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# ECHINODERMATA

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BLASTOID STUDIES

By ROBERT O. FAY



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## ABSTRACT

In order to understand the taxonomy and phylogeny of blastoids it is necessary that all known species of blastoids be revised, with emphasis placed upon internal, anal, and oral features. In the present work only 44 genera are studied (12 new; 3 Permian, 41 Mississippian and older) because of a time limit. These are arranged alphabetically under the orders Fissiculata (exposed hydrospire slits) and Spiraculata (hidden hydrospire slits, with pores and spiracles) and no attempt is made to arrange them into natural families. Certain genera of the Fissiculata may have given rise to some of the Spiraculata independently in Europe and North America. The blastoids of Timor, Europe, Russia, and North America have almost nothing in common. This probably reflects the need for more collecting in critical areas and the restudy of present material, but it could mean that

blastoids were provincial. Genera are distinguished by a combination of characters: (1) spiracles, (2) anal deltsoids and type of overlap along radiodeltoid sutures, (3) hydrospires, (4) lancet plate position, (5) pores, and (6) oral plates. In most genera the first three characters are the most important. If the Fissiculata are considered primitive, a primitive blastoid is one that is steeply conical, with 4 anal deltsoids, slits exposed, radials overlapping deltsoids, lancet covered by side plates, and lancet elongate, reaching almost to the oral opening. An advanced form is globular or winged or both, with 2 anal deltsoids (or 1 as in *Pentremites*), hidden hydrospire slits that open into a spiracular slit or hydrospire canal, elongate deltsoids overlapping radials, and lancet exposed, not adjacent to the oral opening or lancet short and wide. The origin of the Blastoidea is unknown.

## INTRODUCTION

## PURPOSE AND SCOPE

The purpose of this work is to provide basic data for the forthcoming *Treatise on Invertebrate Paleontology*, and to show that the study of blastoids is in its infancy. At present there is no adequate comprehensive compilation of blastoid knowledge, and the present work is only a progress report toward that goal.

The best available morphologic work is that of ETHERIDGE & CARPENTER (1886), upon which most former treatises, textbooks, and research articles have been based. The book lacks photographs and has drawings that show only one anal deltsoid in all blastoids that were studied. Also it is impossible to determine the nature of overlap along the radiodeltoid suture, the variability of internal features, the nature of the pores in the deltsoid plate, the nature of the side plates, and relative covering of the lancet plate. Thus, there is need for a restudy of the Blastoidea, with emphasis on morphology, resulting in a revision of the basic principles underlying the classification of genera.

The scope of this paper is to present a short description of one or more species of each genus of pre-Pennsylvanian blastoids, with attention to features previously overlooked. The type species was studied where available, but where not available, other species had to be studied. The paper is not complete, since only three Permian genera were studied. It is hoped that others will continue with similar investigations.

## PREVIOUS STUDIES

The earliest positive references to blastoids are contained in publications by S. L. MITCHILL (1808) and J. PARKINSON (1808), both of which refer to an "Asterite" or "asterial fossil" from Kentucky, and illustrate the blastoid now called *Pentremites godoni*. In 1819, J. L. M. DEFRANCE named this fossil *encrina Godonii*, thus becoming the first to use a binomial zoological designation for a blastoid species. Until 1825, however, no one knew how to classify this echinoderm, for it obviously differed greatly from such groups as the starfishes, echinoids, and crinoids. It was THOMAS SAY, in 1825, who proposed the "family" Blastoidea, to include fossils of this nature, as distinct from other echinoderms.

In 1851, the first morphologic study of the blastoids was published by C. F. ROEMER, who in this work reported the discovery of marginal pores along the ambulacra and mentioned that the folds beneath the ambulacra continue upward into openings near the mouth. In 1869, these folds were called hyprospires by E. BILLINGS.

New genera and species were discovered in Europe and North America, and need arose for organizing accumulated knowledge both of the morphological features and taxonomy of these fossils. In 1886, R. ETHERIDGE & P. H. CARPENTER published a comprehensive study of the blastoids, similar to but much more exhaustive than the earlier work by ROEMER. Their paper, based on 7 years of intensive study of

specimens in the British Museum of Natural History and others on loan, has served as basic reference material for all subsequent text books and treatises concerned with blastoids. Most pre-Permian genera and species are illustrated and described in ETHERIDGE & CARPENTER's paper, which contains first record of many newly observed morphological features, such as the double oral-esophageal ring, hydrospire plates, and various abnormalities.

In 1908, F. A. BATHER reported the occurrence of Permian blastoids on Timor in the Dutch East Indies, and subsequently similar fossils have been found in the Permian of Russia, Sicily, and New South Wales. In a series of articles written from the early 1920's to 1940, J. WANNER described and illustrated 48 species of blastoids belonging to 16 genera from Permian deposits of Timor, almost all new to science.

Since 1940, I. G. REIMANN has published several articles on Devonian blastoids and in the 1930's L. M. CLINE published on some Devonian and Mississippian blastoids of North America. Since then, little has been added to our knowledge except details of stratigraphic occurrence, as in the papers by K. JOYSEY (1953-1959). In 1943, R. S. BASSLER & M. W. MOODEY prepared a bibliographic index to species, in which they recognized approximately 50 genera and 350 species. There is need for a comprehensive bibliography and objective index to the Blastoida, with a stratigraphic and geographic cross index.

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#### *Abbreviations Used in Text-figures and Plates*

- "A" —anterior ambulacrum.
- Amb—ambulacrum.
- An —anspiracle or anal opening.
- B —basal plate.
- "B" —right anterior ambulacrum.
- Bf —brachiolar facet.
- Bp —brachiolar pit.
- C —radial canal.
- "C" —right posterior ambulacrum.
- Col —columnal.
- CR —cryptodeltoid plate.
- D —deltoid plate.
- "D" —left posterior ambulacrum.
- Db —deltoid body.
- Dc —deltoid crest.
- Di —deltoid lip.
- Ds —deltoid septum.
- "E" —left anterior ambulacrum.
- ED —epideltoid plate.
- Fg —main food groove, represented by an arrow pointing toward mouth.
- H —hydrospire canal.
- HD —hypodeltoid, with dashed lines where inferred and slanted lines for facet.
- HP —hydrospire plate.
- Hs —hydrospire slit.

ISp —inner side plate.  
 L —lancet plate.  
 Lu —lumen.  
 O —oral opening (stippled) or oral plate.  
 OSp —outer side plate.  
 P —pore.  
 Pf —pore furrow.  
 R —radial plate.  
 Rp —radial limb.  
 Rl —radial lip.

S —spiracle.  
 SB —subbasal.  
 SFg —side food groove.  
 Sp —side plate(s).  
 Ss —spiracular slit.  
 Su —superdeltoid plate.  
 Sub —subdeltoid plate.  
 Z —azygous basal, in A-B position when in lower right position.  
 \* —arrow marks position of main food groove, pointing toward mouth (in figures showing side plates).

## MORPHOLOGY OF BLASTOIDS

### INTRODUCTION

Large detailed drawings which show adequately the detailed morphology of the blastoids do not exist, and therefore many small features of skeletal structures have never been clearly illustrated. Consequently I decided to draw enlarged portions of anal areas, oral areas, ambulacra, basal plates, stems, hydrospires, and pores, from the available specimens. A genotype, holotype, syntype, paratype, neotype, or metatype was used for this study wherever possible but otherwise it was necessary to use plesiotypes or hypotypes or unfigured specimens. Portions of this work were initiated in 1954 at the University of Kansas and carried on subsequently at the University of Oklahoma.

### TECHNIQUES

Much of the work done at the University of Kansas is not incorporated in this study and has been or is being published separately. However, certain techniques were used in these early studies and are here mentioned. The serial peel-section technique, along with the camera lucida, was used for most detailed work.

In this procedure parallel sections were ground at selected regularly spaced small intervals using a Croft Parallel Grinding Instrument, which is a well-constructed micrometer mounted on a flat metal table, capable of being rotated on ball bearings. The micrometer mount permits determination of the exact amount of section to be ground and the ball bearings insure that each section is parallel with preceding and succeeding ones. After attaining the desired level, the section was polished and etched with 5-percent hydrochloric acid and allowed to dry. Camera lucida drawings were made of the section itself, and for additional record, peel sections were prepared by immersing the slightly etched surface in acetone and pressing the fossil against an acetate sheet. Some acetate should be

dissolved in the acetone for best results. The peel section, which shows microscopic details of the surface in manner corresponding closely to a thin section, then was placed in a photographic enlarger so that by transmitted light features of the section could be recorded on photographic paper. From these photos, with camera lucida drawings as guide, all information was transferred onto paper by making direct overlays in ink. From the inked drawings 3-dimensional models in glass were built up, and from the models, 3-dimensional drawings were prepared.

Upon examination of each specimen, it gradually became obvious that most genera, in a broad sense, exhibit the same type of basic internal morphology. Therefore, with later studies, diagrams were drawn directly from the sections or specimens.

A universal stage was used to determine the optical character of the calyx plates and it was found that each plate has its own individual orientation.

For later studies at the University of Oklahoma, the camera lucida was used in recording features of thin sections, polished sections, and details of externally visible morphologic parts. The following data are presented to show the results of morphologic studies.

### GROSS MORPHOLOGY

It is assumed that the reader has some basic knowledge of the Blastoidea. Nevertheless, the following definitions may be useful for them, though unnecessary for specialists.

A blastoid may be defined as a stemmed echinoderm with a body (termed *calyx*) that bears internal folded structures called *hydrospires*, which are located in the upper half (in direction away from the stem attachment) of the calyx. As a rule, the calyx is composed of 18 to 21 plates arranged in 4 definite cycles. Normally three plates occur next to the stem at the base of the calyx; these are termed *basals*, the smallest

one (named *azygous*) being almost invariably in the same position (A-B, as subsequently explained in discussion of orientation) in all normal blastoids. The five elements next above the basals, each in position of a radius extending outward from the central mouth, are termed *radials*. The terminal portions (in direction toward the stem attachment) of the five recumbent, petal-like areas (called *ambulacra*) along these radii constantly form a V-shaped indentation (termed *radial sinus*) in the upper margins of the radial plates. In the central portion of each ambulacrum there is a spear-shaped plate (termed *lancet*), rarely visible on the outer surface of the calyx but present beneath minute plates of the ambulacral areas. Above the radials and alternating with them are five to eight subtriangular plates (termed *deltoids*, with one to six in the anal region, each bearing special names), which surround the *oral opening*. The *mouth* was a part of this opening in the living animal. In the adoral parts of the deltoids are small round to elongate openings termed *spiracles*. The *vault* is the vertical portion through which the ambulacra extend and the *pelvis* is the vertical portion from the tip of the ambulacra to the top of the stem. The *pelvic angle* is the angle of the pelvis with center of angle at middle of the base and sides extending upward along sides of basals and radials to the aboral tips of the ambulacra. The *basal circlet* comprises the three basal plates and the *radial circlet* consists of the five radial plates. The hydrospires are located on the radial and deltoid plates in a position marginal to and subparallel to the ambulacra, in general at right angles to the suture between the radial and deltoid plates. In one group (distinguished as an order), the hydrospires are continuous with the spiracles and with small pores (called *hydrospire pores*) which are marginal to the ambulacra.

Each ambulacrum possesses a main, centrally placed food groove (named *ambulacral groove* or *main food groove*), which branches laterally into many *side food grooves* that extend ventrally (in direction away from the stem) onto small thread- or cord-like, biserially arranged appendages termed *brachioles*. In the living animal, as shown by some fossils, this system of food grooves was covered by small, alternating *cover plates* adjoining the large interradiial plates (*orals*) which covered the mouth, centrally located near the summit of the calyx. Between the side food grooves are small, biserially arranged *side plates*, larger ones termed *primary side plates* (or simply *side plates*) and smaller ones (near sides of the ambulacra) being called *secondary* or *outer side plates*. In some

genera there is a third side plate (termed *inner side plate*) adjacent to the main food groove between side plates. *Medial* refers to the line or direction of the main food groove, and *abmedial* is away from this line, whereas *admedial* is toward this line. The side plates have a pit at the abmedial end of the side food groove, termed *brachiolar pit*, with small flat areas on each side termed *brachiolar facets*. A depression or furrow is seen on many side plates, leading toward a pore. This depression is termed a *pore furrow*. The side plates bore slender, freely movable appendages, termed *brachioles*. The *hyprospire pores* are situated between the side plates and are never in contact with the food grooves. It is believed that water circulated into the pores to the hydrospires, moving upward to the summit of the calyx and out through spiracles, whereas food was carried downward along food grooves of the brachioles into the side food grooves of the ambulacrum and thence along the main food groove upward to the mouth.

The *anal opening* is located on the upper half of the calyx, between two adjacent ambulacra and to one side of the mouth. It is larger than a spiracle and in the living animal included the *anus*. The anal opening may be excavated in a single deltoid plate (termed *anal deltoid*) or it may be located between two deltoids (an upper, termed *epideltoid*, and a lower, termed *hypodeltoid*), or there may be three deltoids (*superdeltoid* adjacent to the mouth, *subdeltoid* on the adoral side of the anal opening, *hypodeltoid* on the aboral side of the anal opening), or four deltoids (*superdeltoid* adjacent to the oral opening, two *cryptodeltoids* on either side of the anal opening, and *hypodeltoid* partly covering the cryptodeltoids on the aboral side of the anal opening).

## ORIENTATION

For descriptive purposes, the following conventions for orientation of blastoids, mostly long-established by custom, are important. The axis extending from the oral center to the center of the stem is designated as the *polar axis*. A section parallel to this axis is a *longitudinal section*, one normal to it is a *transverse section* or *cross section*, and one tangent to the outer surface of a blastoid is a *tangential section*. The direction called *proximal* is defined, as in crinoids, that is, the direction toward the point of attachment between stem and calyx; *distal* is the direction upward or downward away from this attachment. *Adaxial* may be defined as any direction toward and normal to the polar axis, and *abaxial* is any direction away from



and normal to the polar axis. *Inward* is any direction toward the geometric center of the calyx or polar axis of the stem, and *outward* is any direction away from this center or axis. The *oral opening* is the orifice in the calyx located in the position of the mouth, and the vicinity of the oral opening may be designated as *oral*. This general region is also termed the *summit*. Any direction away from the oral opening is *aboral* and any direction toward this opening is termed *adoral*. The *peristome* or summit, which is the area around the mouth, comprises minute plates surrounding the mouth, as observed in some blastoids, but generally not recognized. The *anal opening* is an orifice laterally placed near the summit of the calyx, marking the position of the anus, and the vicinity of the anal opening is designated as *anal area* or anal region. Any direction toward or away from the anal opening is termed *adanal* or *abanal*, respectively. *Ventral* and *dorsal* are the same as distal and proximal, respectively, as applied to the calyx.

Viewing a specimen obliquely from the oral side, and with the anal opening toward the observer, or viewing a photograph or figure of a specimen with the anal opening centrally placed on the side toward the observer, left and right sides of the specimen correspond in position to those of the observer. According to convention used by some authors, the ambulacra (and radials) are then numbered I to V in a clockwise direction, starting with I for the first ambulacrum to the left of the anal opening. Another method, introduced by Carpenter (1884) and herein used, is to letter the anterior ambulacrum (opposite the anal opening) with an "A," and proceeding in a clockwise direction, designate the other ambulacra "B," "C," "D," and "E," so that the anal opening is in the "CD" interradial area. If each plate is projected onto a flat surface in the form of a plan layout, with stem at the center, plates of the basal circlet projected radially from this center, and radials and alternating deltoids next outward from these, the anal side must be oriented away from the observer in order to preserve left and right directions in proper position. This is customary. Plan layouts are viewed from the dorsal side, and therefore the orientation of the ambulacra is opposite to that when viewed from the oral side, which results in arrangement of numbers or letters assigned to them having sequence in a counter-clockwise direction, beginning with "I" at the left of the anal opening or "A" opposite the anal opening.

The position of a line extending from the centrally placed mouth to the aboral end of an ambulacrum is

termed *radial*. Accordingly, the position of a line extending from the mouth through the mid-line of a deltoid plate, halfway between adjoining radii is called *interradial*. Lancets, radials, and ambulacra are radial in position and deltoids are interradial. The azygous basal is almost invariably "AB" (right anterior, or preferably anterior right) interradial in position and the other two are "DE"- "EA" (left anterior) and "BC"- "CD" (right posterior) radial in position.

## STEM

The stem is the column that serves as means of attachment for the blastoid. It is slightly expanded at its proximal end into a thickened columnal and in some genera a definite plate or group of three plates is secreted between this columnal and the basal plates. *Pentremites* appears to have one *supplementary* or *sub-basal* plate; *Cryptoschisma* has three. At the distal end of the stem, there is presumed to be an expanded, branching, treelike extension, termed the *root*. ETHERIDGE & CARPENTER (1886) mention its presence in *Pentremites*. In adults of some genera (e.g., *Eleuthero-crinus*, *Notoblastus*, *Pentephyllum*, *Timoroblastus*, *Astrocrinus*) it is quite possible that a stem is absent.

The stem is composed of a regular series of disc-shaped *columnals*, circular in outline, with small radially disposed ridges (*crenellae*) on their distal and proximal surfaces. The crenellae extend about one-third of the distance from the periphery toward the center, which is pierced by a small round opening (*lumen*). More research is necessary to determine if the lumen is continuous with the body cavity and this should be investigated for each species.

## BASALS

The basal plates form the dorsal extremity of the calyx, being attached proximally to the stem and extended distally to meet the radial plates. With the exceptions of *Astrocrinus*, and possibly *Acentrotremites*, there are invariably three basals—two large subequal plates located in the "DE"- "EA" (left anterior) and "BC"- "CD" (right posterior) radial position, and one small azygous basal, which is almost constantly in the "AB" (right anterior) interradial position. If prominent ridges are present on the basals, these have approximately the same placement in all blastoids. In the two subequal large basals, a single ridge extends from the middle of each of the three distal edges adjoining the radials to a common point in the middle of the proximal edge of the basal, thus

quadrisectioning each large basal. In the small azygous basal, a ridge extends from the middle of each of the two distal edges bordering the radials to a common point at its proximal edge, thus trisectioning this plate. The interbasal sutures comprising the junctions of each pair of juxtaposed basal plates are located in shallow depressed areas between the grouped raised ridges of the basals. The angle between interbasal sutures, as measured from their adoral extremities to the center of the stem is 140 degrees for those bounding either of the two large basals and 80 degrees for those bounding the azygous basal. However, near the center of the stem, the two lateral sutures of the azygous basal curve rapidly toward each other so that near their intersection at the stem center, the angle subtended by them is 120 degrees.

Growth of the basals proceeds by uniform accretions outward admarginally from the subcenter of each plate and accordingly growth lines, where perceptible, are parallel to the margins of the plate, with relatively wide spaces between lines parallel to the basiradial suture, narrower spaces between those parallel to the interbasal suture, and almost imperceptible spaces between those adjacent to the stem.

In forms having only a single basal plate, this consolidated plate may be formed in two ways. The discrete plates of the basal circlet may have fused into one large plate (as seems true in *Acentrotremites*), or a small plate remained in the position of the "AB" azygous basal while the other two were resorbed (*Astrocrinus*). In *Zygocrinus*, the small plate is eccentric, being located on the side of the base of the calyx and is in the normal position of the "AB" basal.

The basals are seemingly not diagnostic for generic determinations for apparently they functioned merely as support for the calyx. Nothing is known at present about the nervous system and until something of this is learned, no comparison with other pelmatozoans can be made. In no known blastoid do the basals receive ambulacra nor do they contain pores or slits of any type. In this respect the blastoids differ from various genera of rhombiferoid cystoids. The basal plates were a remarkably conservative and stable element of the calyx throughout their history.

### RADIALS

Situated above the basals are five radial plates, each usually cleft more or less deeply by a V-shaped *sinus*, which receives an ambulacrum. The *body* of the radial is the main portion of the plate located aborally with

respect to the tip of the sinus. The *limbs* are portions of the radial that border the sides of the ambulacrum. The *radial lip* is the thickened tip of the radial sinus. If ridges occur on the outer surface, the "C" (right posterior) and "E" (left anterior) radials, have a single ridge extending longitudinally along the middle from the radial lip to the mid-point of the basiradial suture, whereas the other three radials have two ridges extending from the radial lip to the lower corners. These are characters correlated with the pattern of the basal circlet, together defining an axis of symmetry that passes through the "D" (left posterior) radius and "AB" (right anterior) interradius, although this neglects location of the anal opening; presumably the symmetry indicated is a rather fundamental character which may bear on the question of origin of the blastoids.

Growth of the radials proceeds by accretions marginal to the radial lip, and thus growth lines are concentric about this point, with wider spaces between lines parallel to the basiradial suture and narrower spaces between those parallel to the interradiation sutures.

At the aboral tip of the ambulacrum, the radial plate may extend beneath the lancet plate and the hydrospires may terminate well within the substance of the radial. The radial plates normally bear the aboral portions of the hydrospires.

The radial plates seem to have two functions: (1) to receive the aboral extremities of the ambulacra, and (2) to aid in respiration by forming infolds along the sides of the ambulacra. The nature of the overlap of the radials with the deltoids is probably of generic importance and is a constant character in any one species.

### DELTOIDS AND SPIRACLES

The most important morphological elements in blastoids, as indicated by their significance in taxonomy and phylogeny, are the deltoid plates and their associated structures, for on the nature of these parts most generic distinctions are primarily based. The *deltoid* is so named because of its generally subtriangular outline when viewed in a direction normal to its outer surface; this shape is explained by the manner in which it is wedged between adjacent ambulacra and terminated aborally against, above, or below the distal extremities of the radial limbs. A single deltoid occurs in each interradius (generally more than one on the anal side), with sutures termed *radiodeltoid sutures*, along its aboral margin adjoining the radial limbs.

In many genera, the anal opening is bordered by two plates, one located aborally and the other adorally with respect to the anus; these are termed *hypodeltoid* and *epideltoid*, respectively. In some genera there are three plates, the usual hypodeltoid, and two plates between the oral opening and the mouth. The hexagonal plate adjacent to the oral opening is termed *superdeltoid* and the horseshoe-shaped plate on the adoral side of the anal opening is termed *subdeltoid plate*. In other genera four anal deltoid plates occur—the usual hypodeltoid and superdeltoid, associated with two small elongate plates on either side of the anal opening, termed *cryptodeltoids*. The cryptodeltoids are generally overlapped by the hypodeltoid and pass beneath the radial limbs aborally, folding internally into hydrospires. The hypodeltoid apparently serves to cover the anal opening, the cryptodeltoids separate the anal opening from the spiracles internally, and the superdeltoid separates the anal opening from the oral opening, in addition to helping form the hydrospire canal and spiracles. If these elements become fused into a single plate, this is called the *anal deltoid*. It is common to find specimens in which the hypodeltoid is absent, thus leaving a large gap next to the radial limbs. It is assumed that a hypodeltoid was present in all blastoids of this nature.

In the other four interrarial areas, only one deltoid plate is known. The adoral half of the hydrospires is excavated within the deltoids or may be described as confluent with them. In almost all genera an adoral portion of the deltoid, termed *deltoid lip*, lies adjacent to the oral opening. Although disposed about the opening at the surface, they also extend inward proximally, so that probably they surrounded the esophagus of the living animal. The deltoid lip is connected to the main portion of the deltoid seen externally, here termed *deltoid body*, by a thin septum (or two septa on the anal side as seen in *Pentremites*) called *deltoid septum*. This septum may or may not be seen at the surface, but where present as a raised ridge at the surface it is called the *oral crest* or *deltoid crest*.

The opening near the adoral tip of the deltoid, excavated within the deltoid and generally adjoined laterally by lancet and side plates and bounded adorally and aborally by the deltoid, is termed a *spiracle*. Depending upon the position of the deltoid septum, either one or two spiracles may be present in each deltoid plate. A special type of spiracle is one in which only a single opening appears externally, but the deltoid septum comes almost to the surface, actually forming two incomplete spiracles. This special struc-

ture is called a *paired spiracle*. If there is but one opening on the anal side, as in the Spiraculata, this vent is termed the *anispiracle*. It comprises the anal opening fused with adjacent spiracles. A *spiracular slit* in blastoids of the order Fissiculata is an elongated spiracle at the side of an ambulacrum, normally excavated in the adjoining radial plate in addition to the deltoid.

The growth lines of deltoids indicate that the first-formed portion is near the adoral tip of the deltoid body, increments being secreted on all sides, but with growth extending most rapidly in aboral directions.

The primary functions of the deltoids seem to have been (1) to serve for respiration by means of hydrospires, (2) to help protect the mouth, and (3) to gain a more efficient means of excretion. A possible, additional function may have been to aid in reproduction, for the gonads may have been located inward from the spiracle with which they were presumably associated. This would have been an excellent place for deposition of eggs or sperms, which could have been washed to the exterior.

In a general sense, the superdeltoid on the anal side is similar in shape and homologous to the deltoid lip of the other four deltoids. The cryptodeltoids are homologous to the deltoid septum, and the hypodeltoid is homologous to the deltoid body of the other four deltoids.

Generic distinctions are based largely on (1) position of the deltoid septa, (2) number of anal deltoids, (3) type of overlap by the deltoids on the radial limbs, (4) the presence or absence of hydrospire pores in the deltoids, and if present, their nature, (5) number of hydrospire folds, and (6) relative exposure and position of the lancet plate. If the deltoid septum reaches the exterior, two spiracles are produced in each interradius, and if the cryptodeltoids or septa on the anal side reach the exterior, the two spiracles on that side are separated from the anal opening (termed *anus separate* for abbreviated reference). If the septa and cryptodeltoids remain internal, only five spiracles are formed, the anispiracle occurring on the anal side. If the septa are halfway exposed, five paired spiracles are produced and the anal opening is only slightly separated from the posterior paired spiracle. There is need for more research on many specimens of each species in order to determine the correct anatomy of structures on the anal side. In the present paper it should be noted that only a few specimens of each species were examined and it is easy to mistake a crack or series of partings in the calcite structure for

sutures. Therefore, future workers should prepare thin sections of these areas in order to check each statement. Only perfect specimens should be used and naturally they would be destroyed. Because of a time limit imposed on the present study, the lack of many perfect specimens, and the use of material on loan, I have had to rely on observations of polished sections and only a few thin sections. Type specimens are almost useless for study in this respect.

### AMBULACRA

An *ambulacrum* is a radially disposed area of special sort extending aborally from the mouth. It is linear to subpetaloid in shape and bears a median food groove (depression), called *ambulacral groove* or *main food groove*, extending longitudinally along its mid-line. This groove is joined laterally by *side food grooves*, which connect at margins of the ambulacrum with threadlike, biserially arranged appendages, called *brachioles*. Normally, five ambulacra occur on the ventral side of the calyx and all are plainly visible in most fossils. Only rarely are the brachioles preserved. Strictly speaking, an ambulacrum includes all structures associated with the process of gathering food.

### FOOD GROOVES

The food-groove system is divisible into three main parts. (1) The main food groove, as just explained, occupies the mid-line of the ambulacrum. (2) On either side of this groove and alternately emptying into it are the small, obliquely trending, adorally directed side food grooves, subparallel to each other. (3) These are prolonged distally by *brachiolar food grooves* located medially on the brachioles on the side directed toward the ambulacrum. Minute plates of subpentagonal to elliptical shape, arranged alternately just above the food groove system are termed *cover plates*, because they probably completely covered this system in the living animal. The cover plates are rarely preserved but the sockets (called *cover plate sockets*), which served as places of attachment for the cover plates, are commonly observed in fossil blastoids. Between each socket is a prominence (lobe) equal in size to a cover plate; it reaches to the food groove and meets an opposite cover plate at its extremity. This lobe is called a *cover plate lobe*. It is presumed that food was carried by water currents moving from the brachiolar food grooves into the side food grooves and ambulacral food grooves and thence to the mouth.

The most important fact about food grooves is that they exist, whatever plate or parts of plates occur beneath them; these may include the deltoid lips and lancet plates, but generally, in primitive blastoids with linear ambulacra, the lancet plates do not adjoin the food grooves, proving that the lancet plate is not an ambulacral structure, though radial in position.

### SIDE PLATES

In the descriptions of these plates, the terms *admedial* and *adlateral* refer to directions toward the mid-line and toward lateral margins of an ambulacrum, respectively. The large subquadrangular plates arranged alternately on either side of the main food groove and between side food grooves are termed *primary side plates*, or simply *side plates*. Each of these have two portions, the admedial half (called *side plate body*), and a handle-like extension comprising the adlateral portion (named *side plate limb*). The sutures between adjacent primary side plates beneath the side food grooves are termed *side plate sutures*, or *primary side plate sutures*.

A small plate termed *secondary side plate*, or *outer side plate*, rests on the adoral bevelled edge of the side plate limb. It is roughly triangular in outline, with straight adlateral and adoral margins but a curved admedial-aboral margin. Each secondary side plate is bordered adorally by another side plate limb and adlaterally by a deltoid or radial plate. Another triangular plate rarely seen in blastoids, but common in *Nucleocrinus*, *Placoblastus*, *Pentremitea*?, and *Elaeocrinus* is found between primary side plates at the admedial corners, near or adjacent to the main food groove or just admedial to the pore of some genera. In *Placoblastus*, *Nucleocrinus*, and *Elaeocrinus* this plate is elliptical or lenticular. It is named *inner side plate*. The term *side plates* is used to include both primary and secondary side plates, in addition to inner side plates, but may refer to primary side plates only.

A *brachiolar pit* is a small round opening at the adlateral termination of a side food groove, located just admedial to the junction of the admedial tip of a secondary side plate with two adjacent primary side plates. A *brachiolar facet* is a large elliptical scarlike area on side plates (primary and secondary), adlateral to the brachiolar pit. This facet is divided into two parts, an aboral portion located on the entire surface of the secondary side plate, and an adoral portion placed on the adjacent side plate limb. In all well-preserved specimens seen by me, secondary side plates are present, contrary to reports that these plates may

be absent. It is noteworthy that in all specimens examined by me the brachiolar facet is bifascicular and this seems to be typical of blastoids. A small regularly curved ridge on each primary side plate body curves adlaterally around the brachiolar pit and parallels the adoral, admedial, and aboral edges of the primary side plate body. The depression thus formed in the middle of the side plate body is termed *median pit*, and the ridge is termed *median ridge*, according to usage. The median pits alternate with the brachiolar pits. In some specimens from Permian deposits of Timor, a small canal extends longitudinally beneath a row of primary side plates on either side of an ambulacrum and parallel to the ambulacral groove. These may represent ducts for passage of nerves.

The chief conclusions reached from study of side plates are that they serve three functions: (1) to cover the ambulacral area, (2) to bear food grooves, and (3) to bear brachioles. In primitive blastoids the side plates completely cover the lancet plate but as a result of evolution they moved laterally so as to allow the lancet plate to be exposed at the surface. In many blastoids the side plates adjoin the spiracles but rarely border the oral opening. An evolutionary trend affecting side plates is tendency toward reduction in numbers, in some Permian specimens to as few as two or three on each side of an ambulacrum. The outer side plate appears to have served as a base for one half of a brachiole, perhaps allowing flexibility to the brachiole from the base upward.

### BRACHIOLES

The *brachioles* are threadlike or fine cordlike appendages attached to the side plates, bearing food grooves along their ventral (adambulacral) surfaces. They are composed of a biserially arranged set of rectangular plates, termed *brachiolars*, which are larger near the base of the brachiole and smaller near its distal extremity. Brachioles appear to be persistent morphological features of blastoids and much investigation is needed on these structures.

### LANCET PLATES AND CANALS

The *lancet plate* is generally an elongate spear-shaped plate extending from the aboral tip of an ambulacrum to the oral opening and located along the mid-line of an ambulacrum. At its adoral end (generally internally) its adoral extension, termed *lancet stipe*, rests on the truncated ventral surface of the adjacent deltoid plates and does not adjoin the oral opening internally. Externally, the stipe adjoins the

oral opening and generally borders adjacent spiracles laterally. It is significant that the side plates completely conceal the lancet plate from the exterior in many blastoids, especially in primitive forms.

In all specimens where good preservation is found, a large *radial canal* extends along the length of the lancet plate and reaches the peristome in the following manner. As shown in *Globoblastus norwoodi* (Fay, 1960, Okla. Geol. Notes, November) the main radial canal of each ambulacrum bifurcates and the branches penetrate the center of the deltoid sutures on either side so as to meet the canal of an adjacent ambulacrum at the center of the base of the deltoid septum, which is the point of lateral bifurcation of this septum. At the junction of canals is an additional set of smaller canals which form an inner pentagonal ring around the esophageal opening, each canal of this ring penetrating the center of an outer pentagonal ring at the junction with the inward abaxial portion of the deltoid septum. The inner ring is slightly proximal to and inward from the outer ring to which it is connected. Of primary importance is the presence of small tubes extending distally from the outer ring toward the base of each deltoid septum and seemingly connecting with the spiracles. The entire structure has essential characteristics of the esophageal ring and associated radial canals of living echinoderms. The stone canal and polian vesicles are comparable to the small canals that seemingly reach to the base of each spiracle, and the madreporite is comparable to the anispiracle. These observations and interpretations suggest that the lancet plate is built by secretion around a radial canal and that water entered such canal by diffusion from the hydrospire canal. Some workers interpret the ring and canals as part of the nervous system.

It is significant that in primitive and some advanced blastoids, the lancet plate is entirely concealed by side plates, denoting complete disuse of this plate as primary support of a food groove. In other words, this plate is not part of the ambulacral food-gathering system but probably belongs to the respiratory system, and only later is found to have taken on structural functions in relation to the ambulacral food grooves. With this in mind, it is but a step to postulate a primitive blastoid that possessed no lancet plate, owing to lack of calcareous section about the radial canal.

In many Permian blastoids, the lancet plate is separated from the oral opening by intervening deltoid plates and the ambulacral food groove rests on the

deltoids, thus showing migration of the lancet plate in an aboral direction.

### HYDROSPIRES

An infold of calcareous tissue (stereome) developed from a radial and adjoining deltoid plate, generally at right angles to the radiodeltoid suture and subparallel to the adjacent ambulacral margin, is termed a *hydrospire fold* or *hydrospire*. Multiple hydrospire folds along one side of an ambulacrum comprise a *hydrospire field* or *hydrospire group*. The *hydrospire slit* or *cleft* is a fissure-like opening of a hydrospire fold. If there is no direct communication to the outside and the slits open into a common canal, the canal is termed a *hydrospire canal*. On the anal side of some blastoids, the epideltoid, subdeltoid, or cryptodeltoids may be infolded into hydrospires, or hydrospires may be absent on this side, or present on one side and not on the other, or reduced in number. Accordingly some genera and species are distinguished by these criteria.

Aboral extremities of the hydrospires end in substance of the radial limbs and never extend aborally beyond the aboral tips of the ambulacra. Adoral extremities of the hydrospires of blastoids belonging to the order Spiraculata terminate between small septa attached adaxially to each of two septa that extend laterally from the deltoid septum and meet the underside of the lancet plate. The longest hydrospire fold is admedial to an ambulacrum and the shortest fold is adlateral to an ambulacrum or deltoid. Invariably the wall of the longest fold adjacent to the lancet plate is perfectly parallel to and in constant contact with the lancet plate.

Two schools of thought concerning the function of hydrospires may be recognized. These respectively hold that (1) hydrospires are homologous with bursae, and alternatively, (2) hydrospires are homologous with skin gills. *Bursae* are small internal interradially disposed saclike organs found in modern echinoderms; they function in reproduction and communicate with the exterior by means of a large orifice. Although two bursae generally occur in each interradius, with openings adjoining each other, more than two in each interradius may occur. *Skin gills* are thin areas of the calyx in some living echinoderms, developed where the ectoderm and mesoderm meet so as to allow respiration to take place. In modern forms these areas have no constant position, but in some fossils (e.g., cystoids) structures (pore-rhombs) comparable to skin gills have a regular arrangement with respect

to sutures. A pore-rhomb is a diamond-shaped area of stereome infolds, the longest extending between centers of two adjacent plates and at right angles to the suture between the plates. Successively shorter folds occur on either side of the main fold and are parallel to it, the shortest folds occurring at the corners of the rhomb farthest removed along the suture from the main fold. In order to derive a hydrospire from a pore-rhomb it is necessary that half of the pore-rhomb should become atrophied so as to leave one-fourth of its area on a deltoid and another fourth on an adjacent radial limb. BILLINGS (1869), JAEKEL (1918), and MOORE (1954) have considered that it is rational to derive hydrospires in this manner, even though no evidence of such atrophy has ever been demonstrated in the cystoids. CLINE (1944) has suggested that hydrospires represent successive infolds along margins of the ambulacra, which seems rational and in line with ontogenetic growth.

The weight of evidence tends to show that hydrospires are a distinct structure peculiar to blastoids and lacking in other known echinoderms, and therefore, the blastoids should be segregated as a class. Although bursae are comparable to internal hydrospires they do not correspond to exposed hydrospires (Fissiculata). Pore-rhombs must atrophy in position and manner not known in cystoids, if they are recognized as antecedent structures. There is a distinct possibility that bursa-like organs may have been attached to the abaxial walls of the hydrospires, thus emptying eggs and sperms into a respiratory structure. There is also the possibility that adaxial extremities of the folds may have functioned for reproduction while other portions may have served for respiration, or the hydrospires may have had nothing to do with reproduction.

### HYDROSPIRE PLATE

The *hydrospire plate*, present only in pore-bearing blastoids, is structurally the infolded wall of the adambulacral margin of a radial or deltoid plate adjacent to the lancet plate, folded back against the adjacent adambulacral margin of a radial or deltoid plate. Its presence is detected by the appearance of pores beneath the side plates or lancet plate, where these are removed, or by pores occurring entirely within a radial plate or deltoid plate, or the absence of hydrospire slits where the lancet is missing, or the presence of many more pores than side plates. In some genera the hydrospire plate is concealed by the radial and deltoid margins. This plate is a specialized struc-

ture that may have developed independently in several diverse stocks of blastoids.

### FUSED HYDROSPIRE PLATE

A skeletal element of blastoids termed sublancet plate by previous authors is identical to the hydrospire plate in all respects except two. In the radial portion of the plate, extending admedially from the aboral tip of an ambulacrum almost to the position of the radiodeltoid suture, the admedial walls of adjacent admedial hydrospire folds fuse to form a thick plate beneath the lancet plate. In addition, the sublancet plate may occur in blastoids lacking pores (*Orophocrinus*, *Pentablastus*). The only pore-bearing blastoid in which it is described is *Calycoblastus*.

Because this structure is produced by fusion of two admedial hydrospire plates along an ambulacrum, the term sublancet should be suppressed in favor of *fused hydrospire plate*, thus showing the derivation of the structure from hydrospires. The so-called sublancet is not connected with the lancet plate in origin, shape, or function, and hence another name should be given to this element.

