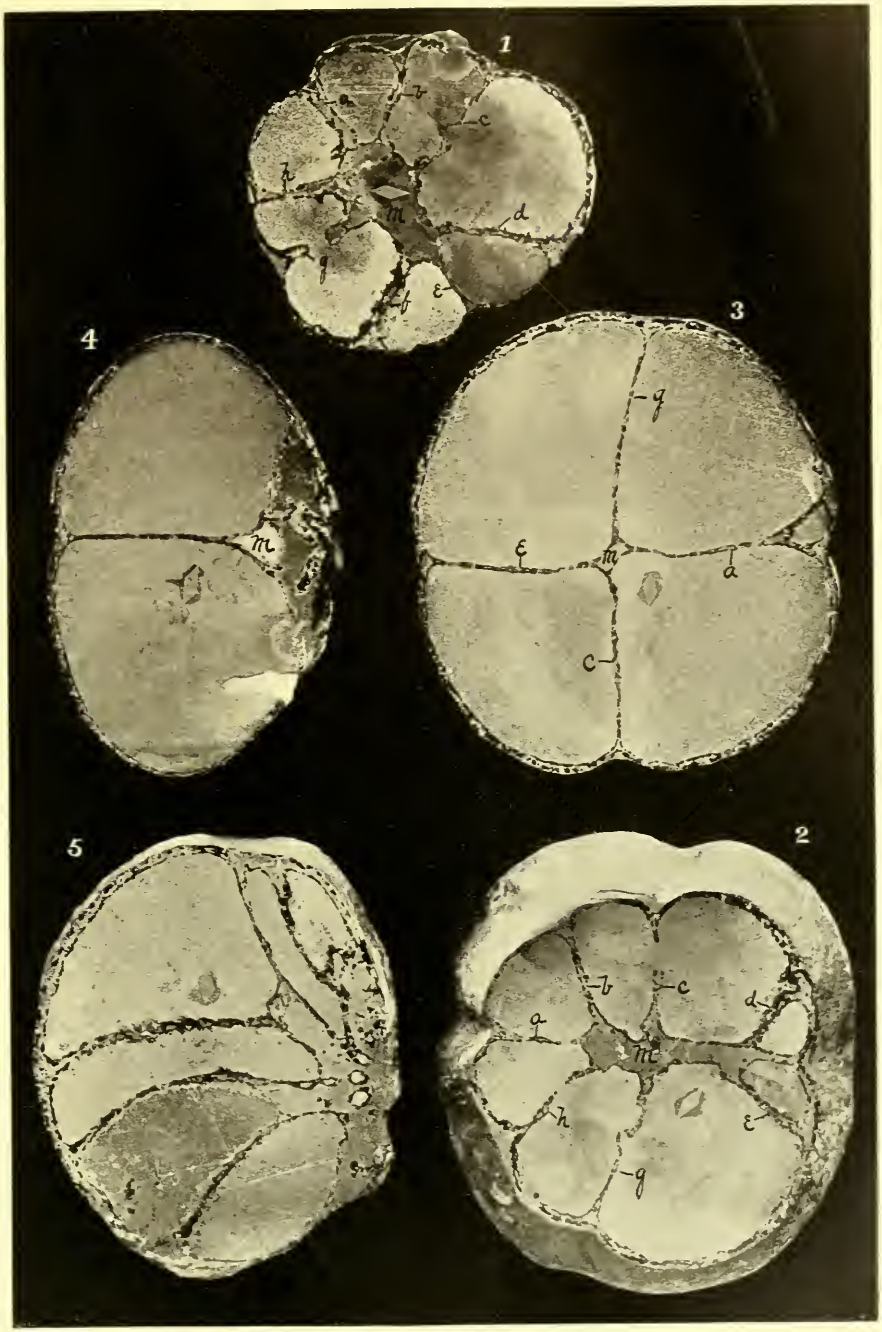
Figs. 1-5. *Camarocrinus stellatus* Hall.....p. 269

Figs. 1–3. Three transverse cuts through the same bulb; the letters indicate the same wall in the different sections; *M*, the medio-basal chamber.

Fig. 4. Another specimen cut through the center longitudinally; *M*, medio-basal chamber.

Fig. 5. A second bulb cut through the center longitudinally. All 35,080.

Manlius formation, near Keyser, West Virginia.



CAMAROCRINUS