The fused hydrospire plate is here interpreted to be an advanced, specialized respiratory structure resulting from adoral migration, outward migration, and thickening of admedial walls of the admedial hydrospire folds beneath the lancet plate. This structure is absent in pre-Mississippian blastoids.

### HYDROSPIRE PORES

*Hydrospire pores* are openings that communicate between the hydrospire canals and exterior. Generally the pores are excavated in the adambulacral margin of a deltoid or radial and are shared partially by the adlateral corner of the aboral edge of a primary side plate where they meet the adoral edge of an adjacent outer side plate. If a hydrospire plate is present, the pores are located between this plate and the adjacent radial or deltoid.

In specimens of *Mesoblastus* there are approximately five pores for each side plate, with an admedial set of three and an admedial set of two seemingly arranged in two rows. This feature seems to denote nothing more than infolds in the hydrospire plate and the adjacent adambulacral margin of the radial whereby a fold near the interior becomes folded once or twice externally, and no evidence is found of two separate sets of pores with different functions.

In the genus *Hyperoblastus* pores seemingly are

formed as gaps between side plates, but in this group the aboral ends of the hydrospire slits are exposed. This affords excellent argument in favor of derivation of the Spiraculata from the Fissiculata by means of infolding of hydrospire fields and consequent formation of pores as gaps between side plates. With continuing evolution it is quite possible that the pores migrated laterally into the substance of the radial and deltoid plates and that these plates subsequently began to infold along their margins to form many pores along each side plate. This probably took place independently in Europe and North America in unrelated stocks.

### ORAL PLATES

An *oral plate* is one of the five plates covering part of the oral area, interradian in position, generally pentagonal in outline, aborally adjoining a deltoid and adoral parts of two adjacent ambulacra, and meeting other orals at a common point above the oral opening. The *anal oral*, or oral plate of the anal interradius, is larger than the other four and generally six-sided. These plates are best seen in *Nucleocrinus*.

In some genera many accessory plates surrounding the orals and extending above the side plates for a short distance are seen. These *accessory orals* meet the cover plates of the ambulacra so as to conceal the entire area around the mouth and adjacent food grooves. Such plates are best seen in *Placoblastus*.

In *Pentremites* an additional structure, termed *oral pyramid*, is seen to be composed of specialized elongate brachiolar plates, which overlap elongate oral plates covering the mouth. In addition to the brachiolar plates, specialized side plates appear to cover most, if not all, of the spiracles. The spiracles probably had outlets toward the inside aboral part of the pyramid and above each ambulacral groove. The only external outlets seem to be large openings above the food grooves, located at the point where the food grooves enter the oral pyramid.

The important conclusion from these observations is that the deltoids are not at all interpretable as oral plates, that, is homologous with the oral plates of crinoids.

### ANAL PLATES

The small polygonal plates covering the immediate anal opening are termed *anal plates*, as shown in *Orophocrinus stelliformis*. In *Pentremites* these appear to be imbricate triangular plates. In most blas-

toids these plates are absent and any descriptions of them would be a contribution to knowledge. The plates appear to have flexible sutures between them and one would hardly expect them to be found in place. From this evidence it is probable that the anal region was tightly covered by plates, and that the living blastoid probably did not have a large gap on the

anal side. In the genus *Polydeltoideus*, two small plates are present on the aboral side of the anal opening, abutting against the hypodeltoid and resting upon the cryptodeltoids. These are termed *paradeltoid* plates. The paradeltoids probably became fused with the hypodeltoid to form an elongate hypodeltoid in later blastoids.

## TAXONOMY AND PHYLOGENY OF BLASTOIDS

### INTRODUCTION

In the past, little uniformity has existed in classification and interpretation of relationships between the several kinds of known blastoids, and this lack of consistency persists. Not only do authors disagree as to placement of genera in families but there is even wide variance of opinion as to delimitation of the echinoderm group called blastoids. At different times specimens regarded by authors as belonging to cystoids, crinoids, and edrioasteroids have been described as true blastoids and the blastoids have been classed by some specialists as a subdivision of the cystoids. It is even true that genera have been shifted back and forth from classification with blastoids to placement with cystoids or crinoids. Therefore, a systematic survey of the Blastoidea is needed in order to evaluate accumulated knowledge of their morphological features and relationships objectively. In this connection effort has been made to understand the significance of every morphologically distinct structure. Because many new structures have been recognized and new genera are yet to be described, a comprehensive classification of Blastoidea is not here attempted. Only two orders are recognized—Fissiculata (hydrospire slits exposed to the surface or bearing spiracular slits) and Spiraculata (hydrospire slits hidden, pores formed with spiracles), as distinguished by JAEKEL (1918). The genera are not now grouped in families but arranged alphabetically under each order.

### PREVIOUS WORK

Since 1825, when THOMAS SAY introduced the name Blastoidea for a "family" of echinoderms intermediate between echinoids and crinoids, there has been controversy over classificatory placement and phylogenetic relations of these fossils. As early as 1808, S. L. MITCHILL called one specimen "an *Echinus* of the family galerite," thus expressing belief that a blastoid is some type of echinoid. In 1819, J. L. M. DEFRANCE used the name *Encrina* for the same blastoid, thus indicating presumed affinity of the blastoids with

crinoids. In order to reconcile these divergent opinions, SAY coined a noncommittal new name, "Blastoidea," referring to the predominant budlike form of the calyx.

In 1851, C. F. ROEMER divided the blastoids into four groups, named **Floreales**, **Elliptici**, **Truncati**, and **Clavati**, based on form of the calyx and ambulacra. He stated that the blastoids stand close to the cystoids because of their lack of arms and presence of a stem. The Floreales group was defined to include conical forms with petaloid ambulacra, the Elliptici contained elliptical forms, the Truncati comprised blastoids with flat or truncated summits, and the Clavati were defined as conical forms with linear ambulacra.

In 1886, R. ETHERIDGE & P. H. CARPENTER recognized the blastoids as a separate class, distinct from other pelmatozoan echinoderms, and they divided them into two orders called **Regulares** and **Irregulares**. The first comprise all blastoids with five normally developed ambulacra, and the second include all forms having four normal ambulacra associated with a distinctly shortened fifth ambulacrum. The Regulares were divided into five families called Pentremitidae (pyriform, with five spiracles); Troostoblastidae (pyriform, with ten spiracles); Nucleoblastidae (elliptical, with ten spiracles); Granatoblastidae (elliptical, with five spiracles); and Codasteridae (without hydrospire pores). The Irregulares comprised a single family named Astrocrinidae (three genera).

In 1900, CHARLES WACHSMUTH, who wrote the chapter on blastoids in ZITTEL-EASTMAN's *Textbook of Palaeontology*, followed ETHERIDGE & CARPENTER in almost every detail. However, in the same year F. A. BATHER published a new classification of the blastoids in which he recognized two "grades," named **Protoblastoidea** and **Eublastoidea**. The protoblastoids included two families: Asteroblastidae (with an indefinite number of thecal plates and possessing diplopores) and Blastoidocrinidae (with an indefinite number of thecal plates and having "incipient" hydrospires). The eublastoids (characterized by a constant



number of thecal plates in the calyx) were subdivided into three "series." These were designated as "Series A," termed *Codonblastida* (not defined), comprising two families (Codasteridae, with hydrospire slits exposed; Pentremitidae, with hydrospire slits not exposed); "Series B," called *Troostblastida* (not defined), containing two families (Troostocrinidae, elongate forms with hydrospire pores; Eleutherocrinidae, elongate forms with hydrospire pores and one ambulacrum shorter than others); and "Series C," designated *Granatoblastida* (not defined), with four families (Nucleocrinidae, lacking a hydrospire plate; Orbitremitidae, having a hydrospire plate; Pentephyllidae, stemless, with subpentagonal theca; Zygocrinidae, stemless, with depressed theca). It was BATHER's belief that poreless blastoids gave rise to those possessing pores as a result of gaps between side plates of the ambulacra. At the same time, however, he thought that diplopore-bearing cystoids were ancestors of the blastoids, thus opposing the idea that poreless blastoids gave rise to pore-bearing forms.

In 1918, OTTO JAEKEL defined the Blastoidea as a subclass of the Cystoidea, linking the two by means of *Cystoblastus*, deriving the blastoids from cystoids that bore pore-rhombs. JAEKEL's chief reason for this view was that the pore-rhombs of *Cystoblastus* are concentrated along margins of the ambulacra. He divided the blastoids into three orders, named *Parablastida* (characterized by a large number of thecal plates), *Radiolata* (with a regular number of plates, presumed to be reduced to 13, and having hydrospires), and *Coronata* (with 13 thecal plates as in the Radiolata but possessing no hydrospires). The parablastids were interpreted by JAEKEL as a separate aberrant group of blastoids consisting of the family Blastocystidae. The radiolatids were subdivided into two suborders, *Spiraculata* (with pores), which include Troostoblastidae, Pentremitidae, Nucleoblastidae, and Granatoblastidae (as defined by ETHERIDGE & CARPENTER); and *Fissiculata* (without pores), with two families, Orophocrinidae (having a single exposed spiracular slit) and Codasteridae (with many exposed hydrospire slits). The coronatids were transferred from the crinoids and defined as comprising several closely related genera. The primary reason for classifying the Coronata as blastoids is that arrangement of their thecal plates and nature of their ambulacra were thought by JAEKEL to be more characteristic of blastoids than crinoids. JAEKEL's classification differs fundamentally from all others in that it includes a new order (Coronata) composed of forms transferred from the crinoids and it

definitely implies derivation of the blastoids from pore-rhomb-bearing cystoids (Rhombifera).

In 1929, H. MATSUMOTO modified BATHER's classification by dividing the class Blastoidea into three orders: *Protoblastida*, *Mesoblastida* (essentially Fissiculata plus *Astrocrinus*), and *Eublastida* (Spiraculata minus *Astrocrinus*), thus arriving at a classification almost identical with that of JAEKEL. The Eublastida were divided into three "series," termed *Troostblastida*, *Pentremitida*, and *Granatoblastida*.

In 1940, J. WANNER retained the class Blastoidea as separate from other echinoderms and recognized JAEKEL's orders Fissiculata and Spiraculata as the two main divisions of the class. WANNER removed the parablastoids, protoblastoids, and coronates from the Blastoidea. Also, he erected five new families of Fissiculata and defined three suborders of Spiraculata. His classification is indicated in the following tabular outline:

*Wanner's Classification of Blastoids (1940)*

Class BLASTOIDEA Say, 1825

Order FISSICULATA Jaekel, 1918

Family CODASTERIDAE Etheridge & Carpenter, 1886  
(eight hydrospire groups, anal deltoid present)

Family DIPTEROBLASTIDAE Wanner, n. fam. (ten hydrospire groups, epideltoid and hypodeltoid present, plates irregular)

Family ZYGOCRINIDAE Bather, 1899 (eight hydrospire groups, plates irregular)

Family ANGIOBLASTIDAE Wanner, n. fam. (eight hydrospire groups, one to three slits in each, epideltoid and hypodeltoid present)

Family PHAENOSCHISMIDAE Etheridge & Carpenter, 1886  
(*recte* PHAENOSCHISMATIDAE) (ten hydrospire groups with many slits, plates irregular, base pyriform)

Family NYMPHAEUBLASTIDAE Wanner, n. fam. (ten hydrospire groups with many slits, plates regular, base flat to concave)

Family ANTHOBLASTIDAE Wanner, n. fam. (ten hydrospire groups, one slit in each, plates regular)

Family NEOSCHISMIDAE Wanner, n. fam. (*recte* NEOSCHISMATIDAE) (ten hydrospire groups, interradial areas prolonged)

Incertae sedes, *Thaumatoblastus* Wanner, 1924

Order SPIRACULATA Jaekel, 1918

Suborder TROOSTBLASTIDA Bather, 1899

Family TROOSTOCRINIDAE Bather, 1899

Family ELEUTHEROCRINIDAE Bather, 1899

Suborder GRANATOBBLASTIDA Bather, 1899

Family NUCLEOCRINIDAE Bather, 1899

Family ORBITREMITIDAE Bather, 1899

Family PENTEPHYLLIDAE Bather, 1899

Suborder PENTREMITIDA Matsumoto, 1929

Family PENTREMITIDAE d'Orbigny, 1852

In 1943, R. S. BASSLER & M. W. MOODEY gave an outline of classification of the blastoids which is almost identical with WANNER's except that these authors included the Protoblastoidea with the blastoids. They divided the blastoids into two orders **Protoblastoidea** and **Eublastoidea**, the latter being subdivided, but slightly modified, after WANNER, 1940. The Neoschismatidae are not recognized and *Thaumastoblastus* is placed in the Codasteridae.

In 1945, GERHARD REGNÉLL transferred the blastoids to the cystoids on the ground that pores pierce the calyx of both groups and biserial brachioles are present in both groups. He also included the Coronata as a separate order of the Blastoidea, along with the Parablastoidea and Eublastoidea, but removed the Asteroblastidae from the blastoids because of the presence of diplopores in *Asteroblastus*. REGNÉLL's order **Parablastoidea** contains only *Blastoidocrinus* and *Blastocystis*. The order Coronata was left unaltered from JAEKEL (1918) and the order Eublastoidea is the same as used by BATHER (1900). The order Coronata was included in the blastoids because REGNÉLL claimed that there are two plates at the aboral extremities of the ambulacra, and he identified these plates as outer side plates which bear biserial brachioles. In two papers by FAY (1960, 1961) it is shown that definite crinoid-type arms are present in this order and that pores are lacking and that this order should be placed with the crinoids.

In 1897, J. F. WHITEAVES described an Ordovician edrioasteroid from North America under the name of *Astrocystites*. Later workers, including WHITEAVES, were never sure whether this is really a blastoid or a very radical type of stemmed edrioasteroid with regular plates and blastoid-like ambulacra. HUDSON (1912-1927), BATHER (1914), BASSLER (1936), and WILSON (1946) concurred in the opinion that this fossil belongs to the Edrioasteroidea, despite the fact that it does not fit well into this group. In a recent article in the *Journal of Paleontology* FAY (1961) suggests that a new class of echinoderms should be erected to receive this form, which may be a possible link between Eleutherozoa and Pelmatozoa. There is also the possibility that some forms of this class may have given rise to the Blastoidea.

In 1954, MOORE gave a short summary on the status of knowledge concerning fossil pelmatozoans. He

expressed the same opinion as that of JAEKEL, 1918, and concluded that the derivation of blastoids from *Cystoblastus*-like and pore-rhomb-bearing cystoids by shifting of radials downward, laterals upward, and partial fusing of basals is plausible. MOORE expressed the opinion that the blastoids should remain separate from the cystoids. He also stated that the hydrospires seem to be strictly homologous to the pore-rhombs in the Rhombifera, thus indicating close affinity of blastoids and rhombiferoid cystoids. CLINE (1944), however, made no attempt to compare pore-rhombs to hydrospires, and WANNER (1940) declined to accept the homology of these two structures.

The latest systematic treatment of blastoids is by F. M. BERGOUNIOUX (1953), taken unchanged from BASSLER & MOODEY (1943). It is difficult, if not impossible, to define without overlap essential characteristics of families as outlined in previous classifications. Also, when each genus is studied in detail, it is impossible to trace lineages of genera within the several families. This alone indicates need for much further study and revision of the Blastoidea.

## SYSTEMATIC DESCRIPTIONS

The arrangement of genera in this work is alphabetical under the orders Fissiculata (slits exposed or spiracular slit present) and Spiraculata (slits hidden, pores and spiracles present). Any attempt to group these genera into natural families at the present time is thought to be premature, but a discussion is given in the section on phylogenetic trends. Only one reference is cited at the beginning of each description; this records the original work in which the genus or species was described. A complete synonymy is meaningless unless specimens are examined and it would be erroneous simply to quote long lists from previous publications. There is need for restudy of all types of specimens representing each species in order to evaluate their true characteristics correctly and arrive at a reasonably correct synonymy.

The purpose of the following descriptions is to establish certain features of new and old genera. In addition, measurements are given for those who may have use for limited mathematical comparisons. Certain new morphological features are described, paving the way for more research and widely opening the classification of blastoids to future workers. It is hoped that more questions will be raised than answered.

## PRESENT CLASSIFICATION

The present classification of the Blastoidea is offered in place of those of previous workers, but is not considered final. The two orders Fissiculata (slits exposed or spiracular slits present) and Spiraculata (slits hidden, pores and spiracles present) are recognized as natural orders, but the family groupings may be arbitrary. Many different characters were considered as bases for familial classification. After careful consideration of the possible origins of each genus, these characters were evaluated and arranged according to their inferred significance until the common stable features were discriminated for use in defining the families herein outlined.

Certain primitive features may be noted in Silurian blastoids, whereas specialized morphological parts can be detected in Mississippian and Permian forms, allowing one to formulate some generalizations. For instance, long, exposed hydrospire slits in ten hydrospire fields, steeply conical calyx shape, and the four anal deltoids of a fissiculate blastoid are interpreted as primitive characters. An advanced fissiculate blastoid has eight reduced hydrospire fields, only one or two anal deltoids, and a globular to wing-shaped theca. A primitive spiraculate form is judged to be one having paired spiracles (five), four anal deltoids, conical shape of theca, lancet covered by side plates, three to five hydrospires on each side of an ambulacrum, and radials overlapping deltoids. An advanced spiraculate form is one characterized by the presence of five, nine, or ten spiracles (anus separate), one or two anal deltoids, globular or rounded-pyriform calyx shape, exposed lancet, one or two or more than five hydrospire folds on each side of an ambulacrum, and in some genera deltoids that overlap the radials. The various ways in which evolutionary changes of morphological parts may have been produced were noted in the course of study, proceeding from one genus to the next (arranged stratigraphically), and this served to eliminate many characters from consideration as bases for classification of the genera in families. For instance, in diverse genera the lancet is seen to be covered in early blastoids of presumed primitive type, but exposed in later advanced forms, thus showing that this morphological part probably should not be used to define families. Primitive blastoids have radials that overlap the deltoids, whereas the reverse relationship is found in advanced forms. Primitive blastoids have three or four anal deltoids, as contrasted with most advanced forms which have only one or two anal deltoids. Primitive blastoids are steep-

ly conical, rather than globular, discoidal, or wing-shaped, as prevailingly seen in advanced forms. Apparently the few stable characters usable for familial differentiation are chiefly nature of the hydrospire fields, spiracular slits, and spiracles.

The nature, type, and arrangement of the hydrospire fields, spiracular slits, and spiracles are herein used to differentiate families, but perhaps shape of the calyx also may be important in familial classification. Many problems have been encountered in this study and it is quite possible that some of the defined families are polyphyletic. For example, in the Pentremitidae (Spiraculata with five spiracles) some of the globular genera may have been derived from *Schizotremites* and the pyriform types from *Hyperblastus* or a similar form. These relationships may be demonstrated when new genera are discovered; meanwhile, the present classification is offered as a provisional arrangement. It is not used in the systematic descriptions given in this paper because of the uncertainties which have been pointed out.

## Outline of Classification of Blastoidea

Class **Blastoidea** SAY, 1825 (=Eublastoidea BATHER, 1899), defined herein.

Order **Fissiculata** JAEKEL, 1918 (=Mesoblastida MATSUMOTO, 1929). Hydrospire slits exposed or spiracular slits present.

Family 1. **Phaenochismatidae** ETHERIDGE & CARPENTER, 1886 (*nom. trans. ex* Phaenochismidae E. & C., 1886) (=Dipteroblastidae, Neoschismidae, and Nymphaeoblastidae WANNER, 1940). Ten exposed hydrospire slits. Type genus, *Phaenochisma* ETHERIDGE & CARPENTER, 1882; *Conoschisma* FAY, n.gen.; *Decaschisma* FAY, n.gen.; *Deltoschisma* FAY, n.gen.; *Dipteroblastus* WANNER, 1940; *Hyperblastus* FAY, n.gen.; *Neoschisma* WANNER, 1924; *Notoblastus* BROWN, 1941; *Nymphaeoblastus* VON PEETZ, 1907; *Phaenoblastus* FAY, n.gen.; *Pleuroschisma* REIMANN, 1945; *Polydeltoideus* REIMANN & FAY, 1961; *Thaumatoblastus* WANNER, 1924.

Family 2. **Brachyschismatidae** FAY, n.fam. Fissiculata with nine exposed hydrospire fields, the field left of the anal opening being absent. Type genus, *Brachyschisma* REIMANN, 1945.

Family 3. **Codasteridae** ETHERIDGE & CARPENTER, 1886 (=Angioblastidae WANNER, 1940). Eight exposed hydrospire fields. Type genus, *Codaster* M'COY, 1849; *Angioblastus*

WANNER, 1931; *Paracodaster* YAKOVLEV, 1940; *Pterotoblastus* WANNER, 1924; *Sagittoblastus* YAKOVLEV, 1937; *Trionoblastus* FAY, n.gen.

Family 4. **Orophocrinidae** JAEKEL, 1918 (=Anthoblastidae WANNER, 1940). Ten spiracular slits present, with hydrospire slits opening into them. Type genus, *Orophocrinus* VON SEEBACH, 1864; *Anthoblastus*, *Indoblastus* WANNER, 1924; *Microblastus* EYKERE, 1942; *Pentablastus* SIEVERTS-DORECK, 1951; *Sphaeroschisma*, *Sundablastus*, *Timoroblastus* WANNER, 1924.

Family 5. **Astrocrinidae** AUSTIN & AUSTIN, 1843 (*nom. correct. pro* Astracrinidae A. & A., 1843, by ETHERIDGE & CARPENTER, 1886) (=Pentephyllidae, Zygocrinidae BATHER, 1899). Eight spiracular slits present; slits absent on the anal side. Type genus, *Astrocrinus* MORRIS, 1843 (*nom. correct. pro* *Astrocrinites* AUSTIN & AUSTIN, 1843); *Ceratoblastus* WANNER, 1940; *Cryptoschisma* ETHERIDGE & CARPENTER, 1886; *Nannoblastus* WANNER, 1924; *Pentephyllum* HAUGHTON, 1859; *Pentremiteida* D'ORBIGNY, 1849.

Order **Spiraculata** JAEKEL, 1918 (=Eublastida MATSUMOTO, 1929). Hydrospire slits hidden; spiracles and pores present.

Family 6. **Pentremitidae** D'ORBIGNY, 1852 (=Eleutheroocrinidae BATHER, 1899, *Eleutheroblastidae* HAMBACH, 1903, *Orbitremitidae* BATHER, 1899). Five spiracles present, or four spiracles plus anispiracle. Type genus, *Pentremites* SAY, 1820 (*nom. correct. pro* *Pentremite* SAY, 1820 by SOWERBY, 1825); *Ambolostoma* PECK, 1930; *Cordyloblastus* FAY, n.gen.; *Devonoblastus* REIMANN, 1935; *Eleutheroocrinus* SHUMARD & YANDELL, 1856; *Ellipticoblastus* FAY, 1960; *Globoblastus* HAMBACH, 1903 (*emend.* FAY, 1960); *Orbitremites* AUSTIN & AUSTIN, 1842 (*emend.* FAY, 1960, 1961); *Petaloblastus* FAY, n.gen.; *Rhopaloblastus* WANNER, 1924.

Family 7. **Troosticrinidae** BASSLER, 1938 (*nom. correct. pro* Troostocrinidae BATHER, 1899) (=Troostoblastidae ETHERIDGE & CARPENTER, 1886). Five paired spiracles present, or four paired spiracles plus a paired anispiracle. Type genus, *Troosticrinus* SHUMARD, 1866; *Diploblastus* FAY, n.gen.; *Metablastus* ETHERIDGE & CARPENTER, 1886; *Schizotremites* REIMANN, 1945; *Tricoelo-*

*crinus* MEEK & WORTHEN, 1868; ?*Pentremitella* LEHMANN, 1949.

Family 8. **Granatocrinidae** FAY, n.fam. (=Granatoblastidae ETHERIDGE & CARPENTER, 1886, invalid because no type genus from which name is derivable exists). Spiraculate blastoids with nine spiracles or eight spiracles plus anispiracle. Type genus, *Granatocrinus* HALL, 1862 (*emend.* herein) (=Granatocrinites TROOST, 1849, *nomen nudum*); *Calycoblastus* WANNER, 1924; *Carpenteroblastus* ROWLEY, 1901 (*emend.* herein); *Cribroblastus* HAMBACH, 1903 (*emend.* herein); *Cryptoblastus*, *Heteroblastus* ETHERIDGE & CARPENTER, 1886; *Lophoblastus* ROWLEY, 1901 (*emend.* herein); *Mesoblastus* ETHERIDGE & CARPENTER, 1886; *Monadoblastus* FAY, n.gen.; *Monoschizoblastus* CLINE, 1936; *Poroblastus* FAY, n.gen.; *Ptychoblastus* FAY, 1960; *Tanaoblastus* FAY, n.gen.

Family 9. **Nucleocrinidae** BATHER, 1899 (=Nucleoblastidae ETHERIDGE & CARPENTER, 1886, invalid because no type genus from which name is derivable exists; Olivaniidae HAMBACH, 1903). Ten spiracles, with anus separate, and two long exposed cryptodeltoids. Type genus, *Nucleocrinus* CONRAD, 1842 (*emend.* FAY, 1960 and herein); *Elaeocrinus* ROEMER, 1851 (*emend.* herein, (=Olivanites TROOST, 1849, *nomen nudum*); *Placoblastus* FAY, n.gen.

Family 10. **Schizoblastidae** FAY, n.fam. Spiraculate blastoids with ten spiracles and anus separate; with either hidden cryptodeltoids or cryptodeltoids absent. Type genus, *Schizoblastus* ETHERIDGE & CARPENTER, 1882; *Acentrotremites* ETHERIDGE & CARPENTER, 1883; *Deltoblastus* FAY, 1961.

### Class BLASTOIDEA Say, 1825

Hydrospire-bearing, stemmed echinoderms; calyx generally composed of 18 to 21 plates, three basals, surmounted by five radials, above which and alternating with them are five deltoids; in addition five lancets occur in radial position located within the radial sinuses; the anal side may comprise one, two, three, or four anal deltoids; hydrospires external or internal; pores and spiracles present mainly in forms with internal hydrospires. *Silurian-Permian*. North America, Europe, Asia, Timor, Australia, N. Africa, S. America.

### Order FISSICULATA Jackel, 1918

Blastoids with exposed hydrosphere slits or spiracular slits. *Silurian-Permian*. North America, Europe, Asia, Timor, Australia, North Africa, South America.

### Genus ASTROCRINUS Morris, 1843

[=*Astracrinites* AUSTIN & AUSTIN, 1842 (*nom. nud.*) and 1843 (invalid original spelling); *Astrocrinites* AUSTIN & AUSTIN, 1843 (*non* CONRAD, 1841, *nec* MATHER, 1843, *nec* DEKONINCK, 1854); *Zygocrinus* BRONN, 1848]

*Type-species*, by original designation (*monotypy*). *Astrocrinus tetragonus* MORRIS, 1843.

**Generic diagnosis.**—Fissiculate blastoids with eight spiracular slits along margins of ambulacra; epideltoid and possible hypodeltoid, slits lacking on anal side, with short wide "D" (left posterior) ambulacrum; one basal plate, and star-shaped in top view, with lancet covered by side plates; calyx spinose. *Lower Carboniferous*, Scotland, England.

**Remarks.**—The genus *Astrocrinus* appears to have been derived from a form similar to *Pentremitidea* in which the interambulacral areas have moved outwards, the (D) ambulacrum becoming foreshortened, the hypodeltoid atrophied or reduced in size, and the basals fused.

### ASTROCRINUS BENNIEI (Etheridge)

Plate 17, figures 1-3, 7-9; text-figs. 1-3

*Astracrinites benniei* ETHERIDGE, 1878, p. 103.

*Astrocrinus benniei* ETHERIDGE & CARPENTER, 1886, p. 301, pl. 19, fig. 1; pl. 20, fig. 3-20.

*Zygocrinus benniei* BATHER, 1899, p. 69; 1900, p. 91, text-fig. 14.

—— WANNER, 1932, p. 456-458, text-fig. 1-4; 1933, p. 496, text-fig. 36.

**Description.**—The studied specimens, which are crushed and damaged on the anal side, range in size from 2.5 to 4.5 mm. Of importance here is the fact that the lancet is covered by the side plates, and the outer side plates rest upon the abmedial-adoral bevelled corners of the primary side plates, with a large brachiolar facet on each.

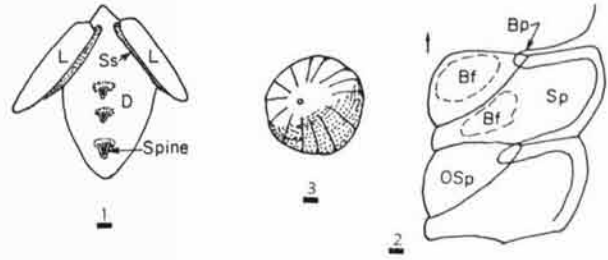
**Occurrence.**—From the shale above the no. 2 limestone of the Lower Carboniferous Limestone group, at Carlops Quarry, Peebleshire, Scotland.

**Types.**—Plesiotypes, 362, six specimens, Harvard Museum of Comparative Zoölogy, Cambridge, Mass.

### Genus BRACHYSCHISMA Reimann, 1945

*Type-species*, by original designation.—*Codaster corrugatus* REIMANN, 1935.

**Generic Diagnosis.**—Fissiculata with nine exposed hydrosphere fields, superdeltoid, subdeltoid, hypodeltoid, lancet covered by side plates, and conical in side view. *Devonian*, New York.



FIGURES 1-3. *Astrocrinus benniei* (ETHERIDGE), Lower Carboniferous, Scotland (Harvard Mus. Comp. Zoölogy, 362).—1. Oral view of "AB" deltoid ( $\times 15$ ).—2. "A" ambulacrum,  $\times 90$ .—Oral view of spine on "BC" deltoid,  $\times 90$ . [Explanation.—Bf, brachiolar facet; Bp, brachiolar pit; D, deltoid; L, lancet; OSp, outer side plate; Sp, main side plate; Ss, spiracular slit.]

### BRACHYSCHISMA CORRUGATUM (Reimann)

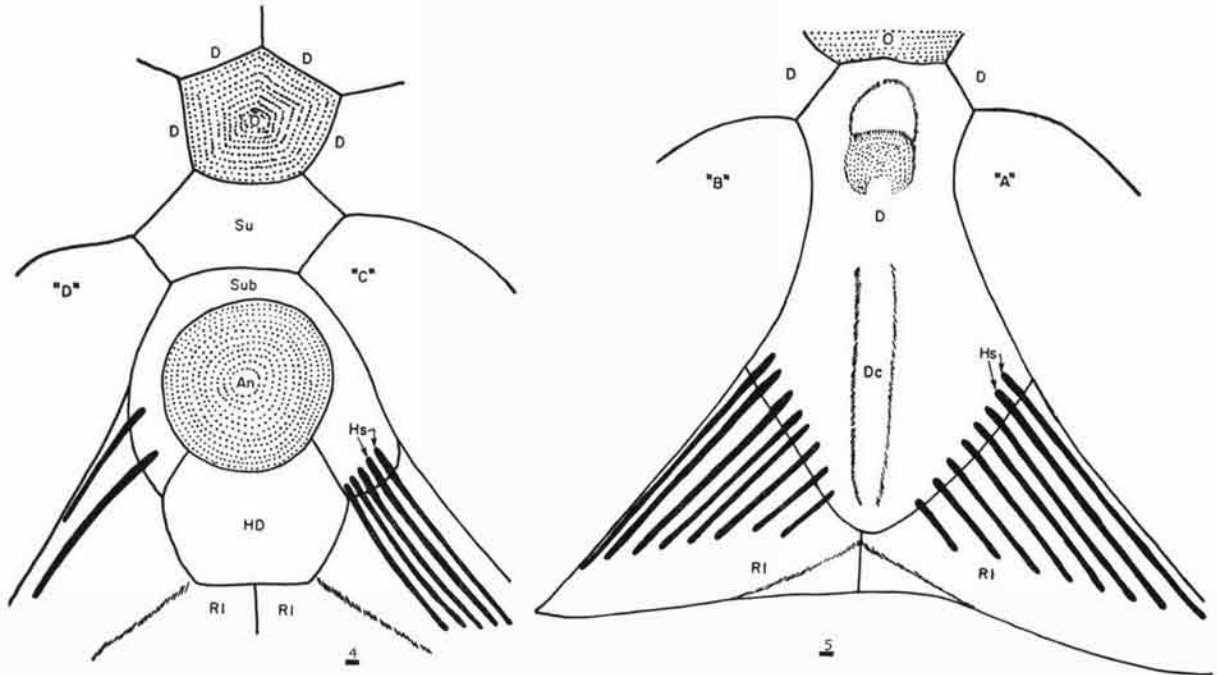
Plate 6, figures 1-9; text-figs. 4-7

*Codaster corrugatus* REIMANN, 1935, p. 25, pl. 4, figs. 1-2.

**Description.**—The description is taken mainly from features seen in specimen E21,134. Calyx broadly conical in side view, stellate in oral view, 16 mm. long by 9 mm. wide; vault 6 mm. long, pelvis 10 mm. long, with pelvic angle on basals 50 degrees and on radial bodies 95 degrees. Basal cirlet broadly pentagonal in outline, 6 mm. long by 7 mm. wide; with round stem impression about 1.5 mm. in diameter in center. Basals three, large, normally disposed, with coarse growth lines parallel to margins. Radials five, each 10 mm. long by 6 mm. wide, with wide sinus 5 mm. long by 6 mm. wide, and coarse growth lines parallel to margins; radials overlapping deltoids.

Deltoids four, bluntly arrow-shaped, confined to summit, with seven or more hydrosphere slits barely notching the margin of each next to radiodeltoid suture. Three deltoids on the anal side, epideltoid adjacent to the oral opening and homologous with deltoid lips of the other four deltoids; subdeltoid on the adoral side of the anal opening, horseshoe-shaped and notched on the right side ("C" ambulacrum) by five hydrosphere slits which extend to the radial limb. On the left side of the anal opening, the subdeltoid limb appears to be notched with two incipient hydrosphere slits which are not seen to penetrate the radial limb and subdeltoid limb at depth. The thick quadrangular hypodeltoid is aboral to the anal opening and rests on the radial limbs and aboral ends of the subdeltoid limbs. Thus, there are nine hydrosphere fields and three anal deltoids. The hydrosphere slits are elongate on each radial limb, within the sinus of each ambulacrum. The oral opening is surrounded by the four deltoid lips and superdeltoid.

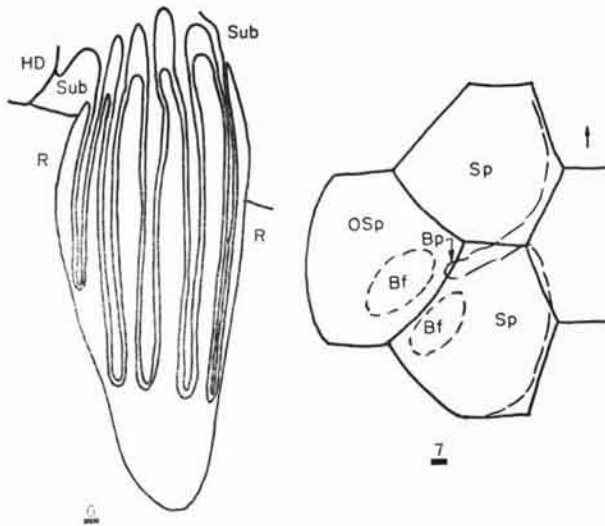
The ambulacra are linear, 8 mm. long by 1.5 mm. wide, with lancet covered by side plates, and 30 side



FIGURES 4, 5. *Brachyschisma corrugatum* (REIMANN), Middle Devonian, New York (Buffalo Soc. Nat. Sci., no. E15,982).

4. Plates around oral opening and near summit on anal side,  $\times 13$ .—5. "AB" deltoid and adjoining elements,  $\times 13$ . [Explanation.—"A," amb.; "B,"

amb.; "C," amb.; "D," amb.; D, deltoid; Dc, deltoid crest; HD, hypodeltoid; Hs, hydrospire slit; O, oral opening; RI, radial limb; Su, superdeltoid; Sub, subdeltoid.]



FIGURES 6, 7. *Brachyschisma corrugatum* (REIMANN), Middle Devonian, New York (Buffalo Soc. Nat. Sci., nos. E15,407, E15,982).—6. Vertical section of subdeltoid of "C" ambulacrum,  $\times 15$ .—7. Main and outer side plates of part of "D" ambulacrum, E15,407,  $\times 45$ . [Explanation.—Bf, brachiolar facet; Bp, brachiolar pit; HD, hypodeltoid; OSP, outer side plate; R, radial; Sp, main side plate; Sub, subdeltoid.]

plates in 10 mm. length. The pentagonal primary side plates alternate with large adorally disposed pentagonal outer side plates, each pair with a brachiolar facet for the reception of one brachiole.

*Remarks.*—The genus *Brachyschisma* appears to have been derived from a form like *Decaschisma* by atrophy of hydrospire slits on the left side of the anal opening in the subdeltoid and adjacent radial limb.

*Occurrence.*—Devonian, Onondaga limestone, near Williamsville (Vogelsanger quarry), New York.

*Types.*—Topotypes, E15,407, seven specimens collected by Fred W. Wattles, 1941; E15,982, one specimen collected by Mr. Wattles, 1943; E21,134, three specimens, one of which was used for the above description. Buffalo Society of Natural Sciences Museum, Buffalo, New York.

### Genus CODASTER M'Coy, 1849

[=*Codonaster* ROEMER, 1851 (obj.)]

*Type-species*, by original designation.—*Codaster acutus* M'Coy, 1849.

*Generic diagnosis.*—Fissiculate blastoids with eight exposed hydrospire fields, epideltoid, ?hypodeltoid, lancet covered by side plates, flat summit, rounded base, lancet not adjacent to mouth, and radials over-

lapping deltoids, with broad sinuses. *Lower Carboniferous, England.*

### CODASTER ACUTUS M'Coy, 1849

Plate 12, figures 1-7, 9; text-figs. 8, 9

*Codaster acutus* M'Coy, 1849, pp. 250-251.

*Description.*—Calyx calcitic, cup-shaped in side view, pentagonal in oral view, 14 mm. long by 11 mm. wide, slightly compressed, with flat summit and rounded base. Stem round, crenellar, with small round lumen. Basal circlet cup-shaped in side view, rounded pentagonal in basal view, large, 6.5 mm. long by 9 mm. wide, with a prominent bluntly rounded median ridge on each basal plate. Radials five, pentagonal in side view, wide, each 9 mm. long by 8 mm. wide, with flat truncated top bearing sinuses so that the ambulacra are almost invisible in side view. Each radial sinus is 2 mm. long by 5.5 mm. wide, with deltoids overlapped by thickened radial limbs.

Deltoids four, short, lancet-shaped, each 6 mm. long by 3 mm. wide, confined to summit, with low crests, and with approximately eight hydrospire slits exposed on each side of an ambulacrum except in anal area where they are lacking. The slits extend to the adjacent radial limbs. Approximately 16 cover plate sockets occur on each side of each deltoid lip. On the anal side, the thick horseshoe-shaped epideltoid, adjacent to the oral opening, surrounds the adoral portion of the anal opening on three sides and is overlapped by the radial limbs. The aboral part of the anal opening was presumably covered by a pentagonal hypodeltoid which is missing, probably as a result of disturbance of sediment in which it was buried, judging from the worn nature of the theca. Hydrospire slits are

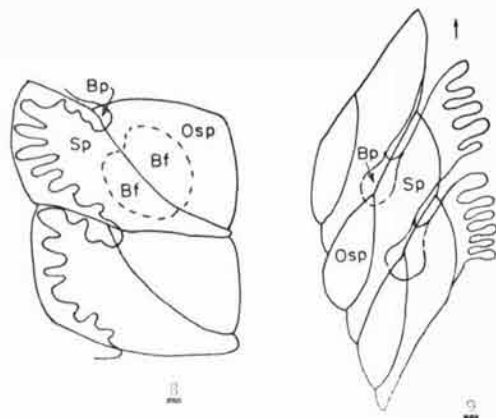
lacking on anal side and therefore only eight hydrospire fields are developed.

Ambulacra five, short, petaloid, confined to summit, each 3.75 mm. long by 1.75 mm. wide, with the adoral end of lancet 2 mm. from oral opening and exposed between side plates for a short distance aborally, but generally covered by side plates. Primary side plates subquadrangular, 30 in a length of 10 mm., with a subtriangular secondary side plate on the adoral-abmedial corner of each primary side plate. The brachiolar area of attachment is shared equally between a primary side plate and its associated secondary side plate. Approximately four main cover-plate sockets correspond to each side plate along the main food groove and three side cover-plate sockets along either side of each side food groove. Surfaces of calyx plates are ornamented with fine growth striae parallel to plate margins.

*Remarks.*—The genus *Codaster* is a specialized form that, as now understood, should be restricted to fossils known from the Lower Carboniferous of England. It was probably derived from a form like *Trionoblastus* of the Devonian, in which the superdeltoid and subdeltoid plates are fused to form the epideltoid.

*Occurrence.*—The labels on the specimens are generalized and merely indicate unspecified Lower Carboniferous strata of Yorkshire, Lancashire, and Derbyshire, England.

*Types.*—Plesiotypes 367, six specimens, Harvard Museum of Comparative Zoölogy, Cambridge, Mass. The description was based mainly on characters of one of these specimens, with an old name "*Pentremite asteria*" and number 2319, Malham, Yorkshire, England, on the label. Plesiotypes 96,267, three specimens, Carboniferous limestone, Yorkshire, England, labelled *Codaster acutus*; S3,200, three specimens, Carboniferous limestone, Lischowney, Derbyshire, England, labelled *Codaster acutus*, Springer collection; S3,218, two specimens, Carboniferous limestone, Lancashire, England, labelled *Codaster trilobatus*, Springer collection; S3,219, three specimens of the Hambach collection, Carboniferous limestone, Lischowney, Derbyshire, England, labelled *Codaster trilobatus* in the Springer collection; and S3,220, two specimens, Carboniferous limestone, Settle, Yorkshire, England, labelled *Codaster trilobatus* var. *acutus*, Springer collection, U. S. National Museum, Washington.



FIGURES 8, 9. *Codaster acutus* M'Coy, Lower Carboniferous, England; part of "A" ambulacrum showing main and outer side plates seen in two specimens (Harvard Mus. Comp. Zoölogy, no. 367, fig. 8,  $\times 45$ ; U. S. Natl. Mus., no. S3,218, fig. 9,  $\times 37.5$ ). [Explanation.—Bf, brachiolar facet; Bp, firachiolar pit; Osp, outer side plate; Sp, main side plate.]

### Genus CONOSCHISMA Fay, n. gen.

*Type-species*, by original designation (herein).—*Codaster* (*Cryptoschisma*?) *laeviusculus* ROWLEY, 1900.

*Generic diagnosis.*—Fissiculate blastoids with ten exposed hydrospire fields, an epideltoid and hypodeltoid, broad radial sinuses, lancet covered by side plates, ambulacra extending down sides of theca; form of calyx conical in side view. *Mississippian*, Missouri.

**CONOSCHISMA LAEVIUSCULUM (Rowley)**

Plate 14, figures 9, 11-12; text-fig. 10, 11

*Codaster (Cryptoschisma?) laeviusculus* ROWLEY, 1900, p. 65, pl. 2, figs. 51-55; p. 271, pl. 5, fig. 74.

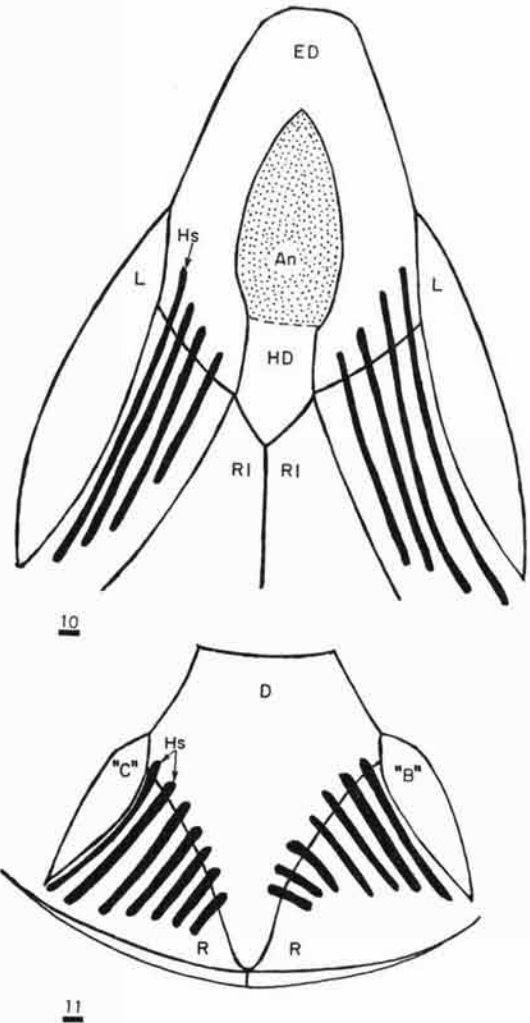
*Description.*—Calyx of topotype consisting of an internal mold, silicified, obconical in side view, rounded pentagonal in top view, 12 mm. long by 7 mm. wide, with periphery near mid-height at radial lips, vault 5 mm. long, pelvis 7 mm. long, and pelvic angle on basal circlet 60 degrees and on radial bodies 35 degrees. Stem impression not observed. Basal circlet conical in side view, pentagonal in basal view, 4.5 mm. long by 5 mm. wide, with three normally disposed basals. Radials five, elongate hexagonal, each 7 mm. long by 4 mm. wide, with short, wide, shallow sinus 3 mm. long by 3 mm. wide; radials overlapping deltoids.

Deltoids four, lanceolate, each 2.5 mm. long by 2 mm. wide, not seen in side view, with approximately seven hydrospire slits on each side of an ambulacrum extending to adjacent radial limbs. On the anal side approximately four hydrospire slits occur on each side of the elongate anal opening, and judging from the sutural markings two deltoid plates seem to be present on the anal side—a large horseshoe-shaped epideltoid with hydrospire slits, and a small pentagonal hypodeltoid that covered the aboral end of the anal opening. Thus ten hydrospire fields and two anal deltoids are recognized.

Ambulacra five, narrow, linear, with small narrow lancet plate 3.5 mm. long by 0.25 mm. wide, completely covered by side plates. The surfaces of the calyx plates

appear to be ornamented with fine growth striae parallel to the plate margins.

*Remarks.*—The genus *Conoschisma* probably was de-



FIGURES 10, 11. *Conoschisma laeviusculum* (ROWLEY), Lower Mississippian, Missouri (Univ. Chicago, 29,904). —10. Plates adjacent to anal opening,  $\times 15$ . —11. Deltoid of "BC" interambulacrum and adjoining elements,  $\times 15$ . [Explanation.—An, anal opening; "B," amb.; "C," amb.; D, deltoid; ED, epideltoid; HD, hypodeltoid; Hs, hydrospire slit; L, lancet; R, radial; RI, radial limb.]

## EXPLANATION OF PLATE 1

[*Preface to Explanation of Plates.* Unless otherwise noted, the oral views are oriented with the anal opening toward the bottom of the page, the side views with the "D" ambulacrum toward the observer, and the aboral views with the "A" ambulacrum toward the bottom of the page and the azygous basal (Z) in the lower right ("AB") position. In oral view, the ambulacra are lettered "A" through "E" proceeding in a clockwise direction with "A"

ambulacrum at the top. In side view, "C" ambulacrum is at right, "D" ambulacrum is in the middle, and "E" ambulacrum is at left, with the oral opening toward top of the page. In aboral view, the ambulacra are lettered "A" through "E" proceeding in a counter-clockwise direction with "A" ambulacrum toward the bottom of the page.]

FIGURE	PAGE
1-3. <i>Decaschisma pulchellum</i> (MILLER & DYER), topotype, 2,810, Washburn coll., Univ. Chicago; Silurian, Waldron Shale, Waldron, Ind.; oral, "D" ambulacral, aboral views (all $\times 6.7$ )	27
4-6. <i>Deltoschisma archiaci</i> (ETHERIDGE & CARPENTER), topotype, 13,876, Gurley coll., Univ. Chicago; Lower Devon-	

ian, Calizas de Ferroñes, from Ferroñes, Asturias, Spain; oral, "D" ambulacral, aboral views, (all $\times 7$ )	29
7-10 <i>Decaschisma pentalobus</i> (HALL), topotype, 2,554, Washburn coll., Univ. Chicago; Silurian, Waldron Shale, Waldron, Ind.; oral, aboral, "D" ambulacral, anal views (7-9, $\times 3.8$ ; 10, $\times 8.8$ )	27





1



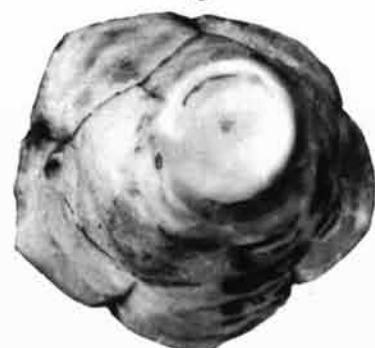
2



3



4



6



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8



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10



1



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3



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8



9



10



11

rived from the Devonian blastoid *Pleuroschisma* by atrophy of a few hydrosfire slits on the anal side and fusion of the cryptodeltoids and superdeltoid into a single epideltoid plate.

*Occurrence*.—Lower Mississippian, upper part of the Burlington Limestone, in chert, Louisiana, Missouri.

*Types*.—Topotype, 29,904, one well-preserved specimen and one fragmentary, Gurley collection, Walker Museum, University of Chicago, Chicago, Illinois. The holotype is supposed to be in the Rowley collection at the University of Illinois but is presumably lost.

### CONOSCHISMA? JESSIEAE (Miller & Gurley)

Plate 14, figures 1, 4, 7

*Codaster jessieae* MILLER & GURLEY, 1896, p. 89, pl. 5, figs. 20-22.

*Description*.—The specimen here described is fragmentary and questionably placed in this genus. Calyx calcitic, conical in side view, pentagonal in top view, 8 mm. long by 7 mm. wide, with vault 3 mm. long, pelvis 5 mm. long, pelvic angle 75 degrees, and periphery above mid-height at radial lips. Basal circlet 3 mm. high by 5 mm. wide, strongly triangular, with depressed interbasal sutures between the three normally disposed basals. Radials five, each 4.5 mm. long by 4 mm. wide, with deep broad sinus 3.5 mm. long by 2.5 mm. wide; radials overlapping deltoids at high angle.

The anal side is partly obscured by limestone matrix and not well preserved. Apparently, a horseshoe-shaped epideltoid surrounds the adoral part of the anal opening on three sides and abuts against the radial limbs. Presumably, the anal opening was covered by a hypodeltoid plate on the aboral side of the anal opening. The four subquadrangular deltoids are 2 mm. wide by 2 mm. long and confined to the summit. According to PECK (1938), five to seven hydrosfire slits occur on each side of an ambulacrum, but apparently none in the anal area. If the anal area is not well preserved, however, this feature may be unobservable. The oral opening is surrounded by four deltoid lips and the epideltoid, but relations to the lancet plate are obscure. The ambulacra seem to be narrow or linear and are obscured by matrix. The surfaces of the calyx plates are ornamented by fine growth lines parallel to the margins.

*Remarks*.—The above description is based upon characters seen in the specimen figured by PECK (1938, pl. 26, fig. 38). The specimen was further cleaned but to little advantage, and until more perfect specimens are found, it is probably best to classify this species doubtfully as belonging to *Conoschisma*.

*Occurrence*.—Lower Mississippian, Chouteau Limestone, Providence, Missouri.

*Types*.—Hypotype 3,573, one specimen, Carl C. Branson collection, University of Missouri. I have been unable to locate the holotype; other specimens (six) presumed to be at the University of Missouri are probably lost.

### Genus CRYPTOSCHISMA Etheridge & Carpenter, 1886

*Type-species*, by original designation.—*Pentremites schultzii* D'ARCHIAC & VERNEUIL, 1845.

*Generic diagnosis*.—Fissiculate blastoids with eight hidden hydrosfire fields, the two normally found on the anal side being absent, epideltoid and hypodeltoid present, lancet completely exposed, spiracular slits prominent, with only aboral ends of the hydrosfire slits exposed, calyx steeply conical in side view. *Devonian*, Spain.

### CRYPTOSCHISMA SCHULTZII (d'Archiac & Verneuil)

Plate 3, figures 1-9; text-figs. 12-17

*Pentremites schultzii* D'ARCHIAC & VERNEUIL, 1845, p. 479, pl. 15, figs. 12-13.

*Description*.—Calyx calcitic, conical in side view, pentalobate in top view, 10.5 mm. long by 8.5 mm. wide, with vault 2 mm. long and pelvis 8.5 mm. long, pelvic angle on subbasals 4 to 5 degrees, on basals and radials 50 degrees, with periphery at radial lips near summit. Stem round, apparently short, elongate conical in side view, approximately 9 mm. long by 2 mm. wide, composed of barrel-shaped columnals, each 2 mm. long, with smooth facets, attached to subbasals proximally. Subbasals three, in same position as basals, collectively cylindrical, 3 mm. long by 2.5 mm. wide, with smooth attachment face at

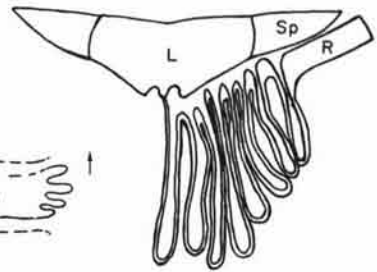
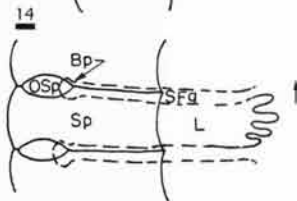
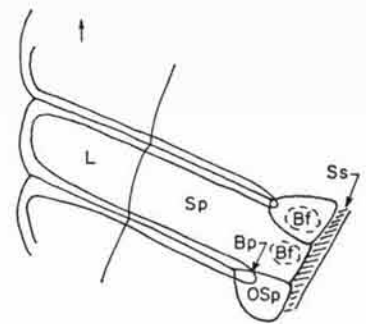
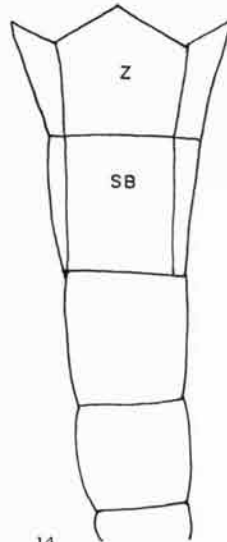
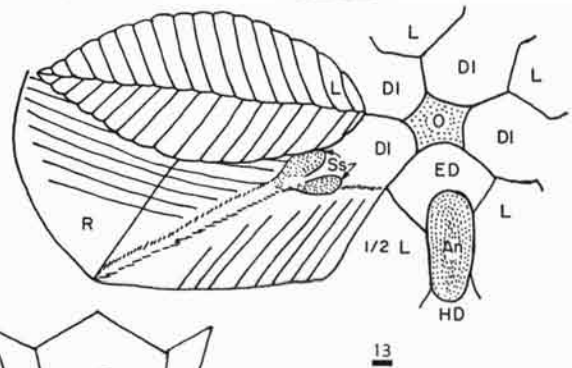
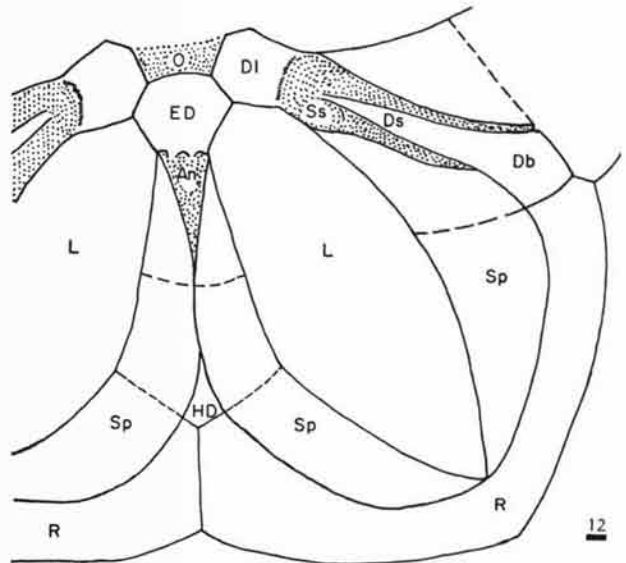
## EXPLANATION OF PLATE 2

FIGURE	PAGE	
1-11. <i>Pentremitea pailletti</i> (DE VERNEUIL), Lower Devonian, Spain.—1-3. Topotype, 13,876, Gurley coll., Univ. Chicago; Calizas de Ferroñes, Asturias; oral, "D" ambulacral, aboral views (all $\times 5.7$ ).—4-6. Topotype, 297, Schultze coll. Harvard Mus. Comp. Zoology; Calizas de Arnao, near Sabero (León); oral, "D" ambulacral, aboral views (all $\times 5.1$ ).—7, 8. Topotypes, S3,620, Springer coll., U.S. Natl. Mus.; Calizas de Ferroñes, Asturias; 7,		oral view ( $\times 9$ ); 8, long. sec. topotype S3,621 ( $\times 13$ ).—
		9, 10. Topotypes, 547, DeKoninck coll., Harvard Mus. Comp. Zoology; Calizas de Ferroñes, Asturias; 9, oral view with lancet plates removed in "D" and "E" ambulacra ( $\times 6.6$ ); 10, oral view of polished section showing marginal slits ( $\times 9.1$ ).—11. Topotype, S3,622, Springer coll., U.S. Natl. Mus.; Calizas de Arnao, near Sabero (León); oral view of specimen with side plates removed ( $\times 9$ ) .....

base. Basal cirlet broadly conical in side view, pentagonal in basal view, 3 mm. long by 5.5 mm. wide, with three normally disposed basals. Radials five, pentagonal in side view, rounded V-shaped or lobate in top view, each 5.5 mm. long by 4 mm. wide, with short wide shallow sinus on summit 2 mm. long by 4 mm. wide, and longer limbs on anal side than on the other sides.

Deltoids four, elongate, lancet-shaped, each 3 mm. long by 1.5 mm. wide, not visible in side view, with approximately nine hidden hydrospire slits on each side of an ambulacrum, extending aborally in the radial limbs. The deltoid crests are exposed between side plates, the lips being exposed around the oral opening, and the aboral ends of the hydrospire slits exposed on the margins of the radial sinuses, but otherwise most of the summit is covered by the broad lancet and side plates. On the anal side two deltoid plates appear to be present—a hexagonal epideltoid adjacent to the oral opening with two aborally disposed anal septa, and a pentagonal hypodeltoid plate on the aboral side of the anal opening that abuts against the truncated radial limbs and is covered over in part by the side plates. Hydrospire slits are absent on the anal side, thus there are eight hydrospire fields. The adoral ends of the spiracular slits are prominent and have the appearance of five spiracles.

Ambulacra five, broad, petaloid, each 4.5 mm. long by 4.5 mm. wide, with lancet completely exposed, and side plates extended almost to the margins of the deltoids and radials, separated from them by a narrow spiracular slit. Each primary side plate is elongate quadrangular, with a small triangular secondary side plate on the abmedial-adoral corner, and 40 side plates in 10 mm. The surfaces of the calyx plates are ornamented with fine growth striae parallel to plate margins.



FIGURES 12-17. *Cryptoschisma schultzei* (d'ARCHIAC & DE VERNEUIL), Devonian, Spain (depositories listed at end).—12. Anal view, slits not shown,  $\times 15$  (no. 311).—13. Oral view showing plates around anal opening and structures of the "DE" interambulacrum and "E" ambulacrum,  $\times 15$  (no. S3,224).—14. Proximal part of calyx and column seen from "AB" side, showing azygous basal and subbasal plates,  $\times 9$  (no. 311).—15. Vertical thin section of an ambulacrum showing lancet and side plates with hydrospire and radial limb on one side,  $\times 15$  (no. E1,063b).—16. Lancet and side plates of part of "E" ambulacrum,  $\times 45$  (no. 311).—17. Lancet and side plates of part of an ambulacrum,  $\times 37.5$  (no. S3,224). [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; Db, deltoid body; Dl, deltoid lip; Ds, deltoid septum; ED, epideltoid; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; R, radial; SB, subbasal; SFg, side food groove; Sp, main side plate; Ss, spiracular slit; Z, azygous basal.] Depositories: Harvard Mus. Comp. Zool., no. 311; U. S. Natl. Mus., no. S3,224; British Mus. (Nat. History), no. E1,063b.

The description is taken mainly from one specimen illustrated on Plate 3, figures 7-9.

*Remarks.*—The genus *Cryptoschisma* was probably derived from *Pentremiidea* by outward migration of the lancet plate to the surface of the calyx and fusion of the subdeltoid and superdeltoid into an epideltoid.

*Occurrence.*—Devonian, Spain; Calizas de Arnao, Sabero, and Calizas des Ferroñes, León and Asturias.

*Types.*—Topotypes, 311, six specimens, DeKoninck collection, old no. 2,357, Sabero, Spain, Harvard Museum of Comparative Zoölogy, Cambridge, Mass.; 220, three specimens, old no. 857, J. M. Barnard collection, labelled Eifel, in Harvard Museum; and S3,224, 20 specimens, Springer collection, Asturias, Spain, and S3,225, 16 specimens Springer collection, León, Spain, in U.S. National Museum, Washington; E1,063b, thin section, British Museum Natural History.

### Genus DECASCHISMA Fay, n. gen.

*Type-species*, by original designation (herein).—*Codaster pentalobus* HALL, 1882 (adv. publ., 1879).

*Generic diagnosis.*—Fissiculate blastoids with ten exposed hydrospire fields, superdeltoid, subdeltoid, hypodeltoid, lancet covered by side plates, exposed spiracular slits, calyx conical in side view. *Silurian*, Indiana.

### DECASCHISMA PENTALOBUS (Hall)

Plate 1, figures 7-10; text-figs. 18-20

*Codaster pentalobus* HALL, 1879, p. 13; 1882, p. 69.

*Description.*—Calyx calcitic, obconical in side view, pentagonal in top view, 17 mm. long by 13 mm. wide, with vault 5 mm. long, pelvis 12 mm. long, and pelvic angle 50 degrees. Periphery well above mid-height at radial lips. Stem impression worn, but in one specimen it appears to be round, smooth, about 1 mm. in diameter, with a small round central lumen. Basal cirlet elongate conical in side view, rounded pentagonal in basal view, 6.5 mm. long by 7.5 mm. wide, with three normally disposed basals and small flat truncated aboral end. Radials five, elongate hexagonal, each strongly lobed, giving the calyx a broadly stellate appearance in top view, with short limbs on anal side. Each radial is 11 mm. long by 5.5 mm. wide, with broad, deep, short sinus 5 mm. long by 3 mm. wide by 2 mm. high, projecting ventrally into low coronal processes except on the anal side. Radials overlap deltoids.

Deltoids four, short, lancet-shaped, not visible in side view, each 2 mm. long by 2.5 mm. wide, with wide V-shaped deltoid lip, low medium septum, high deltoid body, and seven or eight hydrospire slits on each side of an ambulacrum with four or five exposed, the slits extending across the adjacent radial limbs. On the anal

side there are three deltoid plates, a superdeltoid, subdeltoid, and hypodeltoid. The superdeltoid is adjacent to the oral opening, is broadly arrow-shaped, and adjacent to lancet plates on each side. It is overlapped internally by a thin long V-shaped subdeltoid, which is extended on either side of the wide anal opening, beneath marginal parts of the adjacent lancet plates. The subdeltoid limbs are overlapped by the truncated radial limbs aborally, and on the outside, the long wide pentagonal hypodeltoid plate covers the subdeltoid limbs. The hypodeltoid can be seen in side view, is low, abuts against the radial limbs, and is approximately 4 mm. long by 4 mm. wide. Internally, the subdeltoid limbs and adjacent radial limbs are infolded into approximately three hydrospire slits on either side of the anal opening. Thus there are three anal deltoids and ten hydrospire fields, with a reduced number of slits in the two fields on the anal side.

Ambulacra five, short, linear, each 7 mm. long by 1 mm. wide, with lancet covered by side plates and 36 side plates in 10 mm. Side plates normally disposed, with a subtriangular secondary side plate on the abmedial-adoral corner of each subquadrangular primary side plate. The surfaces of the calyx plates are ornamented with fine growth striae parallel to the margins.

*Remarks.*—The genus *Decaschisma* appears to have been derived from *Polydeltoideus* by fusion of the two cryptodeltoids into a single subdeltoid plate.

*Occurrence.*—Silurian, Waldron Shale, Waldron, Indiana.

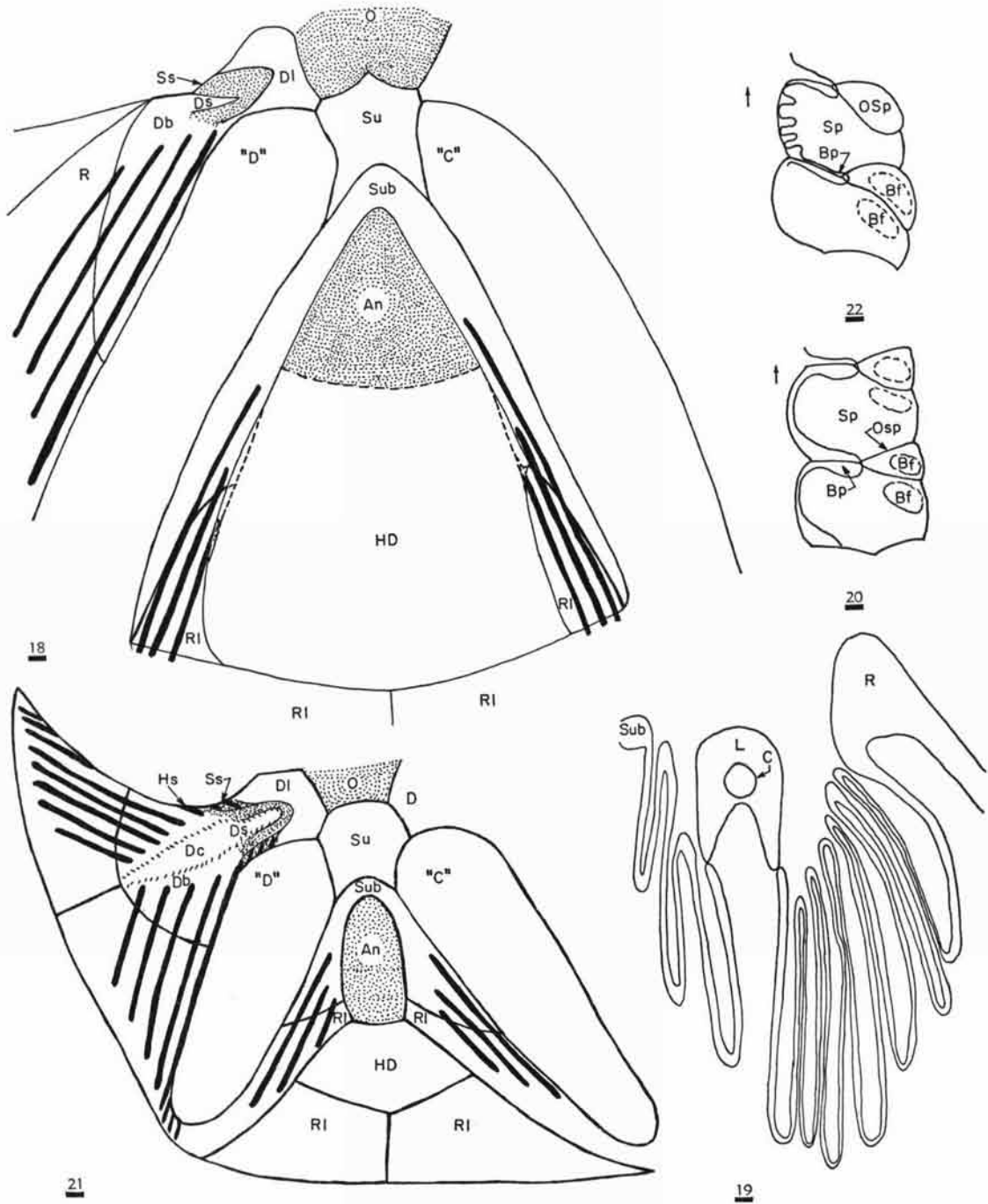
*Types.*—Topotypes, 2,554, eight specimens, Washburn collection, Walker Museum, University of Chicago, Chicago, Ill. The description is based upon characters seen in the specimen figured on plate 1, supplemented by features of the other specimens.

### DECASCHISMA PULCHELLUM (Miller & Dyer)

Plate 1, figures 1-3; text-figs. 21, 22

*Codaster pulchellus* MILLER & DYER, 1878, p. 35, pl. 2, figs. 13, 13a.

*Description.*—Calyx calcitic, obconical in side view with flaring base, pentagonal in top view, 10 mm. long by 7.5 mm. wide, with periphery well above mid-height at radial lips, vault 2 mm., pelvis 8 mm., and pelvic angle on basals 95 degrees, but on radial bodies 25 to 30 degrees. Stem impression small, round, crenellar, 0.5 mm. in diameter, on small flat triangular aboral portion of basals. Basal cirlet widely flaring, almost cup-shaped in side view, 3.5 mm. long by 6 mm. wide, strongly triangular in basal view, with a sharp ridge in the middle portion of each basal plate extending to aboral end, forming a sharp triangular base about 1 mm. in diameter. The geometric center of each basal is flared outward, giving a bluntly conical shape to the base in side view. Radials five, elongate hexagonal to subquadrangular, each 7 mm. long by 4 mm. wide, with short, deep, wide sinus 2.5



FIGURES 18-22. *Decaschisma pentalobus* (HALL) (Univ. Chicago, no. 2,554) and *D. pulchellum* (MILLER & DYER) (Univ. Chicago, no. 2,810), both Silurian, Indiana.

18-20. *D. pentalobus*, anal view,  $\times 16$ ; aboral view of "C" ambulatory,  $\times 16$ , "E" ambulatory,  $\times 50$ .—21, 22. *D. pulchellum*, anal view,  $\times 16$ ; "B" ambulatory,  $\times 50$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); "D,"

amb.; D, deltid; Db, deltid body; Dc, deltid crest; DI, deltid lip; Ds, deltid septum; HD, hypodeltoid; Hs, hydrosphere slit; L, lancet; O, oral opening; OSp, outer side plate; R, radial; RI, radial limb; Sp, main side plate; Ss, spiracular slit; Su, superdeltoid; Sub, subdeltoid.]

mm. long by 2 mm. wide by 1.5 mm. deep, forming part of the summit; radial limbs overlapping deltoids.

Deltoids four, lanceolate, each 2 mm. long by 1 mm. wide, not visible in side view, with a broad V-shaped lip, deep septum, and high body projected into a low coronal process, with approximately eight or nine hydrospire slits on each side of an ambulacrum, of which four or five are exposed. The slits extend to the adjacent radial limbs, parallel to the lancet plate. On the anal side there are three deltoid plates, superdeltoid, subdeltoid, and hypodeltoid. The broad V-shaped superdeltoid is adjacent to the oral opening, the elongate V-shaped subdeltoid resting on the internal aboral surface of the superdeltoid. The subdeltoid has two limbs that extend aborally on either side of the anal opening and partly beneath the adjacent lancet plates, folded internally into three hydrospire slits on each side, the limbs being overlapped by the adjacent radial limbs, and hydrospire slits extended to the radial limbs. The large pentagonal hypodeltoid, 1.25 mm. long by 1.75 mm. wide, visible in side view, covers parts of the subdeltoid limbs and abuts against the radial limbs.

Ambulacra five, short, linear, each 3 mm. long by 1 mm. wide, lancet being completely covered by side plates, of which 35 occur in 10 mm. Primary side plates subquadrangular, with subtriangular secondary side plates on bevelled abmedial-adoral corner. The surfaces of the calyx plates are ornamented with fine growth striae parallel to the margins.

*Remarks.*—This species may readily be distinguished from *D. pentalobus* by the flaring basal circling, not present in *D. pentalobus*.

*Occurrence.*—Silurian, Waldron Shale, Waldron, Indiana.

*Types.*—Topotypes, 2,810, 11 specimens, Washburn collection, Walker Museum, University of Chicago, Chicago, Ill. The description is based mainly on characters seen in the specimen figured on plate 1.

### Genus DELTOSCHISMA Fay, n. gen.

*Type-species*, by original designation (herein).—*Phaenoscisma archiaci* ETHERIDGE & CARPENTER, 1882.

*Generic diagnosis.*—Fissiculate blastoids with ten exposed hydrospire fields, four anal deltoids or a superdeltoid, two cryptodeltoids, and a hypodeltoid, a reduced number of slits on the anal side, lancet covered by large side plates, calyx steeply conical in side view, strongly pentalobate in top view. *Devonian*, Spain.

### DELTOSCHISMA ARCHIACI (Etheridge & Carpenter)

Plate 1, figures 4-6; text-figs. 23-25

*Phaenoscisma archiaci* ETHERIDGE & CARPENTER, 1882, pp. 229-230.

*Description.*—Calyx calcitic, steeply conical in side view, pentagonal in top view, 13.5 mm. long by 7 mm. wide, periphery at radial lips, with vault 1 mm. long, pelvis 12.5 mm. long, and pelvic angle 30 degrees. Stem round, with preserved part 4 mm. long by 2 mm. wide. Each columnal is 0.75 mm. long, smooth, with smooth facets and small round lumen. An enlarged columnal occurs at the aboral extremity of the basal circling, with a tripartite proximal facet, each part concave upward to fit against the convex aboral ends of the basal plates. Basal circling steeply conical in side view, rounded in basal view, 7.5 mm. long by 6 mm. wide, enlarged at base, with the apex of a strongly triangular ridge near the geometric center of the aboral one-fourth of each basal. Radials five, each hexagonal, 7 mm. long by 3.5 mm. wide, with wide, short flaring sinus 2.5 mm. long by 2 mm. wide. In top view each radial plate appears lobed near the radial lip and a slight constriction is seen along each interradial suture, giving a slight pentalobate appearance to the calyx in top view; radials overlapping deltoids.

Deltoids four, lanceolate, not visible in side view, each 1.75 mm. long by 1.5 mm. wide, with approximately eight hydrospire slits on each side of an ambulacrum, parallel to the lancet plate, and continuing aborally to the adjacent radial limbs. Approximately four hydrospire slits are exposed along the steep sinus walls, the other four being only partly exposed. The four hexagonal deltoid lips are adjacent to the oral opening and connected to the deltoid body by a low medium septum that is prominent, thus giving the appearance of eight spiracular slits around the oral opening. On the anal side there are four deltoid plates, a hexagonal superdeltoid, two thin long cryptodeltoids (mostly destroyed) on either side of the anal opening, and a pentagonal hypodeltoid (missing, but facets present) on the aboral side of the anal opening. The hypodeltoid would abut against the truncated radial limbs if preserved in place. The aboral ends of the cryptodeltoids are destroyed, but ETHERIDGE & CARPENTER (1886, p. 277) report that a reduced number of slits are present on either side of the anal opening. Thus there are ten hydrospire fields, the number of slits being reduced on the two anal fields; four anal deltoids occur.

Ambulacra five, linear, short, each 3 mm. long by 1 mm. wide, the lancet being covered by side plates, with a total of eight side plates in each ambulacrum and 30 side plates in a space of 10 mm. Each primary side plate is subquadrangular with a secondary side plate on the abmedial-adoral corner of each, with about four main cover-plate sockets to each side plate along the main food groove and four side cover-plate sockets along each side food groove. The surfaces of calyx plates are ornamented with fine growth striae parallel to the margins.

*Remarks.*—The genus *Deltoschisma* is the most primitive European blastoid known to date. It is similar to *Polydeltoideus* of the Silurian of North America but

differs in that *Deltoschisma* has a greatly reduced number of hydrosphere slits on the anal side, whereas *Polydeltoideus* does not. In this respect, *Polydeltoideus* is considered more primitive than *Deltoschisma*, and it would be natural to assume that *Deltoschisma* was derived from *Polydeltoideus* by reduction in the number of hydrosphere slits on the anal side.

*Occurrence*.—Devonian, Calizas de Ferroñes, Asturias, Spain.

*Type*.—Topotype, 13,876, one specimen in glass vial with five other specimens belonging to *Pentremiteida*, Gurley collection, Walker Museum, University of Chicago.

### Genus HYPEROBLASTUS Fay, n. gen.

*Type-species*, by original designation (herein).—*Pentremiteida preciosa* REIMANN, 1945.

*Generic diagnosis*.—Fissiculate blastoids with ten hidden hydrosphere fields, aboral ends of outermost hydrosphere slits exposed, however, and pores formed as gaps between side plates, five spiracles developed as gaps between deltoid lip, deltoid septum, lancet, and side plates on each interambulacrum, which includes anispiracle on the anal side; four anal deltoids, or a superdeltoid, two cryptodeltoids, and hypodeltoid present, lancet covered by side plates, club-shaped in side view. *Devonian*, North America (New York, Michigan, Indiana, Kentucky, Wisconsin, Ontario).

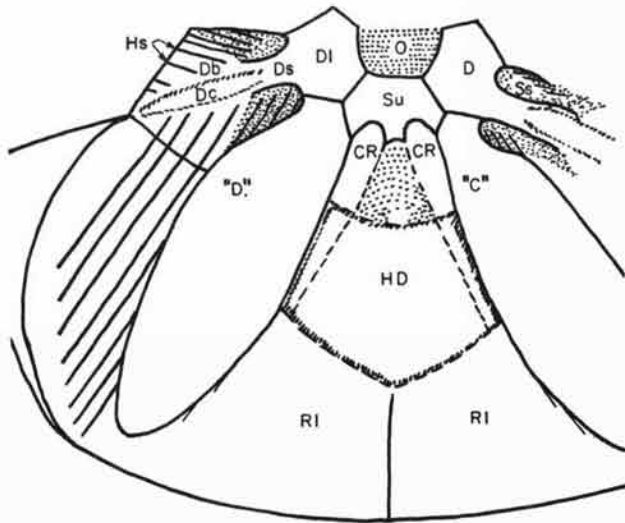
*Remarks*.—The genus *Hyperoblastus* was probably derived from *Polydeltoideus* by closure of the radial and deltoid sinus areas against the side plates, thus bridging the gap between the Fissiculata and Spiraculata, by formation of pores and spiracles. Two species, *H. filus* and *H. preciosus* are described in detail, others being only figured and compared by means of measurements and a few line drawings. The several species described by REIMANN (1935, 1945) are probably valid.

### HYPEROBLASTUS PRECIOSUS (Reimann)

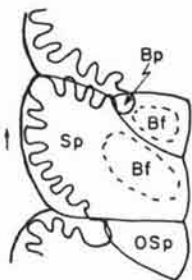
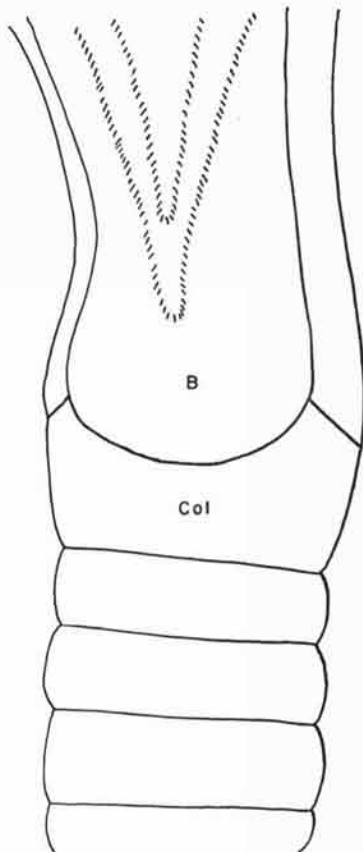
Plate 7, figures 1-8; text-figs. 26, 27

*Pentremiteida preciosa* REIMANN, 1945, p. 39, pl. 8, figs. 1-3.

*Description*.—Calyx calcitic, club-shaped in side view, pentagonal in top view, 15.5 mm. long by 10.5 mm. wide, with periphery near mid-height, vault 11 mm. long, pelvis 4.5 mm. long, pelvic angle on basal cirlet 55 degrees, and 120 degrees on radial bodies. Basal cirlet 4



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FIGURES 23-25. *Deltoschisma archiaci* (ETHERIDGE & CARPENTER), Devonian, Spain (Univ. Chicago, no. 13,876).

—23. Anal area and adjacent elements,  $\times 15$ . —24. Basal plates and proximal part of column from "C" side,  $\times 15$ . —25. Main and outer side plates of part "E" ambulacrum,  $\times 45$ . [Explanation.—B, basal; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; Col., columnal; CR, cryptodeltoid; "D," amb.; D, deltoid; Db, deltoid body; Dc, deltoid crest; DI, deltoid lip; Ds, deltoid septum; HD, hypodeltoid; Hs, hydrosphere slit; O, oral opening; OSp, outer side plate; RI, radial limb; Sp, main side plate; Ss, spiracular slit; Su, superdeltoid.]



mm. long by 5.5 mm. wide, pentagonal in basal view, composed of three normally disposed basals. Radials five, each 11.5 mm. long by 4.5 mm. wide, with deep, narrow, tapering sinus 10.5 mm. long by 2.5 mm. wide; radials overlapping deltoids.

Deltoids four, short, not visible in side view, triangular, covered by radial limbs, with deep median septum between adjacent hydrospire canals. On the anal side, the quadrangular hypodeltoid (missing) abuts against the radial limbs and rests on two internal cryptodeltoids. The cryptodeltoids are on either side of the anal opening, are overlapped by the radial limbs, and overlap the superdeltoid internally on the adoral side of the anal opening. They appear to be continuous with the two anal septa of the superdeltoid and separate the anal opening from the adjacent hydrospire canals internally. The superdeltoid, adjacent to the oral opening, is homologous with the deltoid lips of the other four deltoids and together with them helps to surround the oral opening. Spiracles five, with four piercing the adoral ends of the four deltoids and the anspiracle formed between the superdeltoid and hypodeltoid. Five hydrospire folds occur on each side of an ambulacrum, making ten fields in all, with aboral ends of the outermost slits exposed.

Ambulacra five, linear, each 13 mm. long by 2 mm. wide, slightly recurved onto aboral side, lancet covered by side plates, with 22 side plates in 10 mm. The side plates are normally disposed, with a subtriangular secondary side plate on the adoral-abmedial bevelled corner of each primary side plate, and a large bifasciulate brachiolar muscle scar split between the primary and secondary side plates. The pores are formed as gaps between side plates and margins of the radial sinuses. The brachiolar pit is admedial from the brachiolar facet, leading adorally to a side food groove. Two side cover-plate sockets occur on each side food groove and four main cover-plate sockets on each side plate along the main food groove. A curved pore furrow occurs on each primary side plate, curved aborally and abmedially around the brachiolar facet, ending in a pore. Near the radiodeltoid suture the side plates are firmly fixed against the radial sinus and pores are absent. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

*Remarks.*—This species was selected as the type-species because it clearly shows the internal and external features that characterize the genus.

*Occurrence.*—Middle Devonian, coral zone of the Widder beds, Hungry Hollow Formation, Joseph Bell Quarry, Thedford area, Ontario, Canada.

*Type.*—Holotype, E15,934, one specimen, collected by CHARLES SOUTHWORTH (1943), purchased by Buffalo Society of Natural Sciences, Buffalo, New York.

### HYPEROBLASTUS BASSLERI (Reimann)

Plate 52, figures 3-5

*Pentremiteida bassleri* REIMANN, 1945, p. 33, pl. 7, figs. 3-5.

*Description.*—The figured specimen is 27 mm. long by 13 mm. wide, vault 17 mm. long, pelvis 10 mm. long, and pelvic angle 55 degrees.

*Occurrence.*—Middle Devonian, Traverse Group, Thunder Bay Formation (now Partridge Point Formation), Partridge Point, near Alpena, Michigan.

*Type.*—Paratype, E15,337, one specimen, Buffalo Society of Natural Sciences, Buffalo, New York.

### HYPEROBLASTUS CUMMINGSI (Reimann)

Plate 9, figures 1-3

*Pentremiteida cummingsi* REIMANN, 1935, p. 28, pl. 2, fig. 19, pl. 4, fig. 8.

*Description.*—The figured specimen is 14 mm. long by 9.5 mm. wide, vault 11.5 mm. long, pelvis 2.5 mm. long, and pelvic angle on basal circling 75 degrees and on radial bodies 160 degrees. Approximately five hydrospire folds occur on each side of an ambulacrum.

*Occurrence.*—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, Arkona, Ontario, Canada.

*Type.*—Hypotype, E15,935, one specimen, Buffalo Society of Natural Sciences, Buffalo, New York.

### HYPEROBLASTUS DOTIS (Reimann)

Plate 9, figures 7, 9-11; text-fig. 28

*Pentremiteida dotis* REIMANN, 1945, p. 37, pl. 6, fig. 13.

*Description.*—The figured specimen is 9 mm. long by 5.5 mm. wide, vault 5.5 mm. long, pelvis 3.5 mm. long, and pelvic angle 60 degrees on basal circling and 130 degrees on radial bodies. Five hydrospire folds occur on each side of an ambulacrum.

*Occurrence.*—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, Thedford, Ontario.

*Types.*—Holotype, E15,401, one specimen; paratypes, E13,052, four specimens, Buffalo Society of Natural Sciences, collected by CHARLES SOUTHWORTH (1941), identified by REIMANN (1944); an ambulacrum of one of these specimens is shown in text-figure 23.

### HYPEROBLASTUS ERIENSIS (Reimann)

Plate 11, figures 4-6

*Pentremiteida eriensis* REIMANN, 1945, pp. 37-38, pl. 7, fig. 11.

*Description.*—The figured specimen is 7.5 mm. long by 5.5 mm. wide, vault 6 mm. long, pelvis 1.5 mm. long, and pelvic angle 75 degrees on basal circling and 160 degrees on radial bodies. Base flat, triangular.

*Occurrence.*—Middle Devonian, Tichenor Limestone, Springbrook Station, New York.

*Type*.—Paratype, E13,014, one specimen, collected by F. WATTLES (1941), studied by REIMANN (1944), Buffalo Society of Natural Sciences, Buffalo, New York.

#### HYPEROBLASTUS FILOSUS (Whiteaves)

Plate 7, figure 9; Plate 8, figures 1-6, 10-11; text-figs. 29-33

*Pentremitiidea filosa* WHITEAVES, 1887 (1889), p. 104, pl. 14, figs. 1a, 1b.

*Description*.—This species is described mainly on the basis of features of the holotype. Calyx calcitic, club-shaped in side view, pentagonal in top view, 13 mm. long by 9 mm. wide, vault 9 mm. long, pelvis 4 mm. long, pelvic angle on basals 70 degrees and on radial bodies 140 degrees. Periphery about at mid-height. Stem round, approximately 0.75 mm. in diameter with about 30 crenellae extending half the radial distance from the circumference toward the central lumen. Basal circling pentagonal, 4.5 mm. in diameter, with three normally disposed basals. Radials five, each 11 mm. long by 5 mm. wide, with sinus 10 mm. long by 1-1.5 mm. wide, slightly tapering, with steep subparallel sides; radials overlapping deltoids.

The four deltoids are confined to the summit, each about 1 mm. long, almost completely covered by the radials and forming part of the margins of the ambulacra. Each deltoid is notched by a spiracle in the adoral end, with a deep well-developed deltoid septum that connects the deltoid body with the deltoid lip. On the anal side there are four deltoid plates, a superdeltoid next to the oral opening on the adoral side of the anispiracle, two deeply hidden cryptodeltoids on either side of the anispiracle internally, and a pentagonal hypodeltoid, 1.5 mm. long by 1.5 mm. wide, seen in side view, abutting against the radial limbs and overlapping the cryptodeltoids. The cryptodeltoids are infolded to form hydrospires, the superdeltoid is infolded to help form the anispiracle, and the hypodeltoid is similar to an expanded deltoid body. Five hydrospire folds are present on each side of an ambulacrum, with the aboral ends slightly exposed along the radial sinus, above the pores, in well-preserved specimens.

Ambulacra five, each 11 mm. long by 1.5 mm. wide, linear, with lancet covered by side plates, and 30 side plates in 10 mm. The side plates are normally disposed, with approximately four cover-plate sockets to each side

plate along the main food groove, and one large triangular gap or pore between the side plates and margins of the radial sinuses. The surfaces of calyx plates are ornamented with fine growth lines parallel to plate margins.

*Remarks*.—This species and others of the genus *Hyperoblastus* may readily be distinguished by shape as seen in side view and expressed by various ratios, such as length to width and length of vault to that of pelvis, in conjunction with the pelvic angle.

*Occurrence*.—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, Thedford, and Arkona, Ontario.

*Types*.—Holotype, 3,660, marked by a red dot and red x; syntypes, 3,660a-f, six specimens together with holotype, Rev. H. CURRIE collection (1877-82), old number 13, identified by WHITEAVES (1889), Thedford area, Geological Survey of Canada, Ottawa, Ontario. Hypotypes, E13,960, six specimens, one polished, collected by CHARLES SOUTHWORTH, purchased (1942), near Thedford; E16,206, 14 specimens, one thin section, Charles Southworth collection, near Thedford; E16,209, one specimen, Charles Southworth collection, by purchase, studied by REIMANN (1944), near Arkona, Buffalo Society of Natural Sciences, Buffalo, New York.

#### HYPEROBLASTUS FILOSUS ANGUSTUS (Reimann)

Plate 8, figures 7-9; Plate 9, figure 8; text-fig. 35

*Pentremitiidea filosa* var. *angusta* REIMANN, 1945, pp. 31-32, pl. 6, figs. 20-33.

*Description*.—The holotype is 12.5 mm. long by 7.5 mm. wide, vault 9 mm. long, pelvis 3.5 mm. long, and pelvic angle on basal circling 65 degrees and on radial bodies 115 degrees. It is a thin variety of *H. filosa*.

*Occurrence*.—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, near Thedford, Ontario, Canada.

*Types*.—Holotypes, E15,403, one specimen, Charles Southworth collection, purchased (1942), identified by REIMANN (1944); paratypes, E13,055, eight specimens, Charles Southworth collection, purchased (1941), identified by REIMANN (1944), Buffalo Society of Natural Sciences, Buffalo, New York.

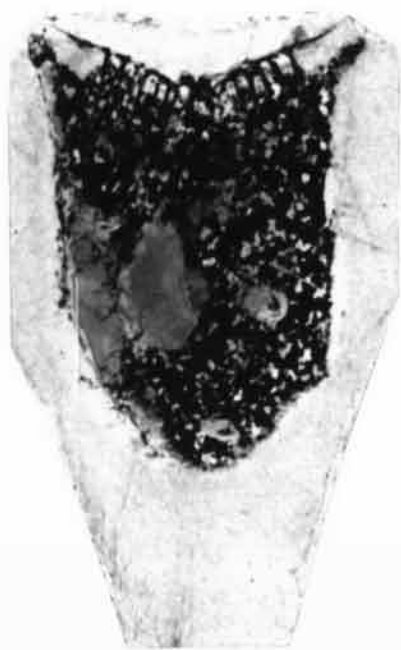
### EXPLANATION OF PLATE 3

#### FIGURE

1-9. *Cryptoschisma schultzei* (D'ARCHIAC & DE VERNEUIL), Lower Devonian, Spain.—1. Topotype, E1,063b, Brit. Mus. (Nat. Hist.); Calizas de Arnao, Colle near Sabero; long, thin sec. of ambulacrum showing the hydrospire folds ( $\times 13$ ).—2, 7-9. Topotypes, 311, Harvard Mus. Comp. Zoology; Calizas de Arnao, Sabero; 2, side view of stem connected to basal plates, ( $\times 6.4$ ); 7, oral view with side plates removed on anal side showing where

#### PAGE

hypodeltoid (missing) would fit ( $\times 5.7$ ); 8-9, "D" ambulacral, aboral views, ( $\times 5.7$ ).—3-6. Topotypes, S3,224, Springer coll., U.S. Natl. Mus.; Calizas de Ferroñes, Asturias; 3, "A" ambulacral view showing three subbasals at top of stem and below basals ( $\times 4.3$ ); 4, 6. "D" ambulacral, aboral view of another specimen ( $\times 7.6$ ); 5, oral view of another specimen showing side plates in place covering hypodeltoid ( $\times 7.8$ ) ..... 25



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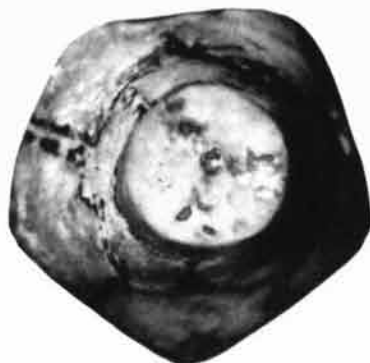
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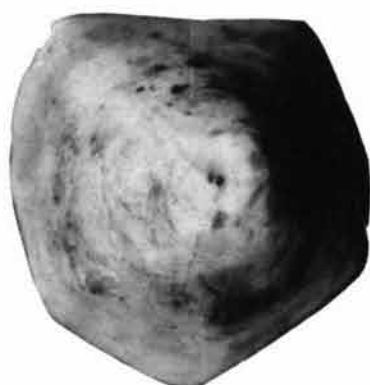
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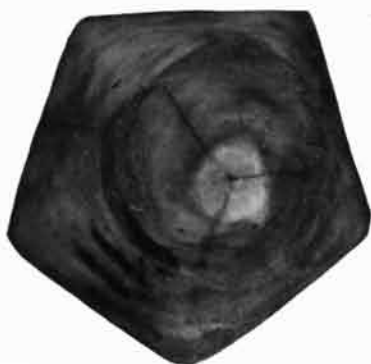
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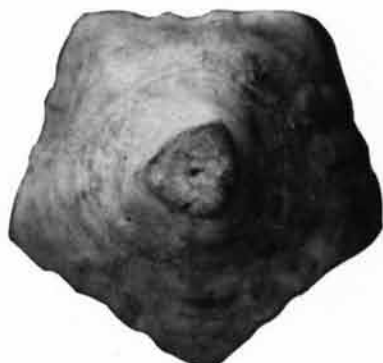
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**HYPEROBLASTUS GOLDRINGAE (Reimann)**

Plate 10, figures 1-3, 8; text-fig. 34

*Pentremiteida goldringae* REIMANN, 1935, p. 26, pl. 2, figs. 1-7.

*Description*.—The figured syntype is 9 mm. long by 6.5 mm. wide, vault 6.5 mm. long, pelvis 2.5 mm. long, and pelvic angle 80 degrees. Hydrosphere folds four on each side of an ambulacrum.

*Remarks*.—The subspecies *H. goldringae juvenis*, *latus*, and *obesus* are here raised to rank of species, taking account of radical differences in shape.

*Occurrence*.—Middle Devonian, *Pleurodictyum* beds, Wanakah Shale of Ludlowville Formation, Cazenovia Creek, about 0.12 mile below Transit Road Bridge, on Gehle farm, New York, and old quarry at Bay View, New York.

*Types*.—Syntype, E9,049, one specimen, Reimann collection; plesiotypes, E21,160, five specimens including one thin section, F. W. Wattles collection, from Bay View, Buffalo Society of Natural Sciences, Buffalo, New York. The syntype is from Cazenovia Creek.

**HYPEROBLASTUS JUVENIS (Reimann)**

Plate 10, figures 4-6

*Pentremiteida goldringae juvenis* REIMANN, 1935, p. 27, pl. 2, figs. 8-9.

*Description*.—Calyx 7.5 mm. long by 4.5 mm. wide, vault 3.5 mm. long, pelvis 4 mm. long, pelvic angle 45 degrees, and five hydrosphere folds on each side of an ambulacrum.

*Occurrence*.—Middle Devonian, *Pleurodictyum* beds of Wanakah Shale, old quarry at Bay View, New York.

*Types*.—Syntypes, E9,054, E9,054a, two specimens, the former figured, Reimann collection, Buffalo Society of Natural Sciences, Buffalo, New York.

**HYPEROBLASTUS LATUS (Reimann)**

Plate 10, figures 9-11

*Pentremiteida goldringae lata* REIMANN, 1935, p. 27, pl. 2, figs. 10-13.

*Description*.—Calyx 11 mm. long by 10 mm. wide, vault 8 mm. long, pelvis 3 mm. long, pelvic angle 70 degrees on basal cirlet and 180 degrees on radial bodies, with four or five hydrosphere folds on each side of an ambulacrum.

*Occurrence*.—Middle Devonian, *Pleurodictyum* beds of Ludlowville Formation, Athol Springs, New York.

*Type*.—Syntype, E9,052, one specimen, Reimann collection, figured by REIMANN (1935), pl. 2, figs. 12-13, Buffalo Society of Natural Sciences, Buffalo, New York.

**HYPEROBLASTUS OBESUS (Reimann)**

Plate 11, figures 1-3

*Pentremiteida goldringae obesa* REIMANN, 1935, p. 27, pl. 2, figs. 14-15.

*Description*.—Calyx 9 mm. long by 8 mm. wide, vault 5 mm. long, pelvis 4 mm. long, pelvic angle 75 degrees on basal cirlet and 125 degrees on radial bodies. Five hydrosphere folds occur on each side of an ambulacrum.

*Occurrence*.—Middle Devonian, *Demissa* beds, Ludlowville Formation, Smokes Creek, Windom, New York.

*Type*.—Holotype, E9,055, one specimen, Reimann collection, Buffalo Society of Natural Sciences, Buffalo, New York.

**HYPEROBLASTUS PEROVALIS (Reimann)**

Plate 10, figure 7

*Pentremiteida perovale* REIMANN, 1942, pl. 9, fig. 2.

*Description*.—Calyx 8 mm. long by 6 mm. wide, vault 6.5 mm. long, pelvis 1.5 mm. long, and pelvic angle of 90 degrees. The specimen is imbedded in rock and is fragmentary.

*Occurrence*.—Middle Devonian, Tully Limestone (pyrite), Cazenovia Creek, at Springbrook, New York.

*Type*.—Holotype, E12,267, one specimen, Buffalo Society of Natural Sciences, Buffalo, New York.

**HYPEROBLASTUS REIMANNI (Kier)**

Plate 11, figures 7-11

*Pentremiteida reimanni* KIER, 1952, p. 64, pl. 4, figs. 9-13.

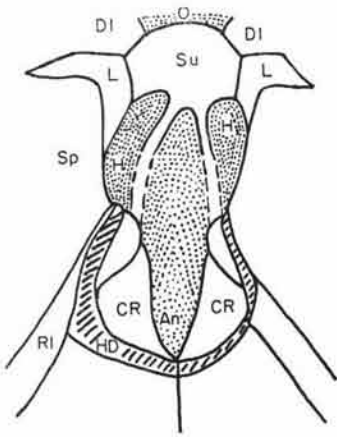
*Description*.—The holotype is 10.5 mm. long by 7.5 mm. wide, vault 6 mm. long, pelvis 4.5 mm. long, and pelvic angle 75 degrees.

*Occurrence*.—Middle Devonian, Silica Shale, Unit 13, Medusa Portland Cement Company Quarry near Silica, Lucas County, Ohio.

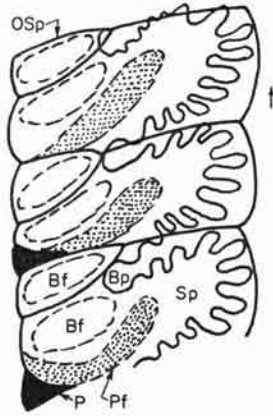
*Types*.—Holotype, 27,678; paratypes, 27,679 (one specimen) and 27,681 (one specimen), Robert R. Klinger collection, University of Michigan.

## EXPLANATION OF PLATE 4

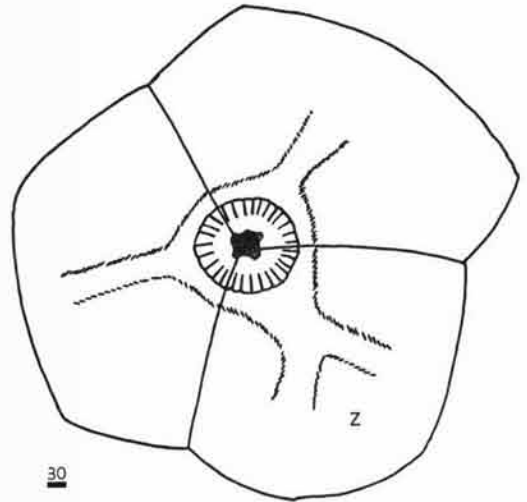
FIGURE	PAGE		
1-3. <i>Trionoblastus subtruncatus</i> (HALL), holotype, X-52, A.H. Worthen coll., Univ. Illinois; Devonian, Hamilton Group, New Buffalo, Iowa; oral, "D" ambulacral, aboral views (all X7.4)	47	Thedford, Ontario; oral, aboral, "D" ambulacral views (all X9)	48
4-6. <i>Trionoblastus canadensis</i> (BILLINGS), hypotype, 3,664, Geol. Survey Canada; Devonian, Hamilton Group, near		7-9. <i>Trionoblastus pyramidatus</i> (SHUMARD), plesiotype, E21,071 Buffalo Soc. Nat. Sci.; Devonian (probably Columbus Limestone), Columbus, Ohio; oral, "D" ambulacral, aboral views (all X6.1)	49



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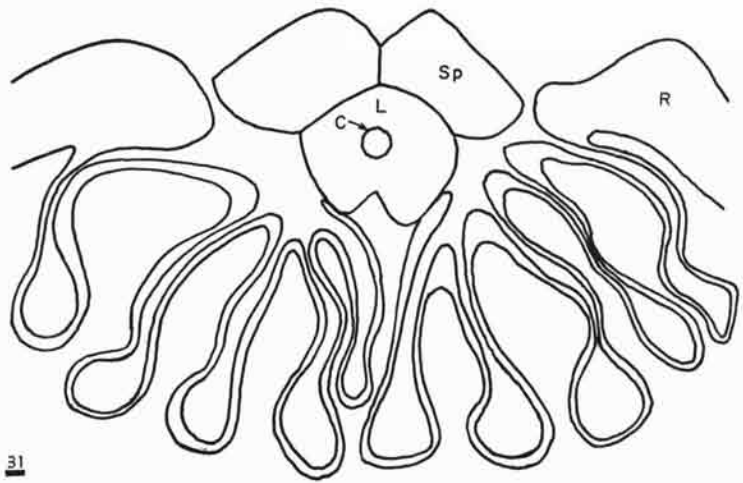
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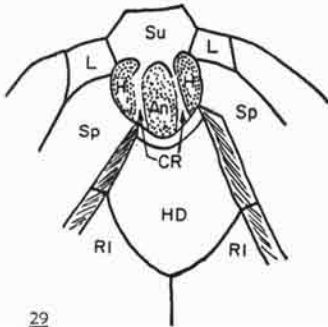
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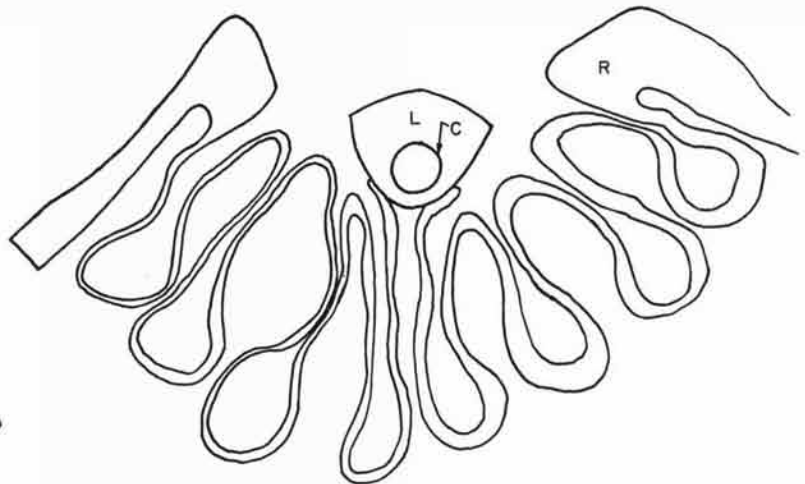
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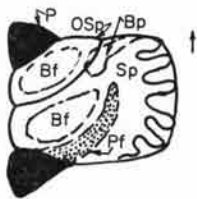
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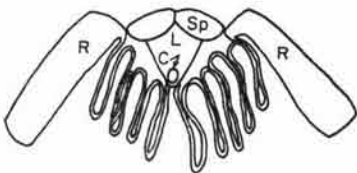
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**HYPEROBLASTUS SOUTHWORTHI (Reimann)**

Plate 9, figures 4-6

*Pentremiteida southworthi* REIMANN, 1935, p. 28, pl. 2, figs. 16-17.

**Description.**—The holotype is 8 mm. long by 6 mm. wide, vault 3.5 mm. long, pelvis 4.5 mm. long, pelvic angle 65 degrees. Four hydrospire folds are present on each side of an ambulacrum.

**Occurrence.**—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, tile yard, Thedford, Ontario, Canada.

**Type.**—Holotype, E11,816, Charles Southworth collection, Buffalo Society of Natural Sciences, Buffalo, New York.

**Genus OROPHOCRINUS von Seebach, 1864**[=*Codonites* MEEK & WORTHEN, 1869; *Mitra* CUMBERLAND, 1826]

**Type-species**, by original designation.—*Pentremites stelliformis* OWEN & SHUMARD, 1850.

**Generic diagnosis.**—Fissiculate blastoids with ten spiracular slits, into each of which four or five hydrospire slits open, anal opening separate between an epideltoid and hypodeltoid plate, lancet exposed along main food groove, with lenticular outer side plates between primary side plates, rarely touching admedial ambulacral margins; sublancet or fused hydrospire plate present, and form conical to club-shaped in side view, *Mississippian*, Europe and North America.

**Remarks.**—The genus *Orophocrinus* may have been derived from a form similar to *Pleuroschisma*, which has closed sinus areas and the cryptodeltoids and superdeltoid fused to form an epideltoid.

**OROPHOCRINUS STELLIFORMIS (Owen & Shumard)**

Plate 13, figures 4-9; text-figs. 36-39

*Pentremites stelliformis* OWEN & SHUMARD, 1850, p. 67, pl. 7, figs. 16a-b.

**Description.**—Calyx calcitic, club-shaped in side view, pelvis conical, base flat and wide, summit rounded;

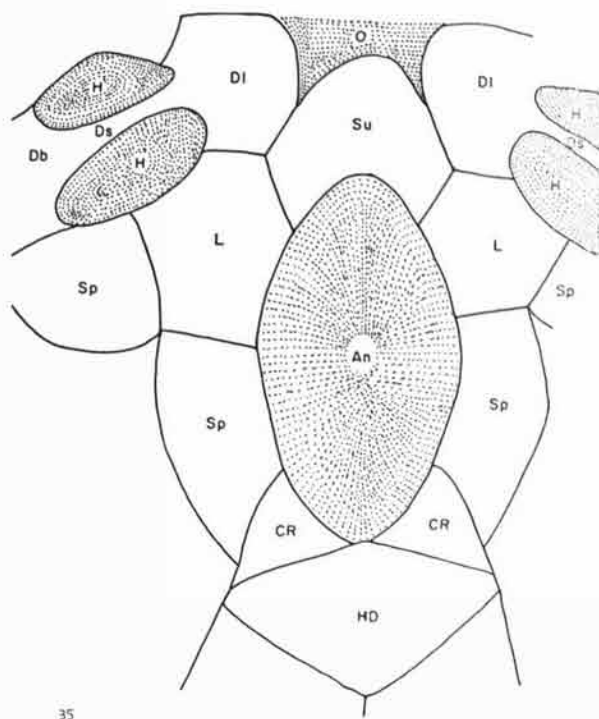


FIGURE 35. *Hyperoblastus filus angustus* (REIMANN), Middle Devonian, Hungry Hollow Formation, near Thedford, Ontario (Buffalo Soc. Nat. Sci., no. E13,055); plate arrangement of anal area, drawn from polished tangential section,  $\times 34$ . [Explanation.—An, anal opening; CR, cryptodeltoid; Db, deltoideum body; DI, deltoideum lip; Ds, deltoideum septum; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; Sp, main side plate; Su, superdeltoid.]

strongly pentalobate in top view. Theca 17 mm. long by 19 mm. wide, vault 6 mm., pelvis 11 mm. long, and pelvic angle on radial bodies 70 degrees. Basal cirlet 5 mm. long by 8 mm. wide, almost cylindrical, with three normally disposed basals. The stem is large, round, about 3 mm. in diameter, with about 64 crenellae extending radially inward about halfway from the circumference

FIGURES 26-34. Species of *Hyperoblastus* FAY, n. gen., Middle Devonian, North America.

26, 27. *H. preciosus* (REIMANN), Hungry Hollow Formation, near Thedford, Ont. (Buffalo Soc. Nat. Sci., holotype, no. E15,934); 26, anal area,  $\times 15$ ; 27, main and outer side plates of part of "B" ambulacrum,  $\times 45$ .—  
28. *H. dotis* (REIMANN), Hungry Hollow Formation, Thedford area, Ont. (Buffalo Soc. Nat. Sci., paratype no. E13,052); cross section of "E" ambulacrum,  $\times 15$ .—  
29-33. *H. filus* (WHITEAVES), Hungry Hollow Formation, near Thedford and Arkona, Ont. (Geol. Survey Canada, no. 3,660; Buffalo Soc. Nat. Sci., nos. E13,960, E16,206); 29, anal area (no. 3,660),  $\times 15$ ; 30, dorsal view of basal cirlet (no. 3,660),  $\times 15$ ; 31, cross section

of ambulacrum (no. E16,206),  $\times 40$ ; 32, cross section of "A" ambulacrum (no. E13,960),  $\times 15$ ; 33, main and outer side plates of part of "C" ambulacrum,  $\times 40$ .—  
34. *H. goldringae* (REIMANN), Ludlowville Formation, Bay View, N.Y. (Buffalo Soc. Nat. Sci., no. E21,160); cross section of "D" ambulacrum,  $\times 40$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; C, canal (radial); CR, cryptodeltoid; DI, deltoideum lip; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; Rl, radial limb; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]

toward the small round lumen. Radials five, elongate hexagonal, with almost subparallel sides, each 10 mm. long by 7 mm. wide, with narrow limbs extended outward from the calyx into bluntly rounded wings; radials overlapping deltoids.

Deltoids four, widely lancet-shaped, each 2 mm. long by 2 to 3 mm. wide, with bulbous adoral end of a spiracular slit excavated in the middle of each side of each deltoid. On the anal side a small rounded anal opening occurs between a 7-sided epideltoid and a 5-sided hypodeltoid. The expanded ends of the anal spiracular slits are excavated in the epideltoid. The slits extend as openings almost one-half the length of each ambulacrum. Internally, five hydrosphere folds occur on each side of an ambulacrum, each fold opening into each spiracular slit and ending admedially in a sublancet or fused hydrosphere plate that underlies the lancet and side plates. The anal opening is covered with about 20 small, flexible, polygonal plates. The oral opening is surrounded by four deltoid lips and the epideltoid, and is covered by five large oral plates that are interradian in position. Radials overlap deltoids.

Ambulacra five, narrow, linear, with narrow sinus, 1.5 mm. wide, with lancet covered by side plates near aboral end of lancet but exposed along the middle fourth of lancet's width along the remainder of each ambulacrum. Approximately 30 side plates occur in a space of 10 mm. along an ambulacrum, normally disposed, with lenticular secondary side plates between the primary side plates, and admedially disposed from the ambulacral margins. The lancet plates are separated from the oral opening by the wide deltoid lips. The surfaces of the calyx plates are ornamented with fine growth striae parallel to plate margins.

*Remarks.*—The type-species was presumably in the Owen collection which was destroyed by fire in 1883 at Indiana University. The specimen evidently was not in the Shumard collection, because Hambach had many of these types when he sold his collection to Springer and they are not in the collection of the United States National Museum. Therefore, neotypes have been erected to replace the destroyed types.

*Occurrence.*—Lower Mississippian, lower part of Burlington Limestone, Burlington, Iowa.

*Types.*—Neotypes, S4,961, two specimens, new holotype with oral plates in place (figures 4-7, 9) and new paratype with anal plates in place (figure 8), Springer collection, old number S3,234, U. S. National Museum, Washington.

#### OROPHOCRINUS CAMPANULATUS (Hambach)

Plate 13, figures 1-3

*Codonites campanulatus* HAMBACH, 1884, p. 553, pl. D, figs. 8-9.

*Description.*—Calyx 18 mm. long by 15 mm. wide, vault 7 mm. long, pelvis 11 mm. long, and pelvic angle of 50 degrees. In side view, the calyx is broadly club-shaped and similar to *O. stelliformis*. The basal cirlet is 4 mm. long, the radial cirlet 12 mm. long, each radial 7 mm. wide, and the deltoids are each 2 mm. long. There are 34 side plates in 10 mm. length of an ambulacrum. Another fragmentary syntype is 21 mm. long by 16 mm. wide.

*Occurrence.*—Lower Mississippian, Chouteau Limestone, Sedalia, Missouri.

*Types.*—Syntypes, S3,236, Hambach collection, purchased by FRANK SPRINGER, one complete specimen and one fragmentary specimen, U. S. National Museum, Washington.

#### OROPHOCRINUS CONICUS Wachsmuth & Springer

Plate 15, figures 1-2

*Orophocrinus conicus* WACHSMUTH & SPRINGER, 1890, p. 201, pl. 15, figs. 1-3.

*Description.*—One specimen is 43 mm. long by 8 mm. wide (Pl. 15, fig. 1); another is 12 mm. long by 8 mm. wide (Pl. 15, fig. 2), with a stem 105 mm. long. The narrow steeply conical form of the calyx and long pelvis readily distinguish this species from all others.

*Occurrence.*—Lower Mississippian, Hampton Formation (Kinderhookian), Le Grand, Marshall County, Iowa.

*Types.*—Topotypes (metatypes), S3,226, 78 specimens, Springer collection, U. S. National Museum, Washington.

### EXPLANATION OF PLATE 5

FIGURE	PAGE		
1-3. <i>Trionoblastus gracilis</i> (WACHSMUTH), plesiotype, E21,142, I. G. Reimann coll., Buffalo Soc. Nat. Sci.; Devonian, Thunder Bay Limestone, Alpena, Partridge Point, Michigan; oral, "D" ambulacral, aboral views (all $\times 6$ ) .....	49		
4-6. <i>Trionoblastus alatus</i> (REIMANN), plesiotype, 30,736, Univ. Michigan; Potter Farm Formation, shale pit just west of		Evergreen Cemetery, west of Alpena, Michigan; oral view (showing six ambulacra), aboral view, "D" ambulacral view (all $\times 6.1$ ) .....	47
		7-9. <i>Trionoblastus canadensis</i> (BILLINGS), plesiotype, E11,760, I. G. Reimann coll., Buffalo Soc. Nat. Sci., Devonian, "Encrinal limestone," Thedford, Ontario; oral, "D" ambulacral, aboral views (all $\times 7$ ) .....	48

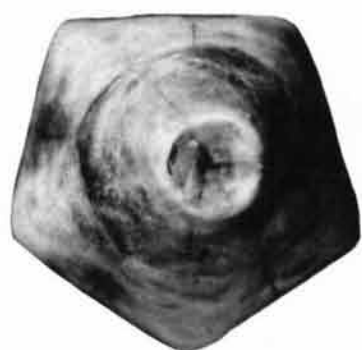




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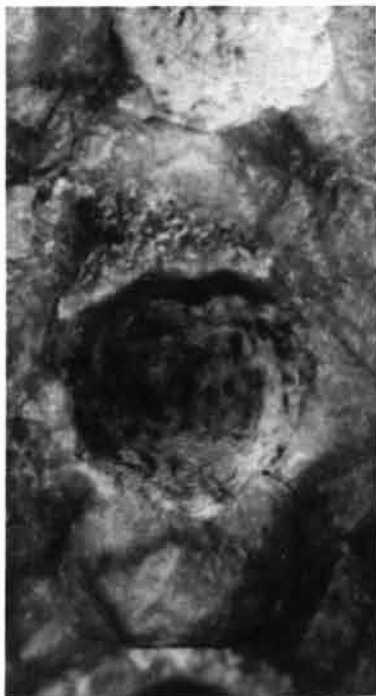
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**OROPHOCRINUS FUSIFORMIS**

(Wachsmuth &amp; Springer)

Plate 15, figures 3-8

*Codonites fusiformis* WACHSMUTH & SPRINGER, in S. A. MILLER, 1889, p. 233, fig. 269.

*Description.*—Calyx steeply conical, narrow, pelvis almost equal in length to vault. Measurements on various forms are slightly different in ratios of length to width. One calyx is 34 mm. long by 11 mm. wide (fig. 6), another is 45 mm. long by 14 mm. wide (fig. 5), one is 28 mm. long by 12 mm. wide with each ambulacrum 1.5 mm. wide (figs. 7-8), and another is 37 mm. long by 11 mm. wide (fig. 4). The narrow form and short pelvis distinguish this species from all others.

*Occurrence.*—Lower Mississippian, Hampton Formation (Kinderhookian), Le Grand, Marshall County, Iowa.

*Types.*—Metatypes, S3,227, ten specimens with pinules; S3,226, one specimen in with *Orphocrinus conicus*, Springer collection, U. S. National Museum, Washington.

**OROPHOCRINUS GRACILIS (Meek & Worthen)**

Plate 16, figures 1-3

*Codonites gracilis* MEEK & WORTHEN, 1870, p. 32.

*Description.*—Calyx 19 mm. long by 10 mm. wide, vault long and pelvis extremely short. The narrow form and short pelvis distinguish this species from all others.

*Occurrence.*—Lower Mississippian, lower part of Burlington Limestone, Burlington, Iowa.

*Types.*—Topotypes, S3,228, three specimens, Springer collection, U. S. National Museum, Washington.

**OROPHOCRINUS ORBIGNYANUS (de Koninck)**

Plate 16, figures 4-6; text-fig. 40

*Pentremites orbignyanus* DEKONINCK, 1842-1844, p. 37, pl. E, figs. 4a-c.

*Description.*—Calyx calcitic, 20 mm. long by 15 mm. wide, vault 7 mm. long, pelvis 13 mm. long, and pelvic angle 45 degrees. Basal cirlet 7 mm. long by 9 mm. wide, with flat base 4 mm. wide and three normally disposed basals. Stem round, 3 mm. in diameter, large, with about 72 crenellae extending about 0.5 mm. inward radially from the circumference toward the small circular lumen. Each radial is 13 mm. long by 7 mm. wide, and

each deltoid is 5 mm. long by 3 mm. wide. Radials overlap deltoids.

Ambulacra five, each 11 mm. long by 2 mm. wide, with lancet covered by side plates along the aboral one-fourth of each ambulacrum and exposed one-third of its width near the oral opening, with 22 side plates in 10 mm. length of an ambulacrum. A thick fused hydrospire plate underlies the lancet and side plates. On the anal side an epideltoid and hypodeltoid occur with anal opening between. Ten elongate spiracular slits are present along the margins of the ambulacra, the anus being separate. The side plates are elongate abmedially-admedially.

The wide form and long pelvis distinguish this species from all others. It is similar to *Orophocrinus campanulatus*.

*Occurrence.*—Lower Carboniferous, Tournai, Belgium.

*Types.*—Topotypes, S3,229, three specimens, one complete, Springer collection, U. S. National Museum, Washington.

**OROPHOCRINUS PUZOS (Münster)**

Plate 16, figures 10-12; text-figs. 41, 41a

*Pentremites puzos* MÜNSTER, 1839, p. 1, pl. 1, figs. 5a-d.

*Description.*—Calyx calcitic, 8 mm. long by 7 mm. wide, vault 5 mm. long, pelvis 3 mm. long, and pelvic angle 80 degrees. Basal cirlet 2 mm. long with three normally disposed basals. Stem round, 1.25 mm. in diameter, with about 33 crenellae. Each radial plate is 6 mm. long by 4 mm. wide, and each deltoid is 2 mm. long by 1.25 mm. wide. The anal opening is between an epideltoid and hypodeltoid. A single spiracular slit occurs on each side of an ambulacrum, extending one-half the length of each ambulacrum along the radial plate and ending adorally in an expanded opening near the middle of the side of each deltoid plate.

Ambulacra five, each 1.25 mm. wide, with lancet exposed along the middle one-third of its width near the oral opening, but completely covered by side plates along the aboral one-third of its length. There are 30 side plates in 10 mm. and four cover-plate sockets to each side plate along the main food groove. Four hydrospire folds occur on each side of an ambulacrum, each set opening into a spiracular slit.

## EXPLANATION OF PLATE 6

FIGURE	PAGE
1-9. <i>Brachyschisma corrugatum</i> (REIMANN), topotypes, E21,134 (figs. 1-3, 5), E15,982 (figs. 4, 6-7, 9), E15,407 (fig. 8), Fred W. Wattles coll., Buffalo Soc. Nat. Sci.; Devonian, Onondaga Limestone, Vogelsanger Quarry, near Williams-ville, N.Y.; 1-3, 5, oral, "D" ambulacral, aboral, "C" ambulacral views, (×3.4); 4, 6, oral, "D" ambulacral views	

of another specimen (×3.5); 7, anal view of specimen shown in fig. 4, hypodeltoid in place (×18.6); 8, oblique vert. sec. showing hydrospires on left side of "C" ambulacrum, (×10); 9, oral view of "D" ambulacrum of specimen illustrated in fig. 4, showing incipient slits on right side of ambulacrum (×12) ..... 21

**Occurrence.**—Lower Carboniferous, Tournai, Belgium.

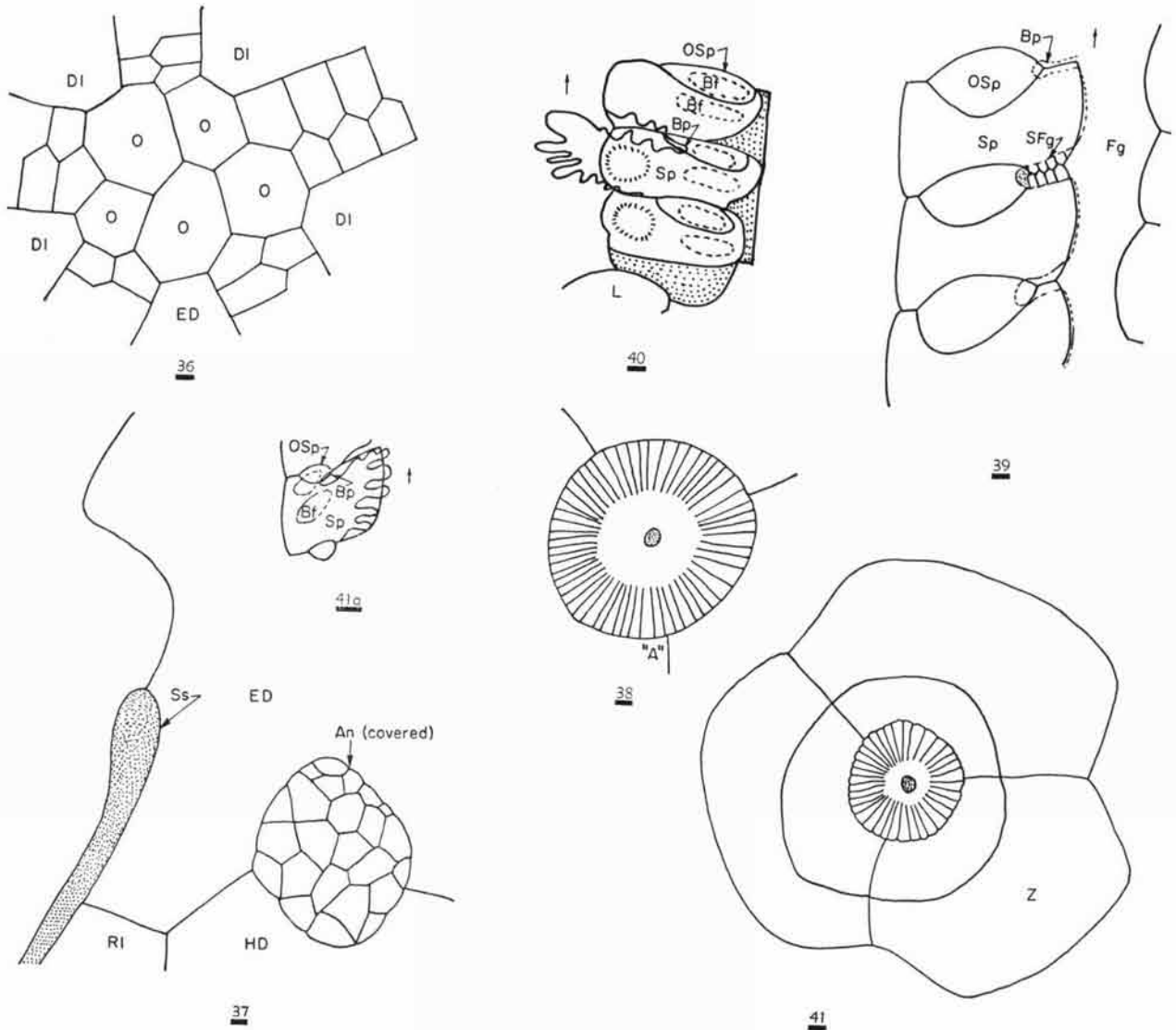
**Type.**—Topotype, S3,230, one specimen, Springer collection, U. S. National Museum, Washington.

### OROPHOCRINUS SIRIUS (White)

Plate 18, figures 8-9

*Pentremites sirius* WHITE, 1862, 1865, p. 20, fig. 3.

**Description.**—The holotype is crushed almost flat,



FIGURES 36-41. Species of *Orophocrinus* VON SEEBACH, from Lower Mississippian, North America, and Lower Carboniferous, Europe.

36-39. *O. stelliformis* (OWEN & SHUMARD), Lower Burlington Limestone, Burlington, Iowa (U.S. Natl. Mus. neoholotype and paratypes, no. S4,961); 36, plate arrangement at summit of calyx,  $\times 22.5$ ; 37, anal area of neoparatype,  $\times 40$ ; 38, stem impression,  $\times 22.5$ ; 39, part of "A" ambulacrum, showing main and outer side plates and food grooves,  $\times 45$ .—40. *O. orbignyana* (DEKONINCK), Tournaisian, Belg. (U.S. Natl. Mus., no. S3,229); part of "A" ambulacrum, showing main and outer side plates,  $\times 30$ .—41, 41a. *O. puzos* (Münster), Tournaisian,

Tournai, Belgium (U.S. Natl. Mus., no. S3,230); 41, base of calyx showing basal plates,  $\times 17.5$ ; 41a, part of "B" ambulacrum, showing main and outer side plates,  $\times 30$ . [Explanation.—"A," amb.; An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; DI, deltoid lip; ED, epideltoid; Fg, main food groove; HD, hypodeltoid; L, lancet; O, oral plate; OSp, outer side plate; RI, radial limb; SFg, side food groove; Sp, main side plate; Ss, spiracular slit; Z, azygous basal.]

calyx about 10 mm. in diameter. The prominent feature that distinguishes this species from all others is the elongate winglike extensions of the radial limbs outward from the calyx.

*Occurrence.*—Lower Mississippian, Burlington Limestone, Burlington, Iowa.

*Type.*—Holotype, 379, Harvard Museum of Comparative Zoölogy, Cambridge, Mass.

### OROPHOCRINUS VERUS (Cumberland)

Plate 16, figures 7-9

*Mitra vera* CUMBERLAND, 1826, p. 31, pl. B, figs. 1-2.

*Description.*—Calyx calcitic, club-shaped in side view, 15 mm. long by 13 mm. wide, pelvis longer than vault. This species is distinguished from all others by its short, wide calyx and pelvis slightly longer than the vault. It is similar to *Orophocrinus puzos*, which has a shorter pelvis and longer vault.

*Occurrence.*—Lower Carboniferous, Mountain Limestone, Lancashire, England.

*Type.*—Plesiotype, S3,237, one specimen, Springer collection, U. S. National Museum, Washington.

### Genus PENTREMITIDEA d'Orbigny, 1849

*Type-species*, by original designation.—*Pentremites pailletti* VERNEUIL, 1844.

*Generic diagnosis.*—Fissiculate blastoids with eight hidden hydrosphere fields that open into spiracular slits, approximately eight hydrosphere slits in each field, with a superdeltoid, subdeltoid, and hypodeltoid on the anal side, hydrosphere absent on the anal side, lancet covered by side plates, with possible inner side plate present; calyx steeply conical in side view, with narrow deep sinuses. *Devonian*, Spain.

*Remarks.*—The genus *Pentremitea* was probably derived from a form like *Deltoschisma*, the subdeltoid being formed by fusion of the two cryptodeltoids, the sinuses closing to form spiracular slits, and the anal hydrosphere fields becoming atrophied.

### PENTREMITIDEA PAILLETTI (de Verneuil)

Plate 2, figures 1-11; text-figs. 42-45

*Pentremites pailletti* VERNEUIL, 1844b, p. 216; 1844a, p. 213, pl. 2, figs. 4-5.

*Description.*—Calyx calcitic, conical in side view, pentalobate in top view, 16 mm. long by 9.5 mm. wide, with vault 2 mm. long, pelvis 14 mm. long, and pelvic angle on basals 25 degrees and on radial bodies 40 degrees, with periphery at radial lips. Stem round, small, crenellar, broken in described specimen but present in another one. Basal cirlet conical in side view, rounded pentagonal in basal view, 8 mm. long by 7 mm. wide, grad-

ually tapering aborally. Radials five, constricted, broadly pentagonal in side view, lobed in top view, each 9 mm. long by 3.75 mm. wide, with short, narrow, steep-sided sinus 3 mm. long by 2.5 mm. wide. Radial limbs shorter on the anal side than on the other four sides; radials overlapping deltoids.

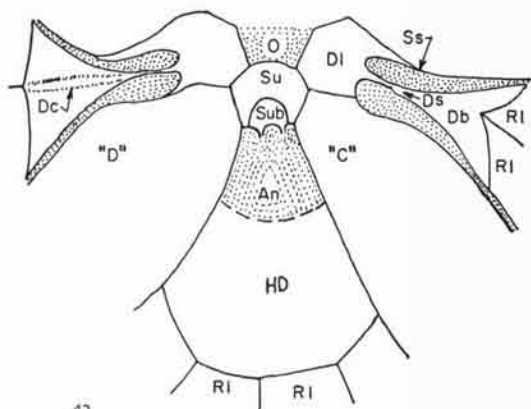
Deltoids four, short, not visible in side view, each 1.75 mm. long by 1 mm. wide, lancet-shaped, with open spiracular slits along ambulacral margins, deep septa, and prominent V-shaped deltoid lips. Approximately eight hidden hydrosphere slits are present on each side of each deltoid except in the anal area, where hydrospheres are lacking. These slits extend to the radial limbs approximately at right angles to the radiodeltoid sutures, opening into each spiracular slit along the ambulacral margins. On the anal side three anal deltoids occur, an elongate V-shaped superdeltoid, upon which a U-shaped subdeltoid rests aborally on the adoral end of the anal opening, and a pentagonal hypodeltoid (missing, but facets present) that covers the subdeltoid limbs and abuts against the adjacent radial limbs.

Ambulacra five, short, moderately wide, each 4.5 mm. long by 1.75 mm. wide, with lancet covered by side plates, 18 side plates to each ambulacrum, and 45 side plates in 10 mm. length of an ambulacrum, if extended. Each primary side plate is elongate abmedially-admedially, quadrangular, with a subtriangular secondary side plate on the admedial-adoral bevelled corner. There appears to be a small triangular inner side plate adjacent to the main food groove, between primary side plates, with apex of triangle at suture between adjacent side plates. Approximately four main cover-plate sockets correspond to each side plate along the main food groove, and four or five side cover-plate sockets along each side food groove. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

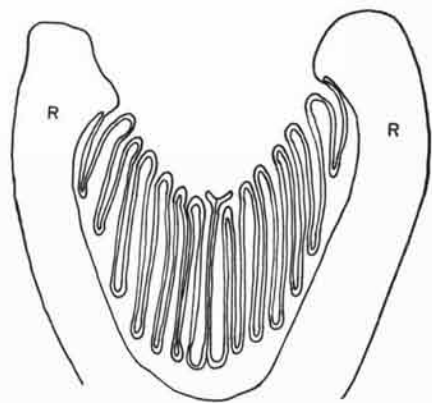
*Remarks.*—The many species referred to *Pentremitea* do not fit in this genus and must be reclassified in other genera, such as *Hyperblastus*, *Cordyloblastus*, and *Deltoschisma*. Except for *Hyperblastus*, it is common to find species of these genera mixed in the same lot of specimens in a museum. *Hyperblastus* occurs in North America, and the others in Europe.

*Occurrence.*—Devonian, Calizas de Ferroñes, Asturias; Calizas de Arnao, near Sabero (León), Spain.

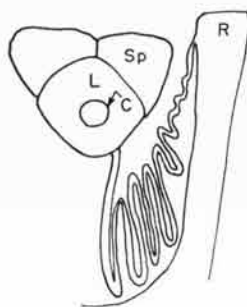
*Types.*—Topotypes, 297, 11 specimens (large one used for description), Schultze collection, old no. 2352, with specimens of other genera, Sabero, Harvard Museum of Comparative Zoölogy, Cambridge, Mass.; 547, seven specimens, de Koninck collection, old no. 2353, Asturias, Harvard Museum; S3,622, three specimens, S3,621, one specimen, Springer collection, Sabero, U.S. National Museum, Washington; 13,876, six specimens, one of which belongs to *Deltoschisma*, Gurley collection, Asturias, Walker Museum, University of Chicago.



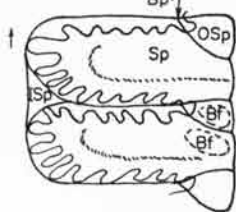
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### Genus PHAENOBLASTUS Fay, n.gen.

*Type-species*, by original designation (herein).—*Pentremites caryophyllatus* DEKONINCK, 1854.

**Generic diagnosis.**—Fissiculate blastoids with ten hydrosphere fields (mostly hidden), an epideltoid and hypodeltoid, with a reduced number of hydrosphere slits on the anal side, lancet plate completely exposed; calyx club-shaped in side view. *Lower Carboniferous*, Belgium.

**Remarks.**—The genus *Phaenoblastus* was probably derived from *Phaenoschisma* by the outward migration of the lancet plate, and *Phaenoschisma* was probably derived from *Deltoschisma* by fusion of the cryptodeltoids and superdeltoid into an epideltoid.

### PHAENOBLASTUS CARYOPHYLLATUS (de Koninck & Lehon)

Plate 14, figures 2-3, 5-6, 8, 10; text-figs. 46-48

*Pentremites caryophyllatus* DE KONINCK & LEHON, 1854, p. 197, pl. 7, figs. 3a-c.

**Description.**—Calyx calcitic, obconical in side view, rounded pentagonal in top view, 12 mm. long by 8 mm. wide, vault 6 mm. long, pelvis 6 mm. long, pelvic angle 65 degrees, summit rounded, base conical, and periphery

FIGURES 42-45. *Pentremitea pailletti* (DE VERNEUIL), Devonian, Spain (Harvard Mus. Comp. Zoology, nos. 297, 547; U.S. Natl. Mus. no. S3,621).—42. Plate arrangement of anal area (no. 297),  $\times 15$ .—43. Cross section of "B" ambulacrum (no. S3,621),  $\times 15$ .—44. Cross section of "B" ambulacrum near radial lip (no. 547),  $\times 15$ .—45. Part of "E" ambulacrum, showing main, inner, and outer side plates (no. 297),  $\times 45$ . [Explanation.—"A," amb.; An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); "D," amb.; Db, deltoid body; Dc, deltoid crest; Dl, deltoid lip; Ds, deltoid septum; HD, hypodeltoid; ISp, inner side plate; L, lancet; O, oral opening; OSp, outer side plate; R, radial; Rl, radial limb; Sp, main side plate; Ss, spiracular slit; Su, superdeltoid; Sub, subdeltoid.]

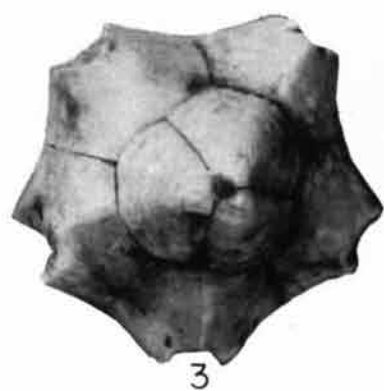
### EXPLANATION OF PLATE 7

#### FIGURE

1-8. *Hyperoblastus preciosus* (REIMANN), holotype, E15,934, Charles Southworth coll., Buffalo Soc. Nat. Sci.; Devonian, Hungry Hollow Formation (coral zone), Joseph Bell's Quarry, Thedford, Ontario; 1-3, oral, "D" ambulacral, aboral views ( $\times 4.4$ ); 4, oral view of oral area ( $\times 8.8$ ); 5, anal view showing two prominent cryptodeltoids ( $\times 10.6$ ); 6, tangential view of interior right side of "E" ambulacrum showing nature of branching of a hydrosphere canal

#### PAGE

or slit beneath deltoid ( $\times 13.2$ ); 7, side view of "E" ambulacrum with lancet removed ( $\times 6.8$ ); 8, side view of "B" ambulacrum showing large gaps between side plates ( $\times 13.2$ ) ..... 31  
9. *Hyperoblastus filosus* (WHITEAVES), holotype, 3,660, Rev. H. Currie coll., identified by WHITEAVES, Geol. Survey Canada; Devonian, Hamilton beds, near Thedford, Ontario; "C" ambulacral view showing gaps between side plates ( $\times 15.3$ ) ..... 32

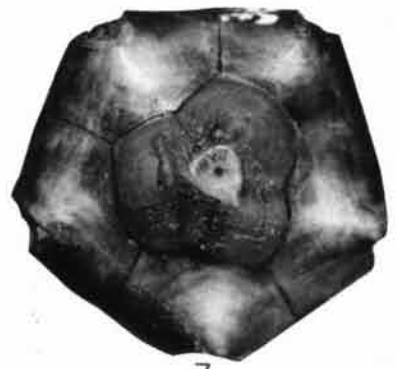




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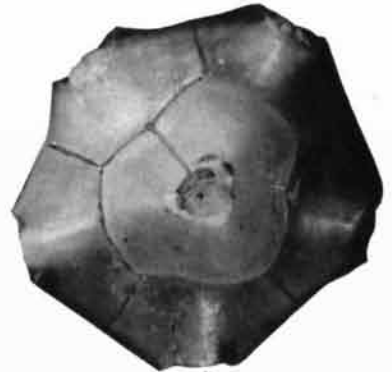
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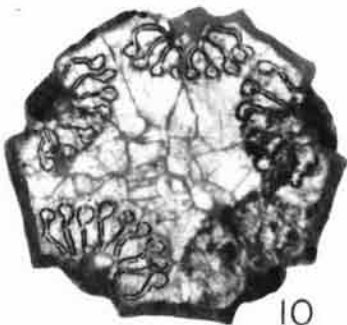
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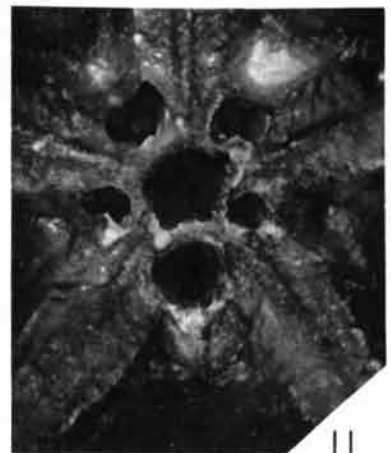
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about one-third down from the top. The stem impression is obscure but appears to be round, 0.5 mm. in diameter, in a small depression. Basal cirlet long, conical, 4 mm. long by 5 mm. wide, with three normally disposed basals. Radials five, elongate hexagonal, each 7 mm. long by 4.5 mm. wide, with deep, wide sinus 4 mm. long by 4 mm. wide; radials overlapping deltoids.

Deltoids four, arrow-shaped, each 3 mm. long by 2.5 mm. wide, with seven or eight hydrospire slits on each side of an ambulacrum (except on anal side) extending to adjacent deltoid limbs parallel to the lancet margins and at right angles to the radiodeltoid sutures. The lancet and side plates cover a large portion of the hydrospire slits. The adoral tips of each deltoid are excavated by a narrow V-shaped notch, each side of the V leading to an open spiracular slit or hydrospire canal, similar to a paired spiracle. On the anal side there is an epideltoid and presumably a hypodeltoid (missing, but facets present). The epideltoid and other four deltoid lips surround the oral opening. The epideltoid is divided internally into two septa that separate the anal opening from the adjacent spiracular slits and four hidden hydrospire slits are present on each septum, extending to the adjacent radial limbs. Thus, ten hydrospire fields occur. The aboral part of the anal opening was presumably covered by a hypodeltoid plate that covered the epideltoid septa and abuted against the adjacent radial limbs.

Ambulacra five, broad, petaloid, each 7 mm. long by 3 mm. wide, with lancet plate exposed almost its entire width, and 20 side plates in 10 mm. Each primary side plate is broadly quadrangular, with a rounded triangular secondary side plate on the abmedial-adoral margin of each primary side plate. An elongate side food groove extends from the admedial tip of each secondary side plate onto the lancet plate. There are six main cover-plate sockets to each side plate along the main food groove on the lancet plate. The surfaces of the calyx plates are ornamented with fine growth striae parallel to plate margins.

*Occurrence.*—Lower Carboniferous, Tournaisian, Tournai, Belgium.

*Types.*—Plesiotypes, 19,082, three specimens, one of

which (figured) was used for description, Gurley collection, Walker Museum, University of Chicago, Chicago, Ill.; S3,268, 11 specimens, Springer collection, U. S. National Museum, Washington.

### Genus PLEUROSCHISMA Reimann, 1945

*Type-species*, by original designation.—*Pentremites lycorias* HALL, 1862.

*Generic diagnosis.*—Fissiculate blastoids with ten exposed hydrospire fields, a superdeltoid, two cryptodeltoids, and a hypodeltoid, lancet completely covered by side plates, ambulacra extended downward along calyx, which is club-shaped in side view. *Devonian*, New York, Ontario.

*Remarks.*—The genus *Pleuroschisma* was probably derived from *Polydeltoideus* by downward growth of the lancet plates (toward base), thus forming a club-shaped blastoid from a conical form, and fusion of paradeltoids into part of the hypodeltoid.

### PLEUROSCHISMA ONTARIO Reimann

Plate 17, figures 4-6; text-figs. 49, 50

*Pleuroschisma ontario* REIMANN, 1945, p. 25, pl. 6, figs. 2-3.

*Description.*—Calyx calcitic, basal cirlet missing, obconical in side view, circular in top view, 5.5 mm. wide, vault 4.5 mm. long, pelvis estimated at 5.5 mm. long, with periphery at radial lips. Radials five, elongate hexagonal, each 7 mm. long by 2.5 mm. wide, with wide, short, deep sinus 4 mm. long by 2.5 mm. wide by 1.25 mm. deep. Radial lip with thick raised ridge. Radials overlap deltoids.

Deltoids four, lancet-shaped, each 2 mm. long by 1.5 mm. wide, forming a thin, low coronal process, with seven or eight hydrospire slits on each side of an ambulacrum, extending aborally to adjacent radial limbs. On the anal side four deltoids appear to occur. The hypodeltoid is missing because the specimen is slightly damaged in that region. The two high, thick, elongate, cryptodeltoids on either side of the anal opening rest upon the superdeltoid adorally and are overlapped by the radial

## EXPLANATION OF PLATE 8

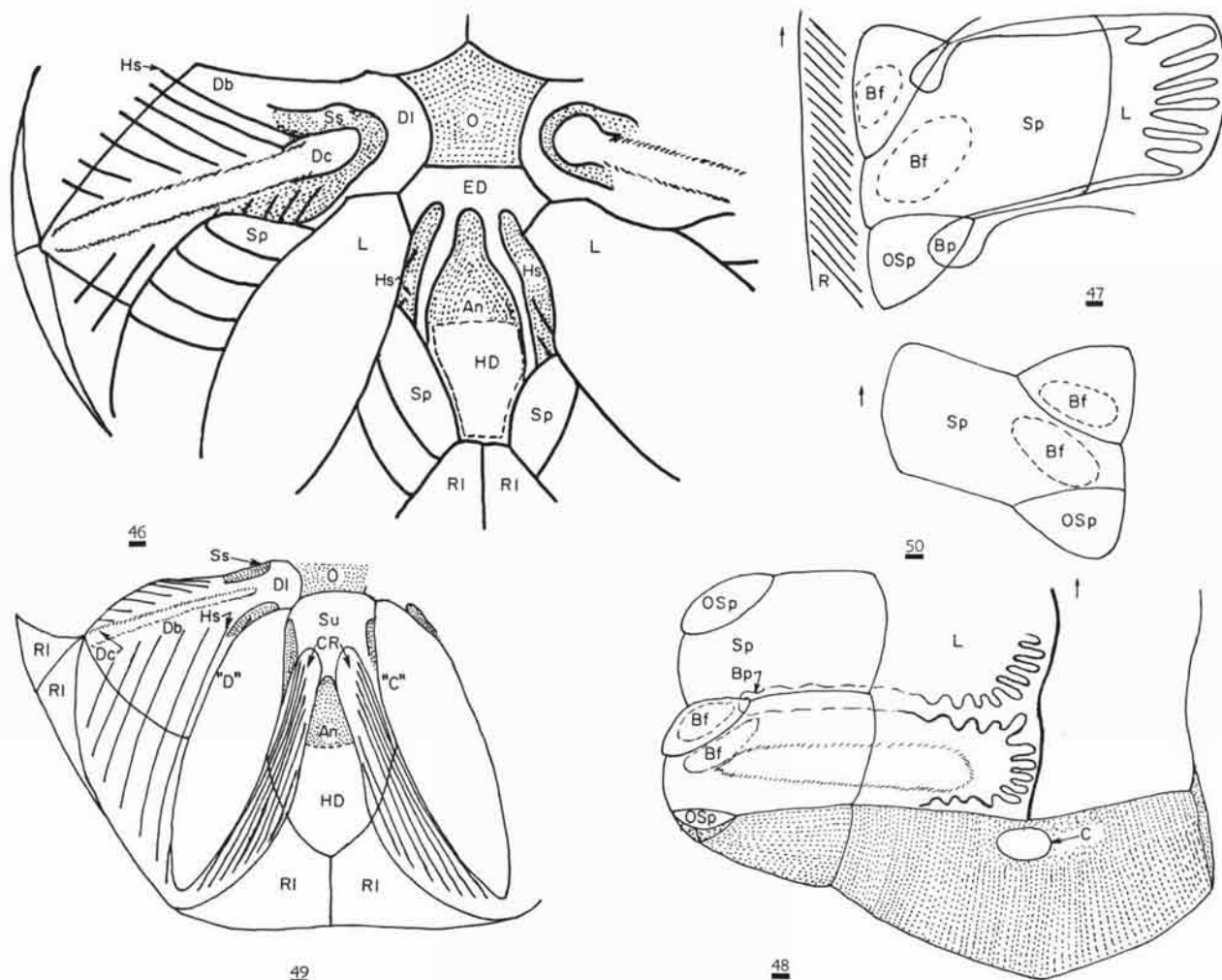
FIGURE	PAGE	
1-6, 10, 11. <i>Hyperoblastus filiosus</i> (WHITEAVES), Devonian, Ontario; 1-6, 11, holotype, 3,660, Currie coll., identified by WHITEAVES, Geol. Survey Canada; Hamilton beds, near Thedford, Ontario; 1-3, oral, "D" ambulacral, aboral views, (all $\times 5.1$ ); 11, view showing the hypodeltoid in place ( $\times 15.3$ ).—4-6, hypotype, E16,209, Buffalo Soc. Nat. Sci.; Hungry Hollow Formation (coral zone of Widder beds), Thedford, Ontario; oral, "D" ambulacral, ab-		oral views (all $\times 6.7$ ).—10, hypotype, E16,206, Charles Southworth coll., Buffalo Soc. Nat. Sci.; Hungry Hollow Formation (coral zone of Widder beds), Thedford, Ontario; aboral view of thin section showing hydrospires ( $\times 3.7$ )
7-9. <i>Hyperoblastus filiosus angustus</i> (REIMANN), holotype, E15,403, Buffalo Soc. Nat. Sci.; Hungry Hollow Formation (coral zone of Widder beds), Thedford, Ontario; oral, "D" ambulacral, aboral views (all $\times 5.9$ )		
		32
		33

limbs aborally. There are seven or eight hydrospire slits in the sides of each cryptodeltoid, extending to the adjacent radial limbs. The low superdeltoid, with spiracular slits on each side, is bluntly arrow-shaped, and together with the other four deltoid lips and five lancet stipes, helps border the oral opening.

Ambulacra five, linear, projecting down the sides of the calyx, each 4 mm. long by 0.75 mm. wide, with lancet completely covered by side plates, and 35 side plates in

10 mm. The side plates appear to be normally disposed, with the broadly triangular secondary side plate resting upon the abmedial-aboral bevelled corner of the primary side plate. The plates are worn so that details are obscure. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

*Occurrence*.—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, Ausable River valley, 2.5 miles northeast of Arkona, Ontario, Canada.



FIGURES 46-50. Species of *Phaenoblastus* FAY, n.gen., and *Pleuroschisma* REIMANN.

46-48. *Phaenoblastus caryophyllatus* (DEKONINCK & LEHON), Lower Carboniferous, Tournaisian, Tournai, Belgium (Univ. Chicago, no. 19,082; U.S. Natl. Mus., no. S3,268); 46, morphological features of anal area and part of "DE" interambulacrum (no. 19,082),  $\times 15$ ; 47, part of "C" ambulacrum, showing main and outer side plates (no. 19,082),  $\times 45$ ; 48, oblique view of part of ambulacrum, showing surface and cross section (no. S3,268),  $\times 37.5$ .—49, 50. *Pleuroschisma ontario* REIMANN, Middle Devonian, near Arkona, Ont. (Univ. Michigan,

no. 35,033); 49, morphological features of anal area and part of "DE" interambulacrum (no. 35,033),  $\times 15$ ; 50, part of "A" ambulacrum showing main and outer side plates (no. 35,033),  $\times 90$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal; CR, cryptodeltoid; "D," amb.; Db, deltoid body; Dc, deltoid crest; DI, deltoid lip; ED, epideltoid; HD, hypodeltoid; Hs, hydrospire slit; L, lancet; O, oral opening; OSp, outer side plate; R, radial; RI, radial limb; Sp, main side plate; Ss, spiracular slit; Su, superdeltoid.]

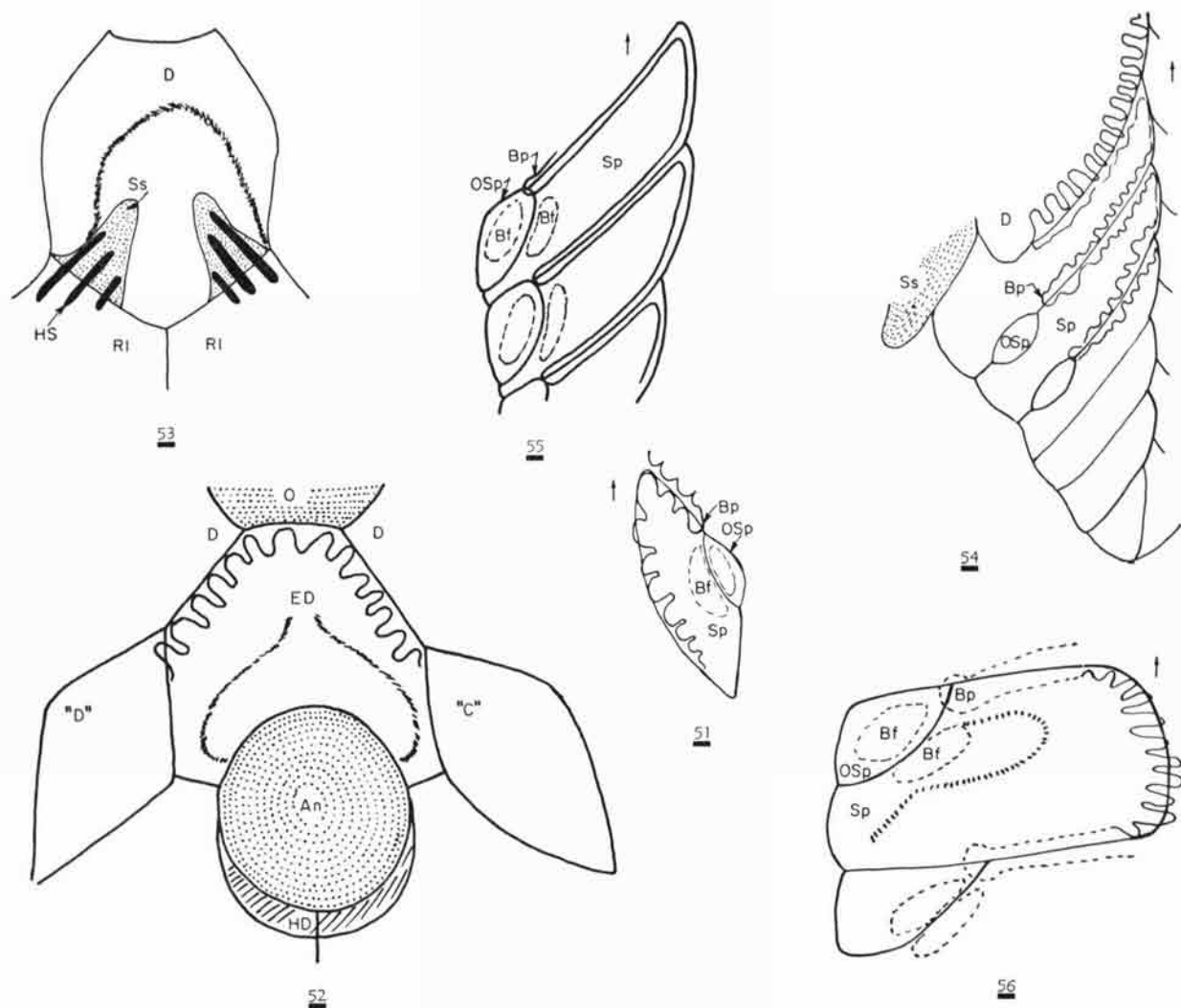
*Type*.—Topotype, 35,033, one specimen, Charles Southworth collection, University of Michigan.

### Genus PTEROTBLASTUS Wanner, 1924

*Type-species*, by original designation.—*Pterotblastus gracilis* WANNER, 1924.

*Generic diagnosis*.—Fissiculate blastoids with eight

short exposed hydrosphere fields, two or three wide hydrosphere slits in each field, one large epideltoid on the anal side and small anal opening between radial limbs and epideltoid, possibly with very small ?hypodeltoid within aboral part of anal opening, ambulacra moderately short and extended onto long winglike projections of the radials, lancet well away from oral



FIGURES 51-56. Species of *Pterotblastus* WANNER, *Sagittoblastus* YAKOVLEV, and *Thaumatoblastus* WANNER.

51. *P. gracilis* WANNER, Upper Permian, Timor, East Indies (U.S. Natl. Mus., no. S4,035); part of "B" ambulacrum, showing main and outer side plates,  $\times 37.5$ .—52-55. *S. wanneri* (YAKOVLEV), Permian, Krasnoufimsk, Urals, USSR (Illinois Geol. Survey, no. 695; U.S. Natl. Mus., no. 102,187); 52, anal area (no. 695),  $\times 15$ ; 53, morphological features of summit part of "AB" interambulacrum (no. 695),  $\times 15$ ; 54, part of "A" ambulacrum, showing main and outer side plates (no. 102,187),  $\times 37.5$ ; 55, part of "D" ambulacrum, showing main and

outer side plates (no. 695),  $\times 90$ .—56. *T. longiramus*, Upper Permian, Timor, East Indies (U.S. Natl. Mus., no. S4,053); part of an ambulacrum, showing main and outer side plates,  $\times 37.5$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; "D," amb.; D, deltoid; ED, epideltoid; HD, hypodeltoid; Hs, hydrosphere slit; O, oral opening; OSp, outer side plate; RI, radial limb; Sp, main side plate; Ss, spiracular slit.]

opening, covered by a few large side plates; shape of calyx in side view like a cup, with three basals. *Permian*, Timor Island, East Indies.

*Remarks.*—The genus *Pterotoblastus* was probably derived from a form similar to *Codaster* in which the hydrosphere slits had become atrophied to a few in each field, the hydrosphere fields reduced to small areas on the summit, and the radial plates developed into wing-like extensions.

#### PTEROTOBLASTUS GRACILIS Wanner

Plate 18, figures 10-11; text-fig. 51

*Pterotoblastus gracilis* WANNER, 1924, p. 10, text-figs. 1-2, pl. 199, figs. 11-18.

*Description.*—The description is the same as that for the genus. The specimen is approximately 8 mm. long by 11 mm. wide. Of importance here is the fact that there are three normally disposed basal plates and not one plate, as previously reported. This is based on examination of five almost perfect specimens recently received from Indonesia.

*Occurrence.*—Upper Permian, Basleo beds, from Tonino, Kioe Kilo, near Basleo, Timor Island, Indonesia.

*Type.*—Topotype, S4,035, one specimen, Springer collection, U. S. National Museum, Washington.

#### Genus SAGITTOBLASTUS Yakovlev, 1937

*Type-species*, by original designation.—*Timoroblastus wanneri* YAKOLEV, 1926.

*Generic diagnosis.*—Fissiculate blastoids with eight small deep exposed hydrosphere fields, with two or three hydrosphere slits in each hydrosphere field, hydrosphere fields on summit, with large epideltoid on anal side and anal opening between radial limbs and epideltoid, with perhaps a small ?hypodeltoid (missing) on the aboral side of the anal opening, extremely short lancet plates covered by large side plates, well away from oral opening; calyx form spherical in side view. *Permian*, Russia.

*Remarks.*—The genus *Sagittoblastus* was probably derived from a form similar to *Codaster* in which the hydrosphere fields are reduced in size to small, deep constrictions, the hydrosphere slits reduced in number in each field, and the form changed to spherical, with consequent shortening of the lancet plates and migration of lancets away from the oral opening.

#### SAGITTOBLASTUS WANNERI (Yakovlev)

Plate 18, figures 1-7; text-figs. 52-55

*Timoroblastus wanneri* YAKOLEV, 1926, pp. 54-55, text-fig. 5, pl. 1, figs. 8-10.

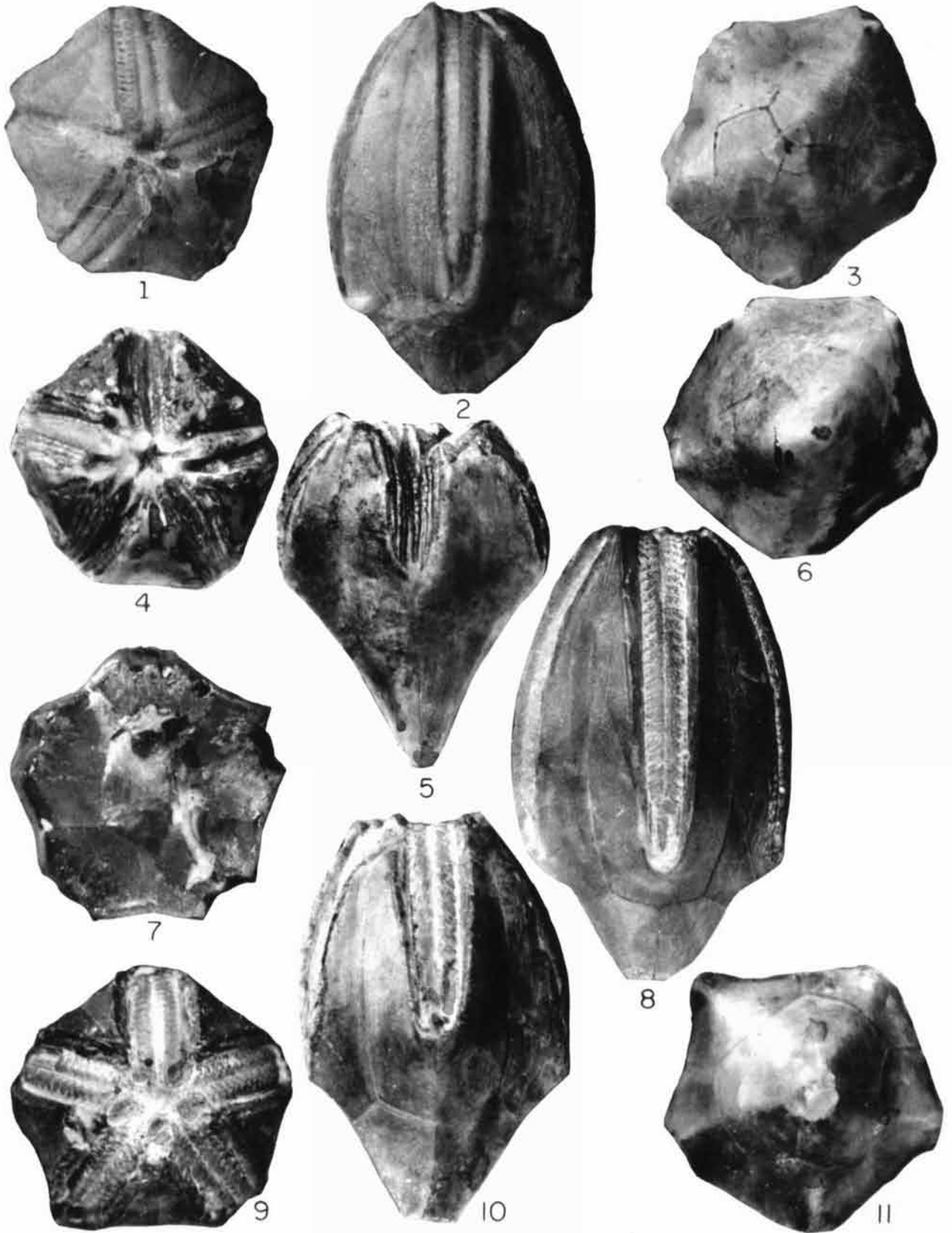
*Description.*—Calyx calcitic, subglobular in side view, rounded pentagonal in top view, 11 mm. long by 10 mm. wide, with slightly flattened summit, convex base, and periphery near mid-height. Stem impression not well preserved, but appears to be round, 0.75 mm. in diameter, and in a basal concavity. Basal circlet wide, rounded pentagonal, 3.5 mm. high by 8.5 mm. wide, with three large normally disposed basals. Radials five, elongate hexagonal, each 7 mm. long by 5 mm. wide, with short, flat to deeply concave radial sinus 1.5 mm. long by 1 mm. wide, with short, flat to deeply concave radial sinus 1.5 mm. long by 1 mm. wide, almost confined to summit. Deltoids appear to overlap radial limbs.

Deltoids four, strongly arrow-shaped, each 2.5 mm. long by 2.5 mm. wide, with two deep concave hydrosphere fields near adjacent ambulacral margins in the aboral part of the deltoid body, with two or three hydrosphere slits in each hydrosphere field parallel to the ambulacra and extending across the radiodeltoid suture. On the anal side a large hexagonal epideltoid is found, with the anal opening between it and the adjacent radial limbs, hydrosphere slits lacking. It is assumed that a small hypodeltoid plate was present on the anal side, adjacent to the radial limbs, but washed away. Thus there are nine openings around the oral aperture, consisting of eight deep hydrosphere fields and a separate anal opening. The deltoid lips and epideltoid surround the oral opening, and the lancet plates are displaced away from the oral opening.

Ambulacra five, short, diamond-shaped, each 3 mm. long by 1.5 mm. wide, with lancet covered by side plates,

#### EXPLANATION OF PLATE 9

FIGURE	PAGE	
1-3.		<i>Hyperoblastus cummingsi</i> (REIMANN), hypotype, E15,935, Buffalo Soc. Nat. Sci.; Devonian, Hungry Hollow Formation (coral zone of Widder beds), Arkona, Ontario; oral, "D" ambulacral, aboral views (all $\times 4.4$ ) ..... 31
4-6.		<i>Hyperoblastus southworthi</i> (REIMANN), holotype, E11,816, Charles Southworth coll., Buffalo Soc. Nat. Sci.; Devonian, Hungry Hollow Formation (coral zone of Widder beds), tile yard, Thedford, Ontario; oral; "D" ambulacral, aboral views (all $\times 7.8$ ) ..... 35
7, 9-11.		<i>Hyperoblastus dotis</i> (REIMANN), holotype, E15,401, (figs. 9-11); paratype, E13,052, (fig. 7); Buffalo Soc. Nat. Sci.; Devonian, Hungry Hollow Formation (coral zone of Widder beds), Thedford, Ontario; 7, cross sec. "E" ambulacrum ( $\times 6.5$ ); 9-11, oral; "D" ambulacral, aboral views ( $\times 8$ ) ..... 31
8.		<i>Hyperoblastus filus angustus</i> (REIMANN), holotype, E15,403, Buffalo Soc. Nat. Sci.; Devonian, Hungry Hollow Formation (coral zone of Widder beds), Thedford, Ontario; "D" ambulacral view ( $\times 6.4$ ) ..... 33





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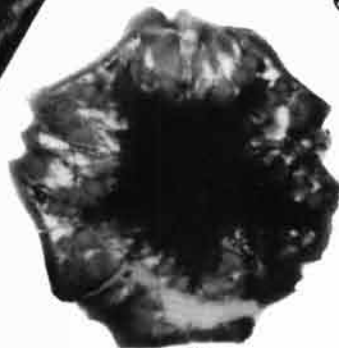
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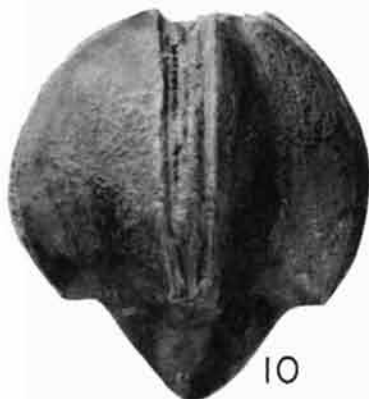
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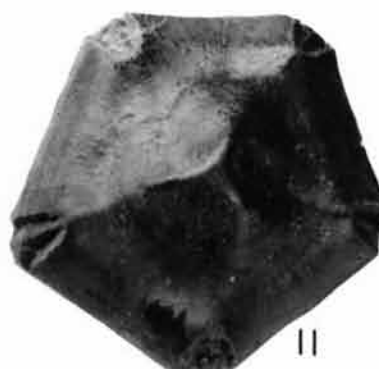
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30 side plates in 10 mm. The lancet is approximately 1 mm. distant from the oral opening and confined to the summit. The primary side plates are elongate, with long side food grooves, and small normally disposed outer side plates on the abmedial margins of the primary side plates. There are five or six main cover-plate sockets along the interdeltoid sutures and two or three sockets on the adoral margin of each deltoid lip adjacent to the oral opening. The surfaces of the calyx plates are worn but appear to have fine growth striae parallel to plate margins.

*Occurrence.*—Permian beds, Krassnoufmsk, Urals, USSR.

*Types.*—Metatypes, 695, one specimen, N. N. Yakovlev collection, upon which description is based, Illinois Geological Survey, Urbana; 102,187, one specimen, N. N. Yakovlev collection, old no. 16, one specimen, U. S. National Museum, Washington.

### Genus THAUMATOBLASTUS Wanner, 1924

*Type-species*, by original designation.—*Thaumatoblastus longiramus* WANNER, 1924.

*Generic diagnosis.*—Fissiculate blastoids with ten hydrospire fields, small anal opening between a large epideltoid and a large hypodeltoid, a reduced number of slits on the anal side, but seven or eight slits on the other interambulacral areas, widely exposed, with long lancet plates extended into winglike extensions of the radials, lancet almost completely covered by side plates, with rounded base and flat summit. *Permian*, Timor Island, Indonesia.

*Remarks.*—The genus *Thaumatoblastus* was probably derived from a form similar to *Conoschisma*, in which the sinuses migrated outward and upward and the radial limbs became winglike.

### THAUMATOBLASTUS LONGIRAMUS Wanner

Plate 18, figure 12; text-fig. 56

*Thaumatoblastus longiramus* WANNER, 1924, p. 201, pl. 2, figs. 1-17; pl. 4, fig. 2; pl. 5.

*Description.*—The one specimen examined is a fragmentary radial plate with lancet and side plates preserved. The important observation that should be added to the description given by WANNER is that an outer side plate is present on each primary side plate, normally disposed on the bevelled abmedial-adoral corner of the primary side plate. Also the lancet plate is almost completely covered by the side plates.

*Occurrence.*—Upper Permian, Basleo beds, Basleo, Timor Island, Indonesia.

*Type.*—Topotype, S4,053, three radial fragments, Springer collection, U. S. National Museum.

### Genus TRIONOBLASTUS Fay, n. gen.

[= *Heteroschisma* WACHSMUTH, 1883]

*Type-species*, by original designation (herein).—*Pentremites subtruncatus* HALL, 1858.

*Generic diagnosis.*—Fissiculate blastoids with eight exposed hydrospire fields, a superdeltoid, subdeltoid, and presumably hypodeltoid on the anal side, hydrospire slits absent on anal side, with lancet covered by side plates, and form steeply conical in side view. *Middle Devonian*, North America (Michigan, Ohio, Indiana, Kentucky, New York, Iowa, Ontario).

*Remarks.*—The genus *Trionoblastus* was probably derived from *Decaschisma* by fusion of the cryptodeltoids into a subdeltoid plate and atrophy of the hydrospire slits on the anal side.

### TRIONOBLASTUS SUBTRUNCATUS (Hall)

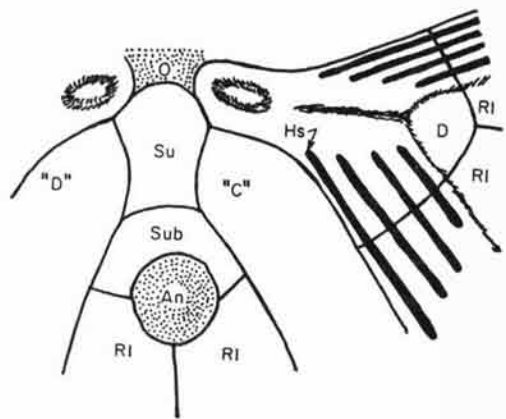
Plate 4, figures 1-3; text-figs. 57, 58

*Pentremites subtruncatus* HALL, 1858, p. 485, pl. 1, fig. 4.

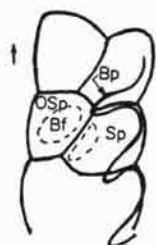
*Description.*—Calyx calcitic, obconical in side view, pentagonal in top view, 11.5 mm. long by 7 mm. wide, vault 2 mm. long, pelvis 9.5 mm. long, pelvic angle 40 degrees, periphery at radial lips well above mid-height, with flat summit and conical base (broken). Basal circlet elongate conical in side view, pentagonal in basal view, 5 mm. long by 5 mm. wide, with three normally disposed

## EXPLANATION OF PLATE 10

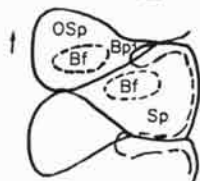
FIGURE	PAGE	
1-3, 8.	4-6.	<i>Hyperoblastus goldringae</i> (REIMANN), 1-3, syntype E9,049, Buffalo Soc. Nat. Sci.; Devonian, Ludlowville Formation ( <i>Pleurodictyum</i> beds), Cazenovia Creek, Gehle farm, 0.12 mile below Transit Road bridge, N.Y.; 1-3, oral, "D" ambulacral, aboral views (all $\times 7.5$ )—8, plesiotype, E21,160, F. W. Wattles coll., Buffalo Soc. Nat. Sci.; Devonian, Wanakah Shale ( <i>Pleurodictyum</i> beds), old quarry at Bay View, N.Y.; cross sec. of specimen showing four hydrospire folds on each side of an ambulacrum, aboral view ( $\times 4$ ) ..... 33
		4-6. <i>Hyperoblastus juvenis</i> (REIMANN), syntype, E9,054, Buffalo Soc. Nat. Sci.; Devonian, Ludlowville Formation ( <i>Pleurodictyum</i> beds), old quarry at Bay View, N.Y.; oral, "D" ambulacral, aboral views (all $\times 11.1$ ) ..... 33
		7. <i>Hyperoblastus perovalis</i> (REIMANN), holotype, E12,267, Buffalo Soc. Nat. Sci.; Devonian, Tully Limestone (pyrite), Cazenovia Creek, Springbrook, N.Y.; side view ( $\times 8$ ) ..... 33
		9-11. <i>Hyperoblastus latus</i> (REIMANN), syntype, E9,052, Buffalo Soc. Nat. Sci.; Devonian, Ludlowville Formation ( <i>Pleurodictyum</i> beds), Athol Springs, N.Y.; oral, "D" ambulacral, aboral views (all $\times 4.6$ ) ..... 33



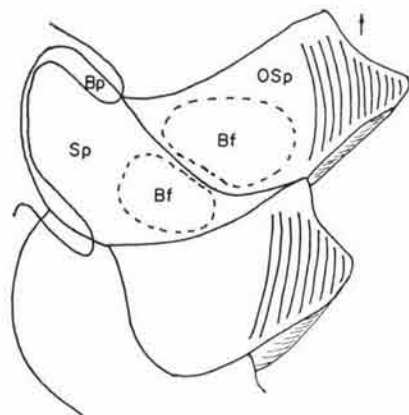
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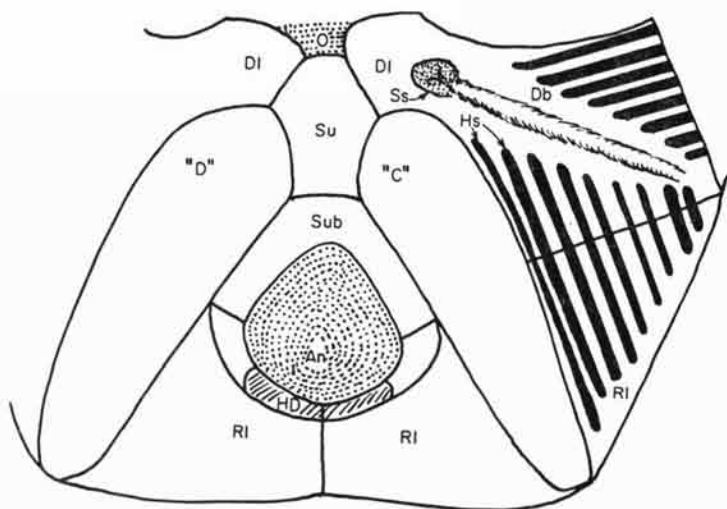
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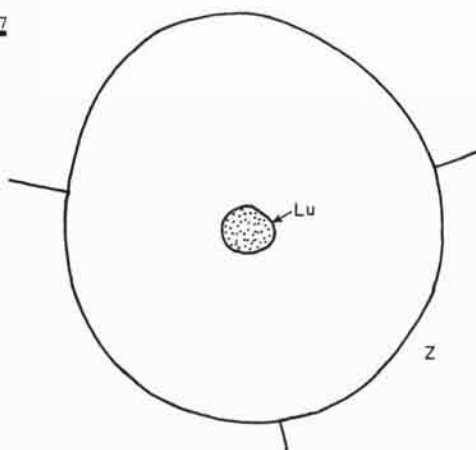
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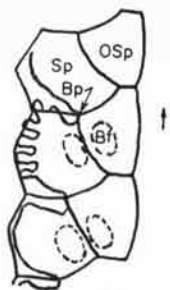
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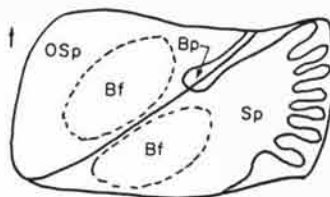
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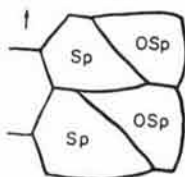
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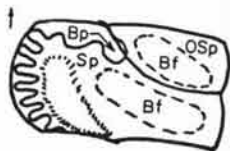
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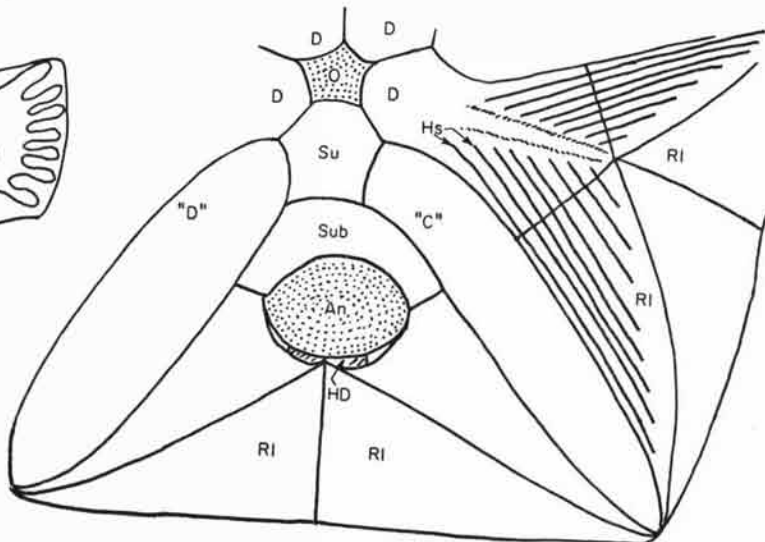
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basals. Radials five, subquadrangular in side view, each 7.5 mm. long by 3.5 mm. wide, with short, wide, moderately deep, flaring sinus 2.5 mm. long by 2.5 mm. wide, with limbs projecting upward into low coronal processes; radials overlapping deltoids.

Deltoids four, arrow-shaped, confined to summit, each 2 mm. long by 2.5 mm. wide, with aboral ends projecting upward into low coronal processes, and four hydrospire slits on each side of an ambulacrum crossing the radiodeltoid suture to the adjacent radial limbs. On the anal side there are three anal deltoids, a superdeltoid, subdeltoid, and hypodeltoid (missing, but probably present in living animal). The superdeltoid plate is hexagonal and adjacent to the oral opening. The U-shaped subdeltoid rests on the aboral inner surface of the superdeltoid and has limbs that extend on either side of the anal opening to the radial limbs. The radial limbs overlap the subdeltoid limbs. Hydrospire slits are lacking on the anal side; thus there are eight exposed hydrospire fields. The hypodeltoid probably covered the aboral part of the anal opening and fitted against the adjacent radial limbs.

Ambulacra five, linear, confined to summit, each 4 mm. long by 0.5 mm. wide, with lancet covered by side plates, 42 side plates in 10 mm. length of an ambulacrum, and side plates normally disposed. The primary and secondary side plates are almost equal in size, each pentagonal, with brachiolar pit and facets normally disposed. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

*Remarks.*—Comparison with other described species clearly indicates that this species is distinct. The specimen (holotype) is apparently mature and has a reduced number of hydrospire slits as compared with other species of *Trionoblastus*. It has not been possible to place this species with others, especially with *Trionoblastus gracilis*, which has eight slits on each side of an ambulacrum.

*Occurrence.*—Middle Devonian, Hamilton Group (Cedar Valley Limestone), New Buffalo, Iowa.

*Type.*—Holotype, X-52, one specimen, A. H. Worthen collection, old no. 10,398 of Illinois State Museum, now in Department of Geology, University of Illinois, Urbana, Illinois.

### TRIONOBLASTUS ALATUS (Reimann)

Plate 5, figures 4-6; text-fig. 59

*Codaster alatus* REIMANN, 1935, p. 23, pl. 1, figs. 2-3.

*Description.*—The described specimen has six ambulacra, and therefore is abnormal. Calyx calcitic, obconical in side view, hexagonal in top view (pentagonal in normal specimens), 9.5 mm. long by 7 mm. wide, with vault 2 mm. long, pelvis 7.5 mm. long, pelvic angle 50 degrees, periphery at radial lips. The stem impression is round, worn, 0.75 mm. in diameter, with small round lumen. Basal cirlet conical in side view, rounded pentagonal in basal view, 4 mm. long by 4 mm. wide, with three normally disposed basals. Radials six (but normally five), each elongate hexagonal, 5.5 mm. long by 3 mm. wide, with short, wide, moderately deep sinus 2 mm. long by 2.5 mm. wide by 1 mm. deep. The radial limbs on the anal side are truncated against the subdeltoid limbs. Radials overlap deltoids.

Deltoids five (normally four), each strongly arrow-shaped, 2.5 mm. long by 1 mm. wide, with approximately five exposed hydrospire slits on each side of an ambulacrum, extending across the adjacent radial limbs, and each deltoid with a ventrally projected low coronal process. On the anal side there are three anal deltoid plates. The pentagonal superdeltoid is adjacent to the oral opening and is bordered by the lancet plates on each side. The thin horseshoe-shaped subdeltoid rests on the aboral margin of the superdeltoid and is overlapped by the radial limbs. It is assumed that the large anal opening between the radial limbs and subdeltoid limbs was

#### FIGURES 57-67. Species of *Trionoblastus* FAY, n. gen., Middle Devonian, North America.

57, 58. *T. subtruncatus* (HALL), Cedar Valley Limestone, New Buffalo, Iowa (Univ. Illinois, holotype, no. X-52); 57, morphological features of anal area and part of "BC" interambulacrum,  $\times 15$ ; 58, part of "D" ambulacrum showing main and outer side plates,  $\times 45$ .—59. *T. alatus* (REIMANN), Traverse Group, Alpena, Mich. (Univ. Michigan, no. 30,736); part of "E" ambulacrum, showing main and inner side plates,  $\times 90$ .—60-63, *T. canadensis* (BILLINGS), Hungry Hollow Formation, Thedford, Ontario (G.S. Canada, 3,664; Buffalo Soc. Nat. Sci., E11,760, E21,098); 60, "BC" interambulacrum, showing morphological features (no. E11,760),  $\times 15$ ; 61, stem (E21,098),  $\times 45$ ; 62, part of "A" ambulacrum showing main and outer side plates (no. E11,760),  $\times 90$ ; 63, part of "C" ambulacrum, showing main and outer side plates (no. 3,664),  $\times 75$ .—64-66. *T. gracilis* (WACHSMUTH),

Partridge Point Formation, Partridge Point, Mich. (Buffalo Soc. Nat. Sci., no. E21,142); 64, summit area showing morphological features of "CD" (anal) and "BC" interambulacra,  $\times 15$ ; 65, part of "C" ambulacrum, showing main and outer side plates,  $\times 45$ ; 66, part of "E" ambulacrum, showing main and outer side plates drawn from polished tangential section,  $\times 45$ .—67. *T. pyramidalis* (SHUMARD), Columbus Limestone, Columbus, Ohio (Buffalo Soc. Nat. Sci., no. E21,071); part of "A" ambulacrum, showing main and outer side plates,  $\times 45$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; "D," amb.; D, deltoid; Db, deltoid body; Dl, deltoid lip; HD, hypodeltoid; Hs, hydrospire; Lu, lumen; O, oral opening; OSP, outer side plate; Rl, radial limb; Sp, main side plate; Ss, spiracular slit; Su, superdeltoid; Sub, subdeltoid; Z, azygous basal.]

partly covered by a small hypodeltoid (pentagonal?) on the aboral side of the anal opening and that this plate is one of the first to become detached. There are no hydrospire slits on the anal side, so that eight hydrospire fields are exposed.

Ambulacra six (normally five), each short, linear, 3.5 mm. long by 1 mm. wide, with lancet covered by side plates and 45 side plates in 10 mm. length of an ambulacrum. The primary side plates are subquadrangular, with alate secondary side plates resting against the abmedial-adoral corners of the primary side plates. The surfaces of the calyx plates are ornamented with fine growth striae parallel to margins of plates.

*Occurrence*.—Middle Devonian, Traverse Group, Potter Farm Formation, from shale pit just west of Evergreen Cemetery, west of the city limits of Alpena, Michigan.

*Types*.—Plesiotypes, 30,736, four specimens, R. V. Kesling collection, 1952, identified by REIMANN, University of Michigan, Ann Arbor, Michigan.

#### TRIONOBLASTUS CANADENSIS (Billings)

Plate 4, figures 4-6; Plate 5, figures 7-9; text-figs. 60-63

*Codaster canadensis* BILLINGS, 1869, p. 79.

*Description*.—The description is based on characters seen in the large hypotype of the Canadian Geological Survey collection, supplemented by other specimens. Calyx calcitic, obconical in side view, pentagonal in top view, 9.5 mm. long by 5 mm. wide, vault 2 mm. long, pelvis 7.5 mm. long, and pelvic angle of 30 degrees. The stem is round, 1 mm. in diameter, smooth, with ill-defined outline on basal cirlet, which is conical, 4.5 mm. long by 3.5 mm. wide, with three normally disposed basals. Radials five, each 5.5 mm. long by 3 mm. wide, with sinus 0.5 mm. long by 2 mm. wide; radials overlapping deltoids.

Deltoids four, arrow-shaped, confined to summit, each 1.5 mm. wide by 1.75 mm. long, with deltoid lips adjacent to oral opening, deltoid crests low, and six exposed hydrospire slits on each side of an ambulacrum extending across adjacent radial limbs. On the anal side there are three deltoid plates. The hexagonal epideltoid is adjacent to the oral opening, and the horseshoe-shaped subdelto-

rests on the aboral inner surface of the superdeltoid, with limbs on either side of the anal opening. The subdeltoid limbs are overlapped by the adjacent radial limbs. It is assumed that a hypodeltoid plate was present on the aboral side of the anal opening, because a small facet occurs on the adoral face of the radial limbs for reception of the hypodeltoid. Hydrospire slits absent in anal inerradius, and therefore there are eight exposed hydrospire fields.

Ambulacra five, linear, each 3 mm. long by 0.5 mm. wide, with lancet covered by side plates, and 43 side plates in 10 mm. length of an ambulacrum. The lancet stipe extends to within 0.5 mm. of the oral opening. The side plates are normally disposed. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

*Occurrence*.—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, Thedford, Ontario.

*Types*.—Hypotypes, 3664, three specimens, the largest used for illustration and description, same types used by WHITEAVES (1887, 1889), p. 109, pl. 14, fig. 44a, Geological Survey of Canada, Ottawa, Canada. Plesiotypes, E21,098, 11 specimens, from tile yard at Thedford, Charles Southworth collection; E11,760, two specimens, Reimann collection, Buffalo Society of Natural Sciences, Buffalo, New York.

#### TRIONOBLASTUS GRACILIS (Wachsmuth)

Plate 5, figures 1-3; text-figs. 64-66

*Heteroschisma gracile* WACHSMUTH, 1883, p. 354, text-figs. 1-2.

*Description*.—Calyx calcitic, subconical in side view, pentagonal in oral view, base broken, 12.5 mm. long by 8 mm. wide, vault 2.5 mm. long, pelvis 10 mm. long, pelvic angle 40 degrees, and periphery at radial lips well above mid-height. The stem appears to be round, smooth, with round central lumen, but too ill-defined to see crenellae. Basal cirlet conical in side view, rounded in basal view, 4.5 mm. long by 4.5 mm. wide, with three elongate normally disposed basals. Radials five, each 8 mm. long by 4 mm. wide, broadly quadrangular, with narrow deep sinus 3 mm. long by 2 mm. wide, with radial limbs projecting upward into coronal processes; radials overlapping deltoids.

### EXPLANATION OF PLATE 11

FIGURE	PAGE	(all $\times 8.1$ )	PAGE
1-3. <i>Hyperoblastus obesus</i> (REIMANN), holotype, E9,055, Buffalo Soc. Nat. Sci.; Devonian, Ludlowville Formation ( <i>Demissa</i> beds), Smokes Creek, Windom, N.Y.; oral, "D" ambulacral, aboral views (all $\times 5.4$ )	33		
4-6. <i>Hyperoblastus eriensis</i> (REIMANN), paratype, E13,014, Buffalo Soc. Nat. Sci.; Devonian, Tichenor Limestone, Springbrook, N.Y.; oral, "D" ambulacral, aboral views			
7-11. <i>Hyperoblastus reimanni</i> (KIER), holotype, 27,678 (figs. 7-9); paratypes, 27,681 (fig. 10), 27,679 (fig. 11), Robert R. Klinger coll., Univ. Michigan; Devonian, Silica Shale, Unit 13, Medusa Portland Cement Company Quarry, Silica, Lucas County, Ohio; 7-9, oral, "D" ambulacral, aboral views (all $\times 5.8$ ); 10, "EA" interambulacral view ( $\times 11$ ); 11, "DE" interambulacral view ( $\times 10.9$ )	35		32



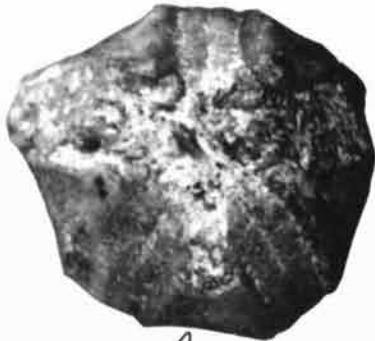
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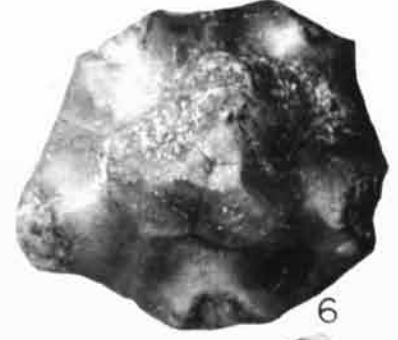
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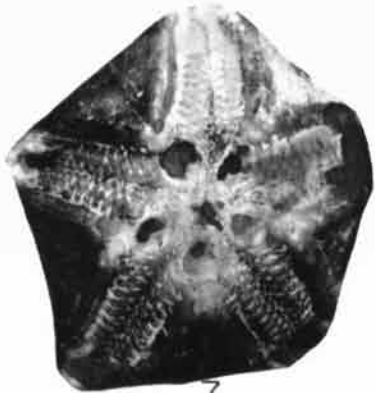
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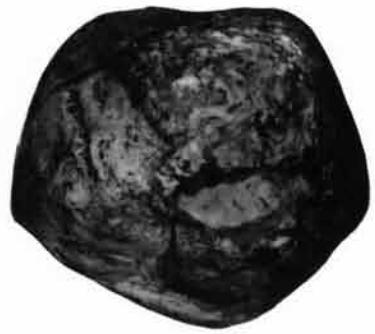
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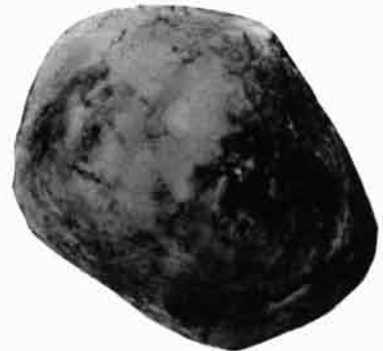
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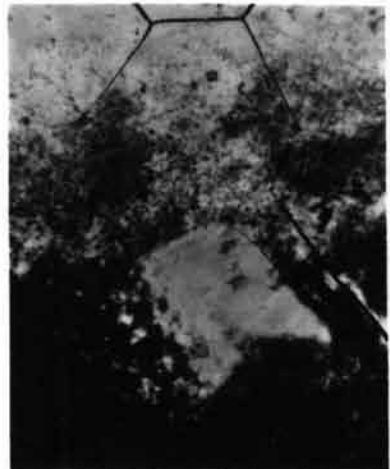
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Deltoids four, arrow-shaped, with moderately high coronal processes, and seven or eight exposed hydrosfire slits on each side of an ambulacrum, extending to adjacent radial limbs. On the anal side there are three deltoid plates. The hexagonal superdeltoid is adjacent to the oral opening and the horseshoe-shaped subdeltoid rests on the inner aboral surface of the superdeltoid. The subdeltoid limbs curve around the sides of the anal opening and meet the truncated radial limbs. It is assumed that a hypodeltoid plate was present on the aboral side of the anal opening, where a facet is present. Hydrosfire slits are lacking on anal side; thus there are eight exposed hydrosfire fields.

Ambulacra five, linear, each 3.5 mm. long by 0.5 mm. wide, with approximately 50 side plates in 10 mm. The primary and secondary side plates are pentagonal and almost equal in size, with four or five cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

*Occurrence.*—Middle Devonian, Partridge Point Formation, Partridge Point, Michigan.

*Types.*—Plesiotypes, E21,142, 12 specimens, Reimann collection, Buffalo Society of Natural Sciences, Buffalo, New York.

### TRIONOBLASTUS PYRAMIDATUS (Shumard)

Plate 4, figures 7-9; Plate 12, figure 8; text-figs. 67, 68

*Codaster pyramidatus* SHUMARD, 1858, p. 238, pl. 9, figs. 1a-c.

*Description.*—Calyx silicified, obconical in side view, pentagonal in oral view, 12 mm. long by 8 mm. wide, with vault 2 mm. long, pelvis 10 mm. long, pelvic angle 45 degrees, and periphery at radial lips well above mid-height. Basal circle rounded in aboral view, broadly triangular near area of stem attachment, 3.5 mm. long by 4 mm. wide, with three normally disposed basals. Stem round, 1 mm. in diameter, with small round lumen. Radials five, each broadly pentagonal in side view, 8 mm. long by 4 mm. wide, with broad flat sinus 3 mm. long by 3.5 mm. wide, and low limbs. The interradial sutures

are in depressed areas flanked by a double or triple row of parallel ridges on either side; radials overlapping deltoids.

Deltoids four, arrow-shaped, with low crests, and seven hydrosfire slits on each side of an ambulacrum, extending to adjacent radial limbs. On the anal side there are three deltoids. The arrow-shaped superdeltoid is adjacent to the oral opening. The subdeltoid is horseshoe-shaped, adjacent to the aboral surface of the superdeltoid, with limbs that extend on both sides of the anal opening and meet the adjacent radial limbs which overlap the subdeltoid limbs. It is assumed that a small hypodeltoid plate covered the aboral part of the anal opening and abutted against the radial limbs. Hydrosfire slits are absent on anal side; therefore there are eight hydrosfire fields.

Ambulacra five, linear, each 4.5 mm. long by 1 mm. wide, with lancet covered by side plates, and 50 side plates in 10 mm. The side plates appear to be normally disposed. The surfaces of the calyx plates appear to be ornamented with fine growth lines parallel to plate margins.

*Remarks.*—The flat summit and ridges parallel to the interradial sutures serve to characterize this species. The variously described species of *Trionoblastus* may readily be distinguished by the number of hydrosfire slits in each field, and the relative height of the deltoid crests.

*Occurrence.*—Middle Devonian, Onondaga (Columbus) Limestone, Columbus, Ohio.

*Types.*—Plesiotypes, 37,759, eight specimens, U. S. National Museum, Washington; E21,071, seven specimens used for the above description, Buffalo Society of Natural Sciences, Buffalo, New York.

### Order SPIRACULATA Jaekel, 1918

Blastoids with hidden hydrosfire slits that open into hydrosfire canals, having definite spiracles and hydrosfire pores. *Silurian-Permian*, North America, Europe, Timor, Australia, Asia, North Africa.

## EXPLANATION OF PLATE 12

FIGURE	PAGE
1-7, 9. <i>Codaster acutus</i> M'COY, plesiotype (figs. 1-3), S3,218, Springer coll., U.S. Natl. Mus., Lower Carboniferous limestone, Lancashire, England; plesiotypes (figs. 4-7, 9), 367, Harvard Mus. Comp. Zoology, Lower Carboniferous limestone, Malham, Yorkshire, England; 1-3, oral, "D" ambulacral, aboral views (all $\times 3.7$ ); 4-6, oral, "D" ambulacral, aboral views (all $\times 4.6$ ); 7, enlarged view of "E" ambulacrum of another specimen ( $\times 16$ ); 9, thin sec. of	23
8. <i>Trionoblastus pyramidatus</i> (SHUMARD), plesiotype, 37,759, U.S. Natl. Mus.; Devonian, Onondaga Limestone, Columbus, Ohio; oral view, for comparison with <i>Codaster</i> , showing subdeltoid plate on adoral side of anal opening, adjacent to superdeltoid plate, with distinct suture between the two plates ( $\times 7$ )	49

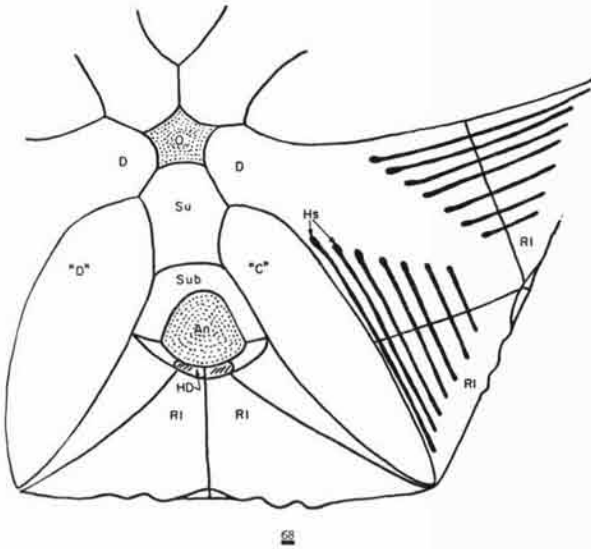


FIGURE 68. *Trionoblastus pyramidatus* (SHUMARD), Columbus Limestone, Columbus, Ohio (Buffalo Soc. Nat. Sci., no. E21,071); summit area showing morphological features of "CD" (anal) and "BC" interambulacra,  $\times 11$ . [Explanation.—An, anal opening; "C," amb.; "D," amb.; D, deltoid; HD, hypodeltoid; Hs, hydrospire slit; O, oral opening; Rl, radial limb; Su, superdeltoid; Sub, subdeltoid.]

### Genus AMBOLOSTOMA Peck, 1930

*Type-species*, by original designation.—*Ambolostoma baileyi* PECK, 1930.

*Generic diagnosis*.—Spiraculate blastoids with five spiracles, including anispiracle in one anal deltoid plate, with five large oral plates covering summit, lancet completely exposed, with one large pore between side plates along deltoid and radial margins, three hydrospire folds on each side of an ambulacrum, and calyx shape elliptical in side view. *Mississippian*, Utah, Alberta.

*Remarks*.—The genus *Ambolostoma* was probably derived from *Pentremites* by enlarged growth of oral plates into five large orals.

#### AMBOLOSTOMA BAILEYI Peck

Plate 53, figures 1-6; text-figs. 69-73

*Ambolostoma baileyi* PECK, 1930, p. 104, pl. 14, figs. 9-13.

*Pentremites grandis* WARREN, 1927, p. 48, pl. 3, fig. 8.

*Pentremites perelongatus* WARREN, 1927, p. 48, pl. 3, fig. 9.

*Description*.—The above-cited nominal species are represented by imperfectly preserved specimens but all appear to be conspecific. The best specimens are the syntypes of *Ambolostoma baileyi*, adequately described by PECK. The largest specimen is 64 mm. long by 35 mm. wide, vault 52 mm. long, pelvis 12 mm. long. The basal

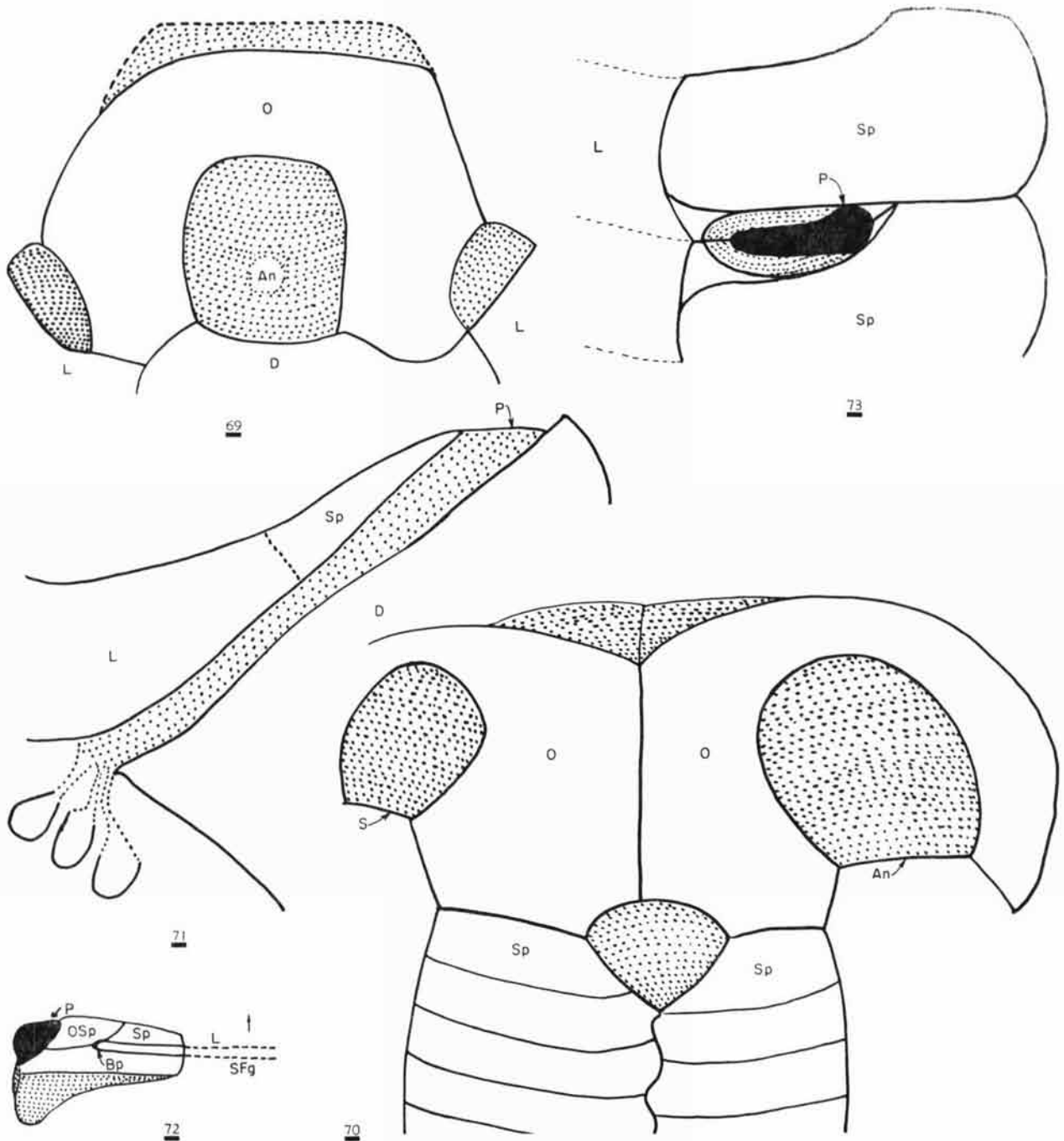
circlet is 5 mm. long, the radials each 40 mm. long by 18 mm. wide, and the deltoids 19 mm. long by 11 mm. wide. In one unfigured syntype 60 mm. long, the stem is round, approximately 0.5 mm. in diameter, and attached to three normally disposed basals.

Of importance is the presence of five large U-shaped oral plates, interradial in position, with a small spiracle or opening adjacent to the adoral tip of each deltoid body. These plates apparently closed the oral opening and fitted tightly against the ambulacral cover plates. Small openings occur at the adoral ends of the food grooves, one to each groove at its juncture with adjacent oral plates, allowing food to pass freely to the mouth. These openings do not connect with the spiracles internally but are separated from them by solid stereom of the oral plates. Thus, food entered in a radial position, and excreta were emitted in an interradial position. The small syntype that shows this feature best is 37 mm. long, with anispiracle 1 mm. wide. A cross-section of this specimen was etched with acid but it is difficult to see the exact number of hydrospire folds. Three small indentations or loops seem to be present on each side of an ambulacrum. Ambulacra are concave, with 28 side plates in 10 mm. Radials overlap deltoids.

The type of *Pentremites grandis* is in a dark-colored crystalline limestone and is imperfectly preserved. The calyx is 53 mm. long by 33 mm. wide, ellipsoidal in side view, with vault 45 mm. long, and preserved part of pelvis 8 mm. long, one side appearing to have a short ambulacrum (40 mm. long, with radial sinus 13 mm. long). Each preserved radial is 25 mm. long by 13 mm. wide, with sinus 20 mm. long by 4 mm. wide. Deltoids are 30 mm. long by 8 mm. wide. Radials overlap deltoids. Each ambulacrum is concave admedially-abmedially, 45 mm. long by 7 mm. wide, with approximately 28 side plates in 10 mm.

The type specimen of the taxon named *Pentremites perelongatus* is fragmentary and fractured, occurring in a dark-colored crystalline limestone. The calyx is 63 mm. long by 31 mm. wide, broadly ellipsoidal, with vault 40 mm. long and pelvis 23 mm. long. The summit is incompletely preserved and the calyx plates are thick. Each radial is 52 mm. long by 12 mm. wide, with sinus 27 mm. long by 5 mm. wide. The deltoids are short, each 14 mm. long by 5 mm. wide, and they appear to overlap the radials. Each ambulacrum is 40 mm. long by 5 mm. wide, with lancet exposed, and apparently three slits on each side of an ambulacrum, 27 side plates occurring in 10 mm. and one pore between pairs of side plates. Each primary side plate appears to be wedge-shaped, 4 mm. deep, 0.4 mm. wide, and 0.5 mm. long (abmedially-admedially), with a secondary side plate normally disposed on the abmedial-adoral corner of each primary side plate.

*Occurrence*.—Upper Mississippian, upper part of Brazer Formation, 6 miles west of Mendon, Utah (PECK'S



FIGURES 69-73. *Ambolostoma baileyi* PECK, Upper Mississippian, Brazer Formation, near Mendon, Utah (U.S. Nat'l. Mus., no. 111,762), and Rundle Limestone, Cascade Mountain, Alberta (Geol. Survey Canada, no. 8,914)

69. Oral plate of "CD" interambulacrum showing anal opening (no. 111,762),  $\times 20$ .—70. Part of "D" ambulacrum and orals at distal extremity (no. 111,762),  $\times 20$ .—71. Partial cross section of "A" ambulacrum near summit (no. 111,762),  $\times 20$ .—72. Part of ambulacrum showing side plates (no. 111,762),  $\times 20$ .—73.

Side plates of small ambulacrum, arrow pointing toward mouth but not in position of food groove (no. 8,914),  $\times 75$ . [Explanation.—An, anal opening; Bp, brachiolar pit; D, deltoid; L, lancet; O, oral plate; OSp, outer side plate; P, pore; S, spiracle; SFg, side food groove; Sp, main side plate.]

syntypes). Rundle Limestone, Stoney Squaw Mountain (*P. perelongatus* type), and Cascade Mountain (*P. grandis* type), Alberta, Canada.

*Types*.—Syntypes, 111,762, three specimens, U. S. National Museum, Washington. Plesiotypes, 8,914 (holotype of *Pentremites grandis* WARREN), one specimen; 8,915 (holotype of *Pentremites perelongatus* WARREN), one specimen, Geological Survey of Canada, Ottawa.

### Genus CARPENTEROBLASTUS Rowley, 1901

*Type-species*, by original designation.—*Granatocrinus* (*Schizoblastus*) *magnibasis* ROWLEY, 1895.

*Generic diagnosis* (*emend.* FAY, herein).—Spiraculate blastoids with eight spiracles in addition to an anispiracle, located between epideltoid and hypodeltoid plates, lancet exposed along food groove proper, with ?two hydrospire folds on each side of an ambulacrum, one pore between adjacent side plates along deltoid and radial margins, base convex, radials overlapping deltoids, and calyx form conico-elliptical. *Mississippian*, Missouri, ?Kentucky.

*Remarks*.—The genus *Carpenteroblastus* may have been derived from a form similar to *Lophoblastus* in which the three hydrospire folds atrophied to produce two folds on each side of an ambulacrum.

### CARPENTEROBLASTUS MAGNIBASIS (Rowley)

Plate 37, figures 11-12; plate 45, figures 10-12; text-figs. 74-76

*Granatocrinus* (*Schizoblastus*) *magnibasis* ROWLEY, 1895, p. 220, figs. 11-14.

*Description*.—Calyx calcitic, flattened ellipsoidal, with convex base in side view, strongly pentagonal in top view, 11 mm. long by 11.5 mm. wide, vault 9 mm. long, pelvis 2 mm. long, pelvic angle 130 degrees, periphery at mid-height, summit flat. The stem is not well preserved, but is round, crenellar, and about 1 mm. in diameter. Basal cirlet 1.5 mm. long by 6 mm. wide, pentagonal in basal view, convex outward, with large round ridges on each side of basiradial sutures, and with three normally disposed basal plates. Radials five, each hexagonal in side view, 9 mm. long by 5 mm. wide, with narrow, mod-

erately deep sinus 7 mm. long by 1.5 mm. wide, with outward-projecting sides and rounded raised rims, giving a marked stellate appearance to the calyx in top view; radials overlapping deltoids.

Deltoids four, large, broadly lancet-shaped, each 3.5 mm. long by 4.5 mm. wide, the adoral tips of each pierced by two separate spiracles, thus forming eight spiracles around the oral opening. On the anal side the anispiracle is located between a pentagonal epideltoid and pentagonal hypodeltoid; thus, a total of nine spiracles occur around the oral opening.

Ambulacra five, long, linear, recurved below, each 13 mm. long by 1.5 mm. wide, with lancet exposed along food groove, the exposure being progressively wider toward the adoral end. There are 30 side plates in a space of 10 mm. along an ambulacrum, normally disposed, with one pore between plates, notched slightly in the sides of the deltoids and radials. There are four cover-plate sockets to each side plate along the main food groove, and ?two hydrospire folds on each side of an ambulacrum. The surfaces of the calyx plates are ornamented by coarse growth ridges parallel to margins.

*Occurrence*.—Lower Mississippian, upper part of Burlington Limestone, Louisiana, Missouri.

*Types*.—Holotype, RX-194, one specimen, Rowley collection; metatypes, RX-22, three specimens, Rowley collection, Department of Geology, University of Illinois, Urbana.

### Genus CORDYLOBLASTUS Fay, n. gen.

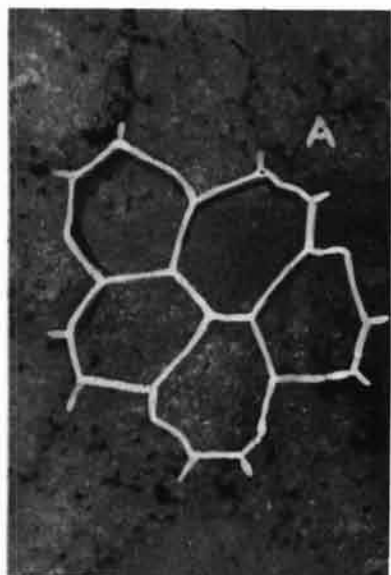
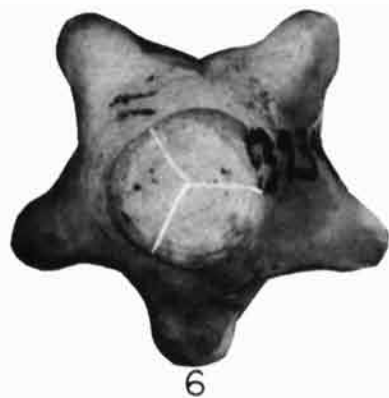
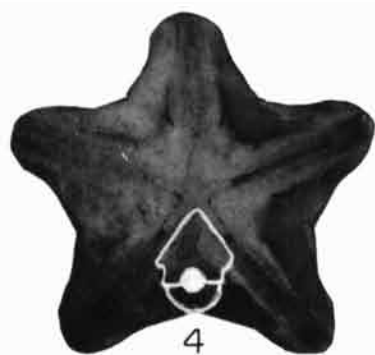
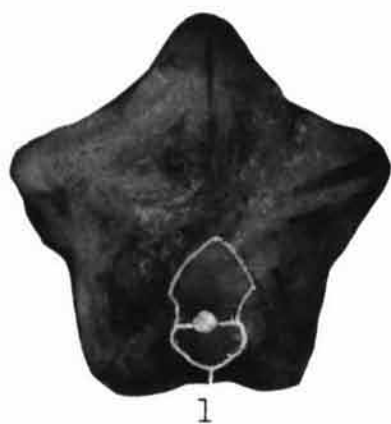
*Type-species*, by original designation (herein).—*Pentremites acutangulus* SCHULTZE, 1867 (adv. publ., 1866).

*Generic diagnosis*.—Spiraculate blastoids with five spiracles, one of which is an anispiracle located between a superdeltoid and hypodeltoid, with two internal cryptodeltoids and large hypodeltoid, seen in side view, but the other four deltoids are overlapped by radials and not visible in side view, a single pore occurring between adjacent side plates along radial margins, lancet covered by side plates, four to nine hydrospire folds on each side of an ambulacrum; calyx club-shaped in side view. *Devonian*, Germany, Spain.

## EXPLANATION OF PLATE 13

FIGURE	PAGE	
1-3. <i>Orophocrinus campanulatus</i> (HAMBACH), syntype, S3,236, coll. (purchased by SPRINGER), U.S. Natl. Mus.; Lower Mississippian, Chouteau Limestone, Sedalia, Mo.; oral, "D" ambulacral, aboral views of HAMBACH's original figured specimen (all $\times 3.1$ ) .....	36	
4-9. <i>Orophocrinus stelliformis</i> (OWEN & SHUMARD), neotypes, S4,961 (new holotype figs. 4, 7, 9, new paratype fig. 8), Springer coll., old number S3,234, U.S. Natl. Mus.; Lower Mississippian, Lower Burlington Limestone, Burlington, Iowa; 4-6, oral, "D" ambulacral, aboral views (all $\times 2.5$ ) (also figured by ETHERIDGE & CARPENTER, 1886, pl. 15, fig. 11); 7, oral view of oral plates of holotype, A indicating anal side ( $\times 30$ ); 8, anal view of new paratype showing anal covering plates in place between epideltoid and hypodeltoid plates ( $\times 25$ ); 9, detail view of "B" ambulacrum, mouth toward top, one outer side plate outlined in white ( $\times 44$ ) .....	36	

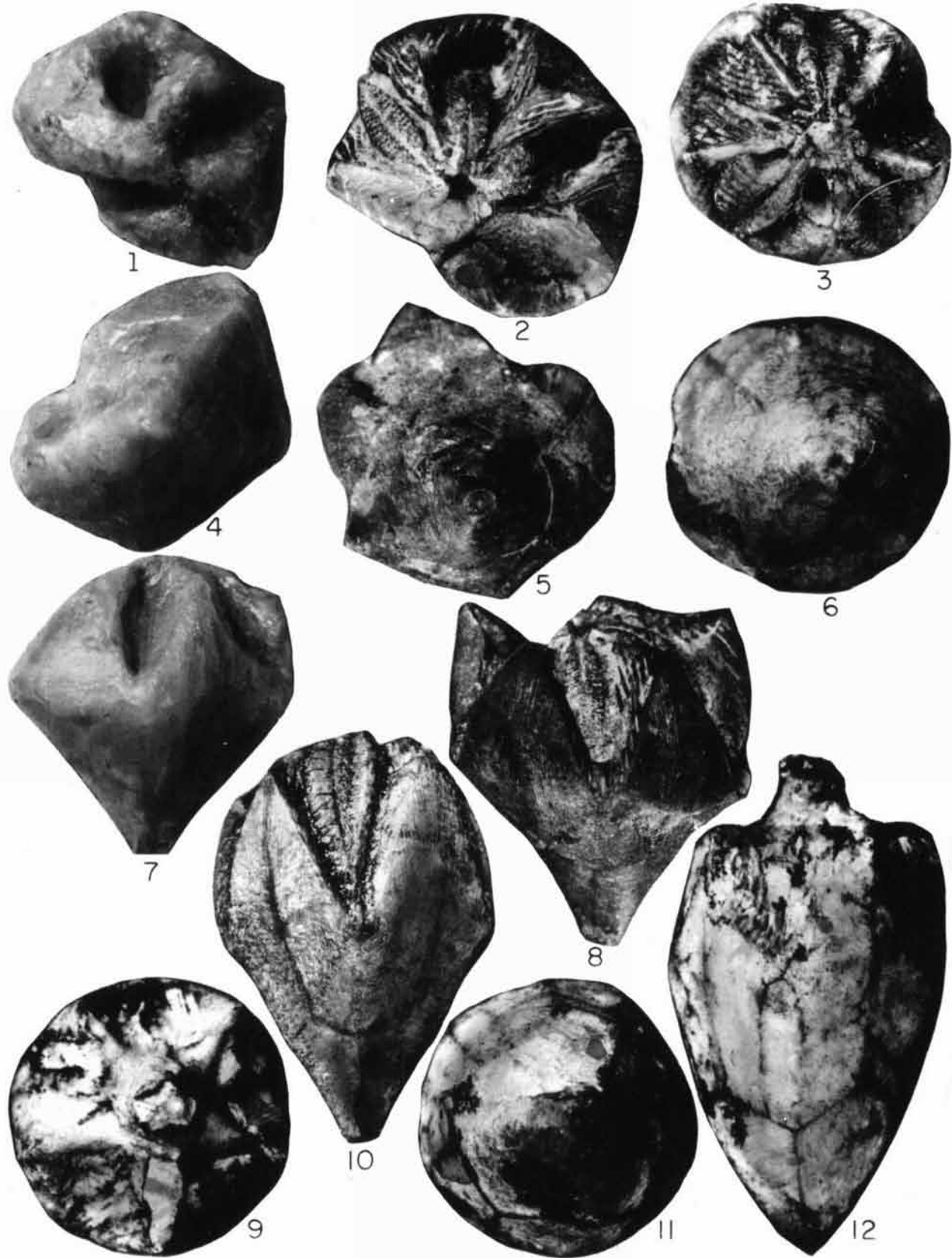




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*Remarks.*—The genus *Cordyloblastus* was probably derived from *Hyperoblastus* by complete closure of the sinus areas, with consequent formation of five spiracles and simple pores. *Pentremitidea* differs from

*Cordyloblastus* in having eight hydrospire fields that open into spiracular slits.

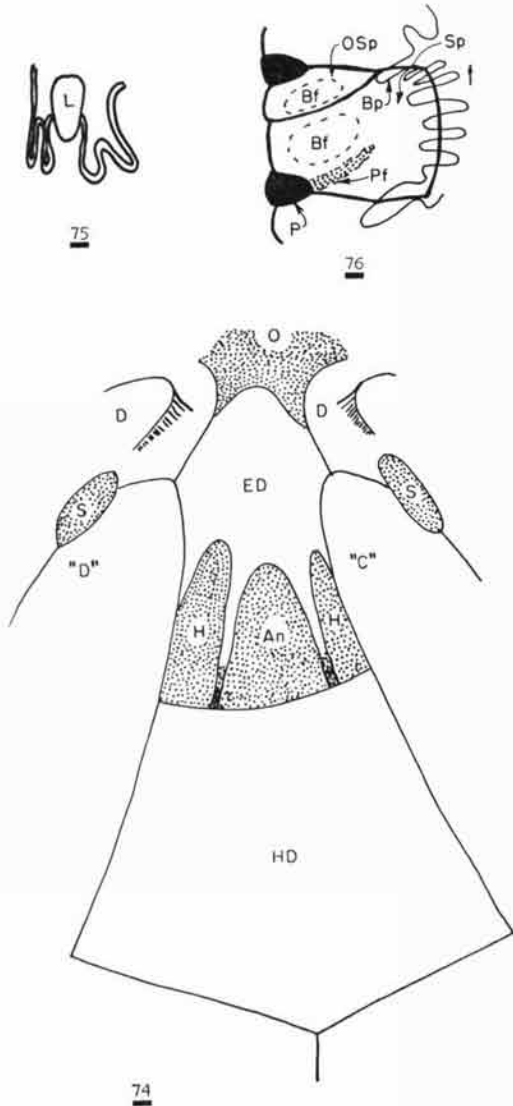
### CORDYLOBLASTUS ACUTANGULUS (Schultze)

Plate 23, figures 4-8; text-figs. 77-79

*Pentremites acutangulus* SCHULTZE, 1866, 1867, p. 225, pl. 13, fig. 6.

*Description.*—Calyx calcitic, oval in side view with short conical base, lobed pentagonal in top view, 21.5 mm. long by 19.5 mm. wide, with vault 17.5 mm. long, pelvis 4 mm. long, pelvic angle on basals 70 degrees and on radial bodies 145 degrees, with periphery at radial lips well above mid-height. Stem round, crenellar, 2 mm. in diameter, with large round lumen. Basal circling widely conical in side view, pentagonal in basal view, 3 mm. long by 7 mm. wide. Radials five, elongate subquadrate in side view, each 18.5 mm. long by 8 mm. wide, with long narrow sinus 16 mm. long by 1.75 mm. wide. In basal view the radial bodies each have a sharply rounded ridge along a median line from each radial lip, giving a strongly lobed stellate appearance to the calyx in basal view. Radials overlap deltoids and conceal them, except on anal side, where the hypodeltoid is visible in side view.

Deltoids four, short, not seen in side view, each with a quadrangular deltoid body 0.5 mm. long by 0.5 mm. wide, and deltoid lip 1 mm. wide, with a large oval spiracle between, the deep deltoid septum connecting lip to body. On the anal side a superdeltoid and hypodeltoid appear to occur, with two hidden cryptodeltoids, and an anispiracle. The hypodeltoid is pentagonal, 1.5 mm. long by 1.5 mm. wide; it abuts against the radial limbs,



FIGURES 74-76. *Carpenteroblastus magnibasis* (ROWLEY), Lower Mississippian, Burlington Limestone, Louisiana, Mo. (Univ. Illinois, nos. RX22, RX194).—74. Anal area,  $\times 15$ .—75. Section of aboral tip of "A" ambulacrum (internal mold),  $\times 15$ .—76. Part of "A" ambulacrum, showing main and outer side plates,  $\times 45$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; "D," amb.; D, deltoid; ED, epideltoid; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; S, spiracle; Sp, main side plate.]

### EXPLANATION OF PLATE 14

FIGURE	PAGE		PAGE
1, 4, 7. <i>Conoschisma? jessiae</i> (MILLER & GURLEY), hypotype, 3,573, Carl C. Branson coll., Univ. Missouri; Lower Mississippian, Chouteau Limestone, Providence, Mo.; oral, aboral, "B" ambulacral views (all $\times 6.5$ )	25	Belgium; plesiotype (figs. 3, 6, 10), 19,082, Gurley coll., Univ. Chicago, Lower Carboniferous limestone, Tournai, Belgium; 2, 5, 8, oral, aboral, "B" ambulacral views (all $\times 6.1$ ); 3, 6, 10, oral, aboral, "D" ambulacral views (all $\times 6$ )	41
2, 3, 5, 6, 8, 10. <i>Phaenoblastus caryophyllatus</i> (DE KONINCK & LEHON), plesiotype (figs. 2, 5, 8), S3,268, Springer coll., U.S. Natl. Mus., Lower Carboniferous limestone, Tournai,		9, 11, 12. <i>Conoschisma laeviusculum</i> (ROWLEY), topotype, 29,904, Gurley coll., Univ. Chicago; Lower Mississippian, Upper Burlington Limestone (chert), Louisiana, Mo.; oral, aboral, "D" ambulacral views (all $\times 7.3$ )	24

overlapping the cryptodeltoids. The hexagonal superdeltoid is adjacent to the oral opening on the adoral side of the anal opening or anispiracle. Thus there are five spiracles surrounding the oral opening—four spiracles in addition to the anispiracle. Five hydrosipre folds occur on each side of an ambulacrum.

Ambulacra five, linear, each 20 mm. long by 1.5 mm. wide, with side plates covering lancet plate, and 34 side plates in 10 mm. length of each ambulacrum. The side plates are normally disposed, with the subtriangular secondary side plates resting on the bevelled adoral-abmedial corners of each elongate subquadrangular primary side plate. One large pore is present between adjacent side plates and radial margins, but pores are absent along the deltoid margins. There are five cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

*Remarks.*—The above description is based on characters seen in two specimens, one complete and one polished specimen, here considered to be the original types.

*Occurrence.*—Middle Devonian, Eifel beds, Pelm, Germany.

*Types.*—Holotype, 325, one specimen complete, Schultze collection, figured by SCHULTZE pl. 13, fig. 6; paratype, 325, one polished section, figured by SCHULTZE pl. 13, fig. 6c (selected lectotypes by me), Harvard Museum of Comparative Zoölogy, Cambridge, Mass.

#### CORDYLOBLASTUS CLAVATUS (Schultze)

Plate 20, figures 1-9; text-figs. 80-81

*Pentremites clavatus* SCHULTZE, 1866, 1867, p. 225, pl. 13, fig. 7.

*Description.*—Calyx calcitic, club-shaped in side view, pentagonal in top view, 15 mm. long by 9 mm. wide, with vault 8 mm. long, pelvis 7 mm. long, pelvic angle on basals 40 degrees and on radial bodies 115 degrees, with periphery at radial lips slightly below mid-height. Stem impression round, crenellar, not well preserved. Basal cirlet conical and elongate in side view, round in

basal view, flattened triangular at contact with stem, 5.5 mm. long by 4.5 mm. wide, with three normally disposed basals that each has a prominent medium ridge near the aboral end. Radials five, each elongate hexagonal, 10 mm. long by 4.5 mm. wide, with long, narrow, shallow sinus 8 mm. long by 2 mm. wide; radials overlapping deltoids.

Deltoids four, short, not visible in side view, with one spiracle in each adoral tip and four V-shaped deltoid lips adjacent to oral opening. On anal side the anispiracle is visible between the superdeltoid and hypodeltoid. Hypodeltoid visible in side view.

Ambulacra five, linear, each 9 mm. long by 2 mm. wide, with lancet covered by side plates except near adoral end. Side plates normally disposed, with 24 side plates in 10 mm., and one pore between adjacent plates along radial margins. The surfaces of the calyx plates are ornamented with fine growth striae parallel to plate margins.

*Occurrence.*—Devonian, Calizas de Arnao, León, Spain (described specimen), and Devonian near Kerpen, Nollenbach, Germany (syntypes).

*Types.*—Syntypes, 539, nine specimens, Schultze collection, old number 2346, Harvard Museum of Comparative Zoölogy, Cambridge, Mass. Plesiotype, 19,090, one specimen (described), Gurley collection, Walker Museum, University of Chicago, Chicago, Illinois. Plesiotype, S3,613, two specimens, Springer collection, from area near Sabero, Spain, U. S. National Museum, Washington.

#### CORDYLOBLASTUS EIFELENIS (Roemer)

Plate 21, figures 1-10; text-figs. 82-89

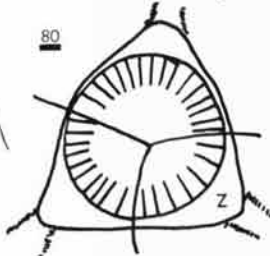
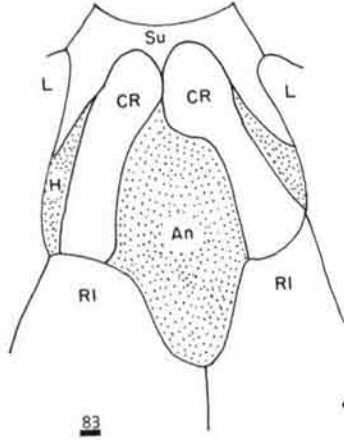
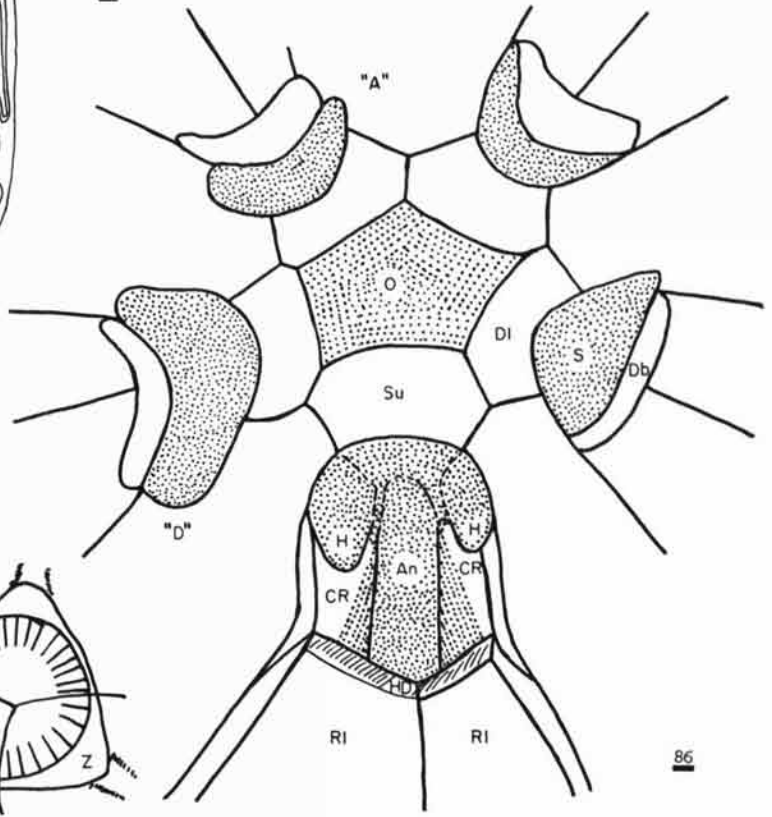
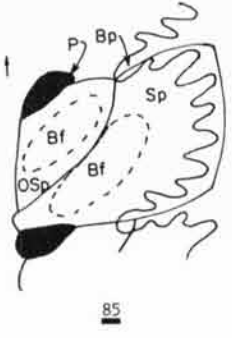
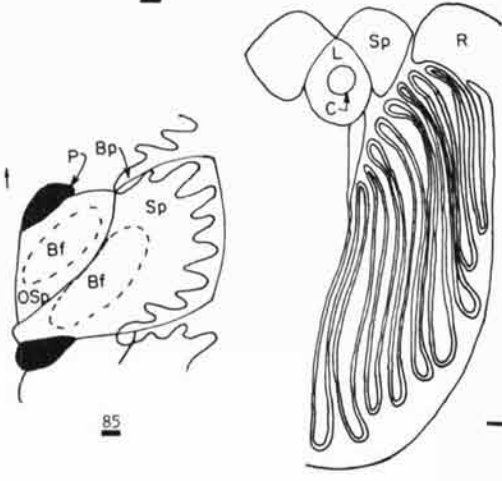
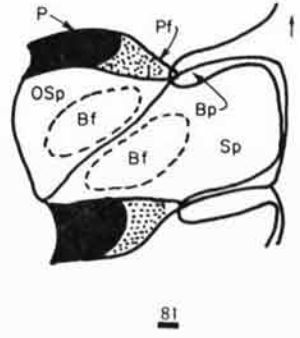
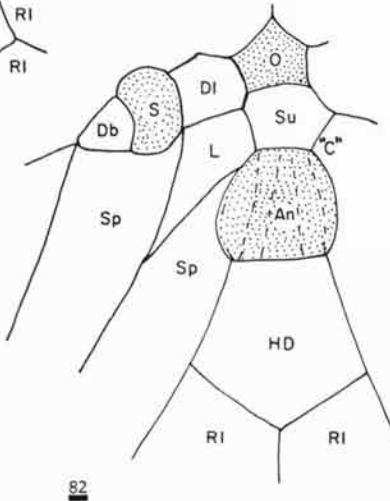
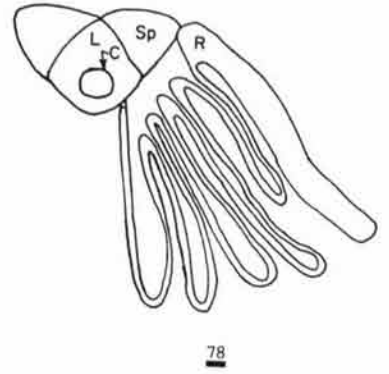
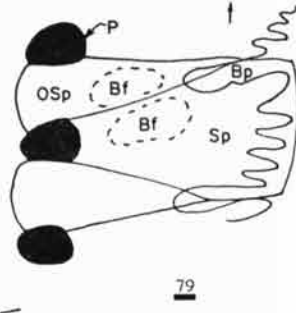
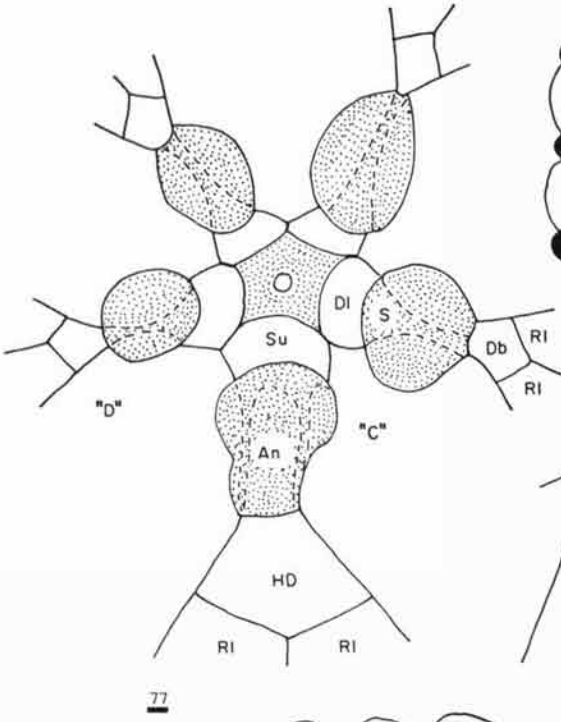
*Pentatrematites eifelenis* ROEMER, 1852-54, p. 280.

*Description.*—The description is based mainly on observed characters of one specimen (no. 213) in the Schultze collection. Calyx calcitic, club-shaped in side view, pentalobate in top view, 18.5 mm. long by 13.5 mm. wide, vault 4.5 mm. long, pelvis 14 mm. long, pelvic angle on basals 35 degrees and on radial bodies 70 degrees, with periphery at radial lips well above mid-height. Stem

#### FIGURES 77-86. Species of *Cordyloblastus* FAY, n. gen., Devonian, Europe.

77-79. *C. acutangulus* (SCHULTZE), Eifelian, Pelm, Germany (Harvard Mus. Comp. Zoölogy, no. 325); 77, summit area of calyx and part of "CD" (anal) interambulacrum,  $\times 15$ ; 78, partial cross section of "D" ambulacrum,  $\times 15$ ; 79, part of "C" ambulacrum, showing main and outer side plates,  $\times 15$ .—80, 81. *C. clavatus* (SCHULTZE) Middle Devonian, Nollenbach, Germany (Univ. Chicago, no. 19,090); 80, stem impression at base of calyx,  $\times 15$ ; 81, part of "B" ambulacrum, showing main and outer side plates,  $\times 45$ .—82-86. *C. eifelenis* (ROEMER), Eifelian, Nollenbach, Germany (Harvard Mus. Comp. Zoölogy, nos. 213, 305; Buffalo Soc. Nat. Sci. no. E21,087); 82, anal area (no. 213),  $\times 15$ ; 83, anal area,

drawn from polished tangential section, hypodeltoid lacking (no. 305),  $\times 15$ ; 84, partial cross section of "A" ambulacrum (no. 213),  $\times 15$ ; 85, part of "C" ambulacrum, showing main and outer side plates (no. 213),  $\times 45$ ; 86, summit area and part of "CD" (anal) interambulacrum (no. E21,087),  $\times 45$ . [Explanation.—"A," amb.; An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); CR, cryptodeltoid; "D," amb.; Db, deltoid body; Dl, deltoid lip; H, hydrosipre; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; Rl, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]



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broken. Basal cirlet conical in side view, rounded pentagonal in basal view, 9 mm. long by 7 mm. wide. Radials five, wide, subquadrangular, each 10 mm. long by 6 mm. wide, with short, narrow, shallow sinus 6 mm. long by 1.5 mm. wide, with outward-flaring radial lips, giving a pentalobate appearance to the calyx in top view. The radial limbs are shorter on the anal side than on the other sides. Radials overlap deltoids.

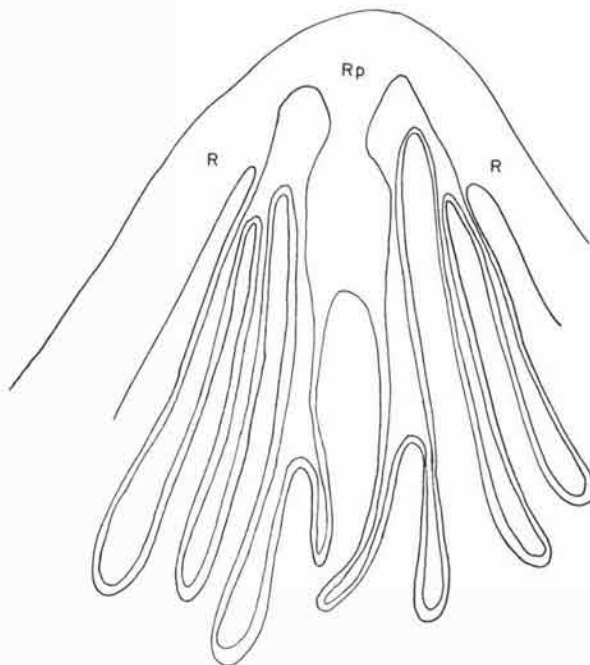
Deltoids four, not visible in side view, each divided into a small quadrangular deltoid body 0.5 mm. long by 0.5 mm. wide and a lip that is approximately 0.5 mm. wide, with a large, wide oval spiracle between, each spiracle bordered laterally by a lancet stipe and side plates. On the anal side there are four deltoid plates, two of which (superdeltoid and hypodeltoid) are seen externally, the two cryptodeltoids being hidden beneath the hypodeltoid. The superdeltoid is adjacent to the oral opening and bordered aborally on each side by a lancet stipe. The wide oval spiracle is located between the superdeltoid and pentagonal hypodeltoid, the latter plate being 1.5 mm. long by 1.5 mm. wide and barely visible in side view. Internally, the two cryptodeltoids rest on the aboral face of the superdeltoid, separating the anal spiracles from the anal opening internally and they are overlapped by the radial limbs and hypodeltoid. Thus, there are five openings around the oral opening, the four spiracles and anispiracle.

Ambulacra five, linear, each 8 mm. long by 1.5 mm. wide, with lancet covered by side plates except along the main food groove at the adoral end. There are 22 side plates in a space of 10 mm. along an ambulacrum, one pore between adjacent side plates along radial margins, and pores absent along deltoid margins. In mature specimens there are nine hydrosphere folds on each side of an ambulacrum, including the anal side. The surfaces of the calyx plates are ornamented with fine growth striae parallel to plate margins. One abnormal specimen has a sixth short radial developed on the summit between the (D) and (E) radials.

There is much variation in this species and more work needs to be done on the small specimens. In one small specimen there appeared to be only four hydrosphere folds on each side of an ambulacrum.

*Occurrence.*—Middle Devonian, Eifelian, Prüm, Gerolstein, Nollenbach, Germany.

*Types.*—Topotypes, 213, one specimen, Schultze collection, old no. 25, Eifel; 305, six specimens, old no. 2348, Nollenbach bei Kerpen, Schultze collection. Plesiotype, 195, one specimen, old no. 26, Eifel, Schultze collection, Harvard Museum of Comparative Zoology, Cambridge, Mass. Plesiotypes, E21,087, two specimens, Eifel and E21,109, two specimens, Gerolstein, Prussia, Buffalo Society of Natural Sciences, Buffalo, New York. Others not studied in detail or figured are in the Walker Museum,



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FIGURE 87. *Cordyloblastus eifelensis* (ROEMER), Eifelian, Nollenbach, Germany (Buffalo Soc. Nat. Sci., no. E21,109); partial cross section of "E" ambulacrum,  $\times 45$ . [Explanation.—R, radial; Rp, radial lip.]

University of Chicago, and in the United States National Museum.

### CORDYLOBLASTUS GILBERTSONI

(Etheridge & Carpenter)

Plate 23, figures 1-3

*Pentremitea gilbertsoni* ETHERIDGE & CARPENTER, 1886, pp. 24, 179, pl. 5, figs. 9-11.

*Pentremites clavatus* SCHULTZE, 1866, 1867, p. 225, pl. 13, fig. 7c only.

*Description.*—Calyx calcitic, 8.5 mm. long by 7.5 mm. wide, vault 6 mm. long, pelvis 1.5 mm. long, pelvic angle on basals 50 degrees, and on radial bodies 170 degrees, with ambulacra slightly recurved below, and periphery above radial lips.

*Remarks.*—The figured specimen appears to be the same one as figured by SCHULTZE on pl. 13, fig. 7c and is here removed from *Cordyloblastus clavatus*.

*Occurrence.*—Middle Devonian, Eifel beds, Pelm, Germany.

*Types.*—Plesiotypes, 313, three specimens, Schultze collection, the figured specimen probably being one of SCHULTZE's syntypes of *Pentremites clavatus*, old no. 2347, Harvard Museum of Comparative Zoology, Cambridge, Mass.

**CORDYLOBLASTUS LUSITANICUS**  
(Etheridge & Carpenter)

Plate 22, figures 4-9; text-figs. 90-93

*Pentremiteida lusitanica* ETHERIDGE & CARPENTER, 1882, p. 223.

*Description*.—Calyx calcitic, 6.5 mm. long by 4.5 mm. wide, vault 2 mm. long, pelvis 4.5 mm. long, pelvic angle on basal circlet 15 degrees and on radial bodies 60 degrees, calyx obconical in side view. Otherwise similar to *Cordyloblastus eifelensis*.

*Occurrence*.—Devonian, Calizas de Arnao, León, Spain; Eifel beds, Gerolstein, Germany.

*Types*.—Plesiotypes, 19,091, two specimens (one described), Germany, Gurley collection, Walker Museum, University of Chicago; S3,616, 32 specimens in a glass vial and 59 specimens of Hambach collection in another glass vial, Germany, Springer collection; S3,619, one specimen,

Spain, Springer collection, U. S. National Museum, Washington.

**CORDYLOBLASTUS ROEMERI**  
(Etheridge & Carpenter)

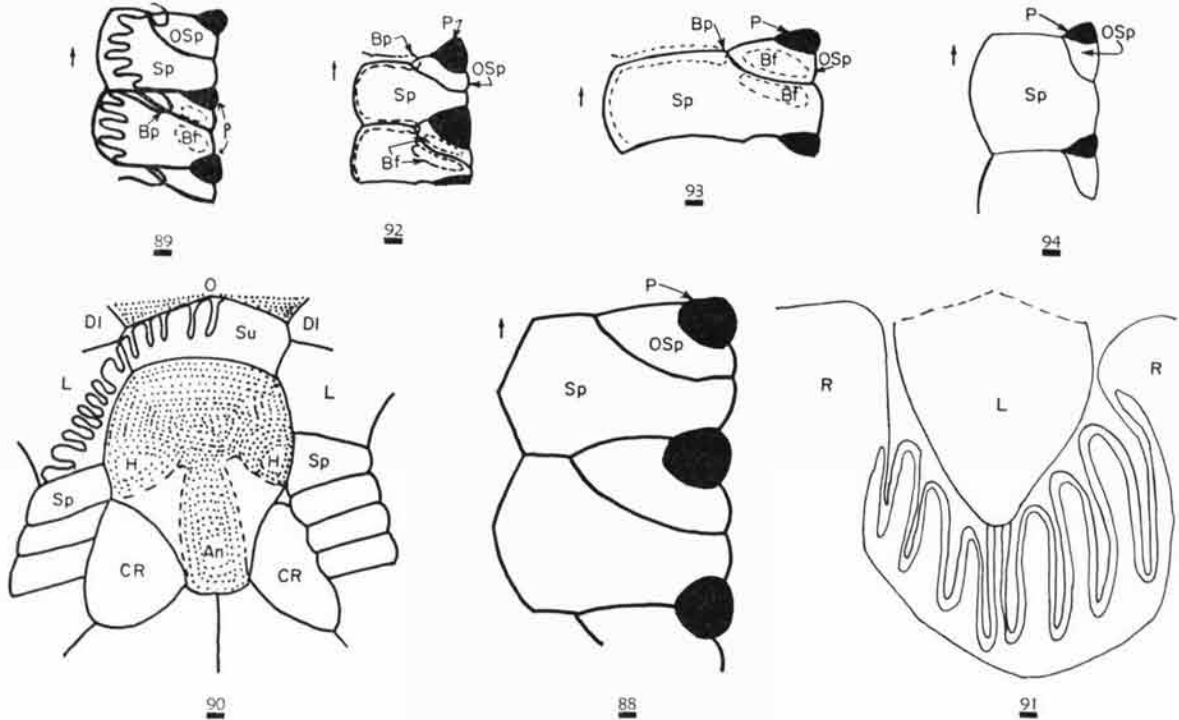
Plate 22, figures 1-3; text-fig. 94

*Pentremiteida roemeri* ETHERIDGE & CARPENTER, 1886, pp. 104, 171, 175, pl. 5, fig. 15; pl. 16, fig. 11.

*Description*.—The specimen here figured is 9 mm. long by 7 mm. wide, and may be distinguished from examples of other species by shape of the calyx in side view. The rounded summit, together with the almost equal length of the vault and pelvis, and wide calyx serve to distinguish this species.

*Occurrence*.—Devonian, Calizas de Arnao, León, Spain.

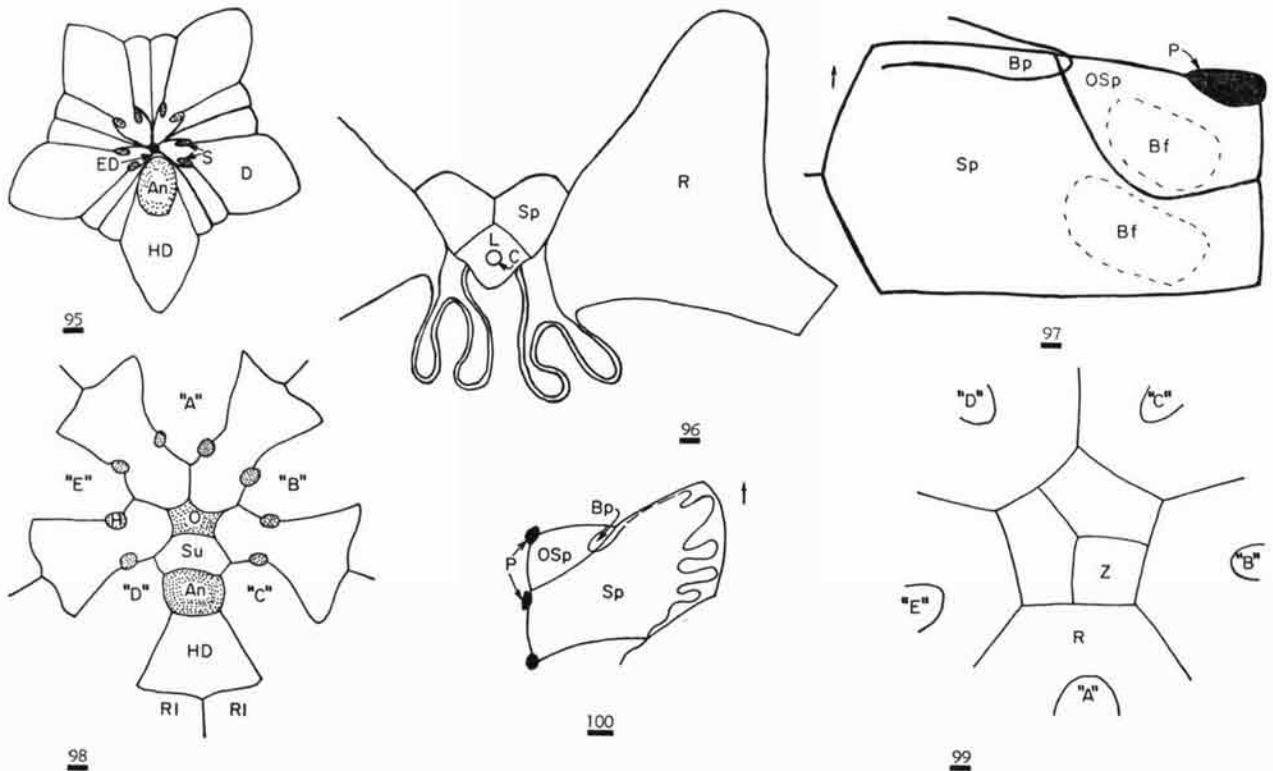
*Type*.—Plesiotype, S3,615, one specimen and one cast, Springer collection, U. S. National Museum, Washington.



FIGURES 88-94 Species of *Cordyloblastus* FAY, n. gen., Devonian, Europe.

88-89. *C. eifelensis* (ROEMER), Eifelian, Nollenbach, Germany (Buffalo Soc. Nat. Sci., no. 21,087); 88, part of "A" ambulacrum, showing main and outer side plates,  $\times 90$ ; 89, part of "C" ambulacrum, showing side plates,  $\times 45$ .—90-93. *C. lusitanicus* (ETHERIDGE & CARPENTER), Calizas de Arnao, León, Spain (U.S. Natl. Mus., no. S3,616, S3,619; Univ. Chicago, no. 19,091); 90, anal area (no. S3,616),  $\times 37.5$ ; 91, cross section of "B" ambulacrum (no. 19,091),  $\times 45$ ; 92, part of "D" ambulacrum,

showing side plates (no. S3,616),  $\times 37.5$ ; 93, part of another ambulacrum (no. S3,619),  $\times 37.5$ .—94. *C. roemeri* (ETHERIDGE & CARPENTER), Calizas de Arnao, León, Spain (U.S. Natl. Mus., no. S3,615); part of ambulacrum, showing side plates,  $\times 37.5$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; CR, cryptodeltoid; DI, deltoid lip; H, hydrosipire; L, lancet; O, oral opening; OSp, outer side plate; P, pore; R, radial; Sp, main side plate; Su, superdeltoid.]



FIGURES 95-100. Species of *Cribroblastus* HAMBACH and *Cryptoblastus* ETHERIDGE & CARPENTER.

95-97. *Cribroblastus cornutus* (MEEK & WORTHEN), Upper Mississippian, St. Louis Limestone, Illinois (Univ. Illinois, no. X-361) and ?Warsaw Limestone, Fenton, Mo. (U.S. Natl. Mus., no. S3,771); 95, summit area (no. S3,771),  $\times 7.5$ ; 96, cross section of ambulacrum (no. S3,771),  $\times 15$ ; 97, part of ambulacrum, showing main and outer side plates (no. X-361),  $\times 90$ .—98-100. *Cryptoblastus melo* (OWEN & SHUMARD), Lower Mississippian, Burlington Limestone, Burlington, Iowa (U.S. Natl. Mus., no. S3,766, S4,959); 98, summit area (no.

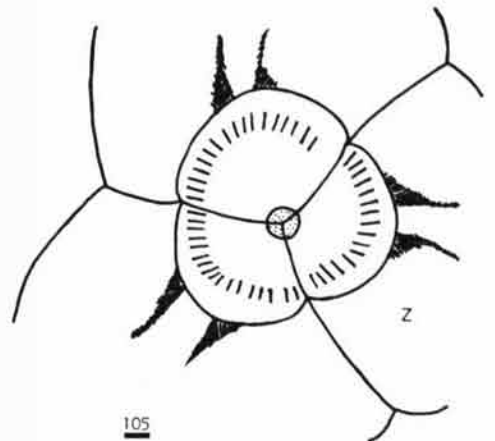
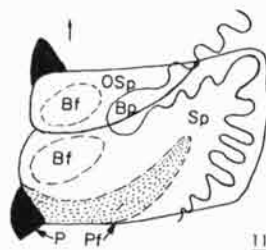
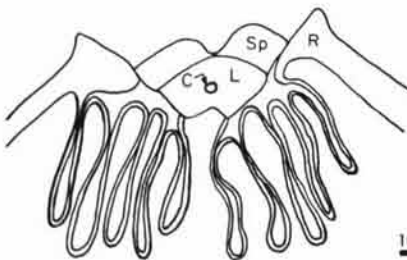
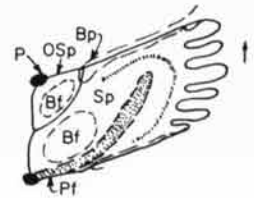
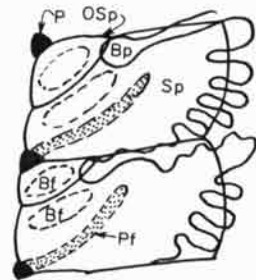
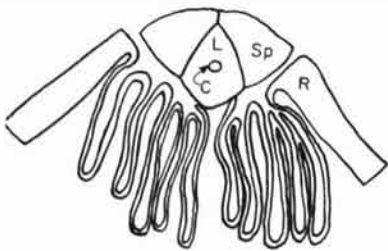
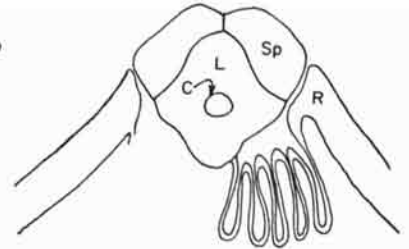
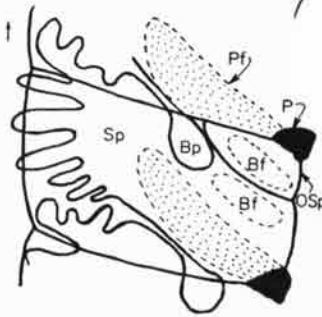
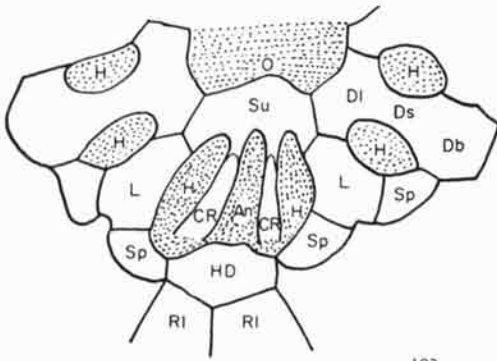
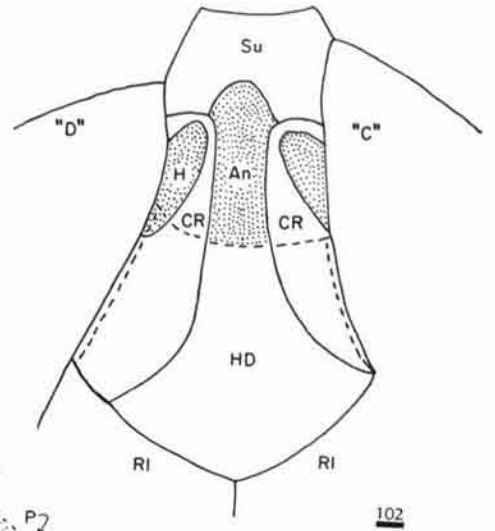
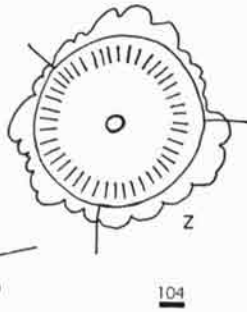
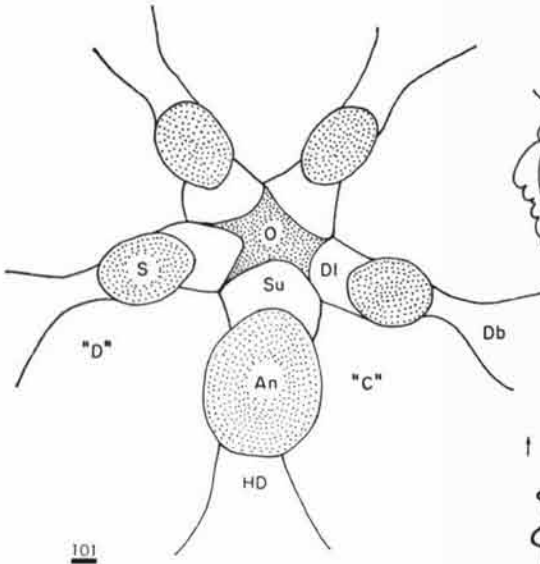
S4,959),  $\times 7.5$ ; 99, basal area (no. S4,959),  $\times 7.5$ ; 100, part of "D" ambulacrum, showing main and outer side plates (no. S3,766),  $\times 37.5$ . [Explanation.—"A," amb.; An, anal opening; "B," amb.; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); "D," amb.; D, deltoid; "E," amb.; ED, epideltoid; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; R, radial; RI, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]

FIGURES 101-112. *Devonoblastus whiteavesi* REIMANN, Middle Devonian, Hungry Hollow Formation, Thedford and Arkona, Ontario (Univ. Michigan, nos. 34,467, and 35,036; Buffalo Soc. Nat. Sci., no. E13,065; Geol. Survey Canada, no. 3,661; U.S. Natl. Mus., no. S4,648), and Tichenor Limestone, New York (U.S. Natl. Mus., No. 142,025).

101. Summit area (no. 35,036),  $\times 15$ .—102. Anal area, drawn from polished tangential section (no. 34,467),  $\times 15$ .—103. Anal area, drawn from deep polished tangential section (no. E13,065),  $\times 15$ .—104. Proximal columnal, aboral view (no. 35,036),  $\times 15$ .—105. Stem impression (no. 3,661),  $\times 15$ .—106. Partial cross section of "E" ambulacrum (no. 34,467),  $\times 15$ .—107. Cross section of "E" ambulacrum (no. E13,065), aboral view,  $\times 15$ .—108. Cross section of "E" ambulacrum (no. S4,648), oral view,  $\times 15$ .—109. Part of "C" ambulacrum, showing side plates (no. 3,661),  $\times 40$ .—

110. Part of "E" ambulacrum, showing side plates (no. E13,065),  $\times 40$ .—111. Part of "A" ambulacrum, showing side plates (no. 35,036),  $\times 45$ .—112. Part of ambulacrum (no. 142,025),  $\times 30$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); CR, cryptodeltoid; "D," amb.; Db, deltoid body; Dl, deltoid lip; Ds, deltoid septum; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; RI, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]





**Genus CRIBROBLASTUS Hambach, 1903**

*Type-species*, by subsequent designation (Bassler, 1938).—*Pentremites cornutus* MEEK & WORTHEN, 1861.

*Generic diagnosis*.—Spiraculate blastoids with eight spiracles in addition to anispiracle, which is located between epideltoid and hypodeltoid, two hydrospire folds on each side of an ambulacrum, lancet covered by side plates with single pore between side plates along radial and deltoid margins, hydrospire plate present, radials overlapping deltoids, deltoids with high coronal processes; calyx ellipsoidal in side view. *Mississippian*, Illinois, Missouri.

*Remarks*.—The genus *Cribrblastus* may have been derived from a form similar to *Carpenteroblastus* in which the deltoids developed coronal processes, the pores remained simple, and the base became concave.

**CRIBROBLASTUS CORNUTUS (Meek & Worthen)**

Plate 46, figures 6-11; text-figs. 95-97

*Pentremites cornutus* MEEK & WORTHEN, 1861, p. 141.

*Granatocrinus cornutus* (MEEK & WORTHEN), 1866, p. 276, pl. 20, fig. 1.

*Description*.—Calyx calcitic, subspherical, with concave base, rounded summit, 13 mm. long by 12 mm. wide, periphery near mid-height, and adoral ends of deltoids extended into high coronal processes. Stem not visible. Basal circlet small, hidden in basal concavity, 2 mm. wide. Radials five, each elongate hexagonal, 10 mm. long by 7 mm. wide, strongly recurved below in basal concavity, with broad shallow sinus 10 mm. long by 3 mm. wide, limbs flared into broad raised ridges; radials overlapping deltoids.

Deltoids four, arrow-shaped, each 5 mm. long by 3 mm. wide by 3 mm. high, the adoral tips of each extended ventrally into a high hornlike coronal process. Two spiracles are found on the adoral end of each deltoid, separated by a wide medium septum at the marginal base. On the anal side the large oval anispiracle is located between a small adoral epideltoid and a large pentagonal aboral hypodeltoid. Two hydrospire folds occur on each side of an ambulacrum, with a hydrospire plate, but only a single pore between side plates along the

radial margins. Pores are present along the deltoid margins.

Ambulacra five, linear, each 13 mm. long by 1-1.25 mm. wide, lancet covered by side plates, and 30 side plates in space of 10 mm. length along an ambulacrum. Side plates and pores normally disposed, with one large pore between adjacent side plates along radial and deltoid margins of ambulacra. The surfaces of the calyx plates are worn smooth.

*Occurrence*.—Upper Mississippian, St. Louis Limestone, Brown County, Illinois (holotype); ?Warsaw Limestone, Fenton, Missouri (plesiotypes).

*Types*.—Holotype, X-361, specimen in rock, Illinois State Museum, old no. 10,058, Department of Geology, University of Illinois, Urbana. The above description is primarily based on this specimen. Plesiotypes, S3,771, 13 specimens in three slabs of rock (one slab cut and polished), Springer collection, U. S. National Museum, Washington.

**Genus CRYPTOBLASTUS Etheridge & Carpenter, 1886**

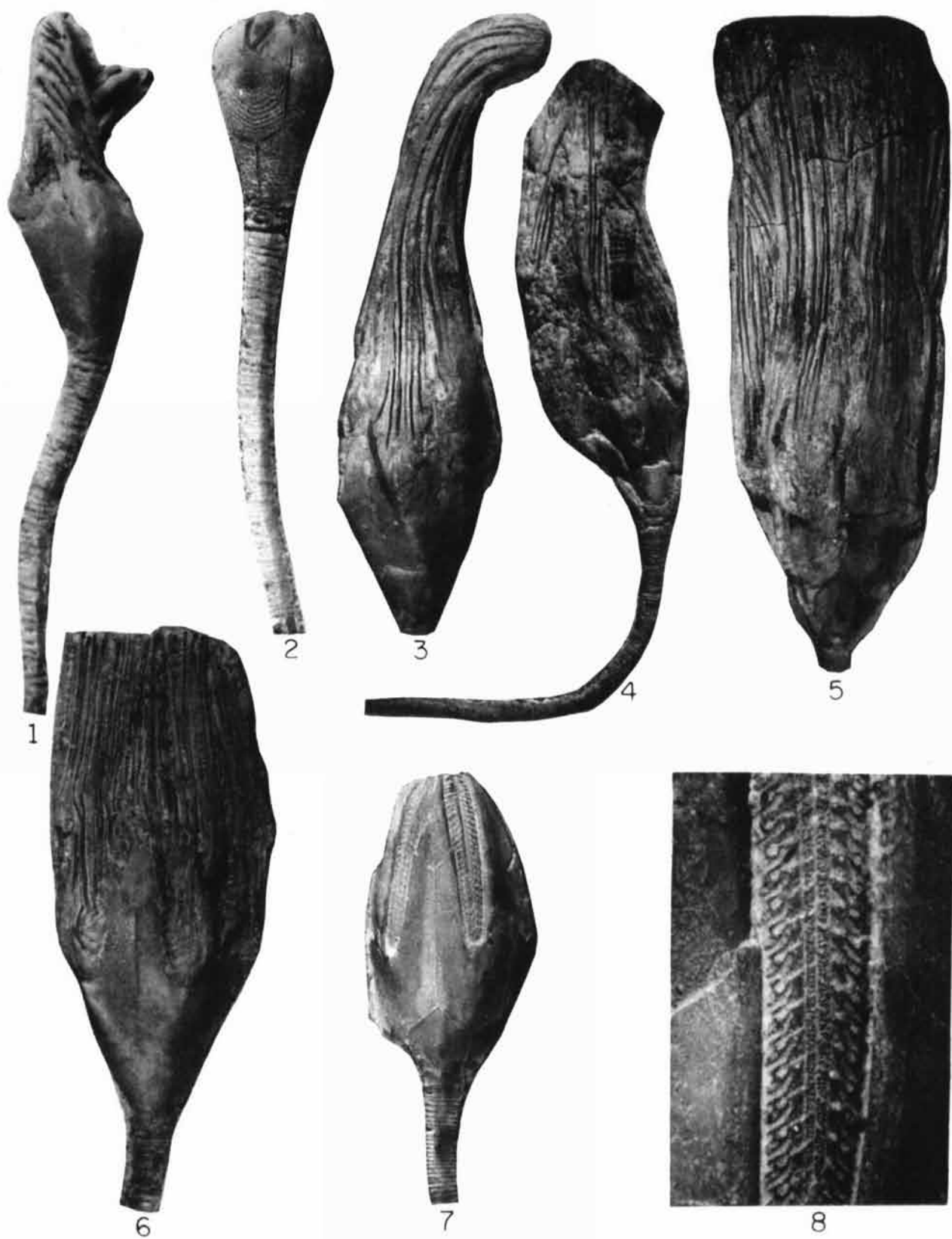
*Type-species*, by original designation.—*Pentremites melo* OWEN & SHUMARD, 1850.

*Generic diagnosis*.—Spiraculate blastoids with eight spiracles in addition to anispiracle, located between epideltoid? and hypodeltoid, possibly with two deep cryptodeltoids, lancet exposed along middle one-third of its width except near aboral end, two hydrospire folds on each side of an ambulacrum, hydrospire plate present, pores absent along deltoid margins, radials overlapping deltoids except at extreme adoral tip of the radial limbs where deltoids project slightly over the radials, base slightly concave; calyx ellipsoidal in shape, with depressed interrarial sutures. *Mississippian*, Iowa, Missouri.

*Remarks*.—The genus *Cryptoblastus* was probably derived from *Tanaoblastus* by slight overlap of deltoids on adoral tips of radial limbs, the interrarial sutures having been depressed, and the base becoming concave.

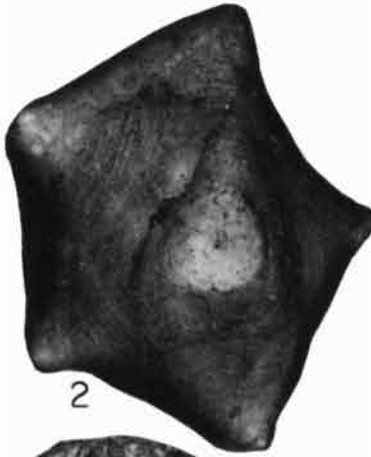
**EXPLANATION OF PLATE 15**

FIGURE	PAGE	
1-2. <i>Orophocrinus conicus</i> WACHSMUTH & SPRINGER, metatypes, S3,226, Springer Coll., U.S. Natl. Mus.; Lower Mississippian, Kinderhook Group, Le Grand, Marshall County, Iowa; 1, side view ( $\times 3$ ); 2, side view of another specimen ( $\times 2.6$ )	37	metatypes, S3,226 (fig. 3), S3,227 (figs. 4-8), Springer coll., U.S. Natl. Mus.; Lower Mississippian Kinderhook Group, Le Grand, Marshall County, Iowa; 3, side view of specimen ( $\times 3.6$ ); 4, side view of another specimen ( $\times 2.2$ ); 5, side view of another specimen ( $\times 2.5$ ); 6, side view of another specimen ( $\times 3$ ); 7, side view of another specimen ( $\times 2.5$ ); 8, detail view of an ambulacrum of specimen shown in fig. 7 ( $\times 14.6$ )
3-8. <i>Orophocrinus fusiiformis</i> (WACHSMUTH & SPRINGER),		37

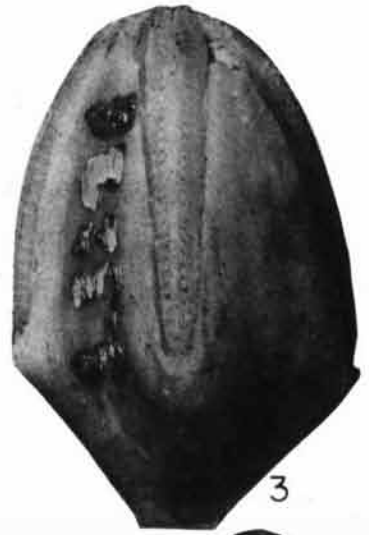




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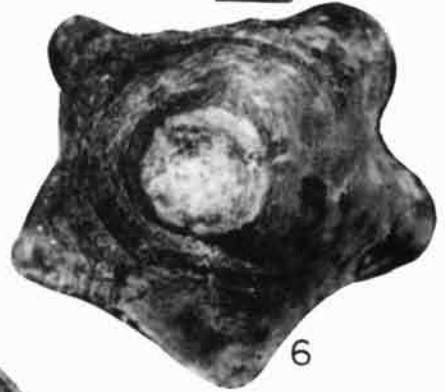
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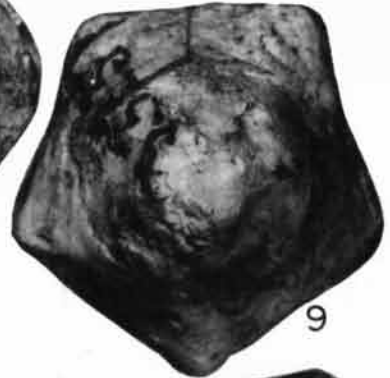
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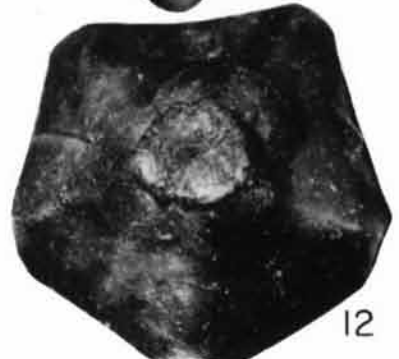
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## CRYPTOBLASTUS MELO (Owen &amp; Shumard)

Plate 38, figures 6-9; text-figs. 98-100

*Pentremites melo* OWEN & SHUMARD, 1850, p. 65, pl. 7, figs. 14a-c.

*Description.*—Calyx calcitic, subspherical, 13 mm. long by 11 mm. wide, with truncated summit and depressed base. Stem round, 1 mm. in diameter, with approximately 40 crenellae extending almost one-half the radial distance in from the circumference. Basal circlet pentagonal, 3 mm. wide, depressed in basal concavity, with three normally disposed basals. Radials five, elongate, recurved below, each 12 mm. long by 5.5 mm. wide, with narrow sinus and depressed interrarial sutures; radials overlapping deltoids except at the adoral tip of radial limbs where in reverse manner aboral ends of the deltoid bodies slightly overlap the radial limbs, giving the appearance that the radial limbs are wedged in the deltoid bodies.

Deltoids four, arrow-shaped, each 1.5 mm. long by 1.5 mm. wide, with two spiracles notched in the adoral tip of each on the ambulacral margins, and without pores along margins of the ambulacra. On the anal side a large oval anispiracle occurs between an epideltoid and hypodeltoid, but internally, in a specimen seen in the Philadelphia Academy of Sciences collection, there probably are two hidden cryptodeltoids beneath the hypodeltoid. If this is true, the plate adjacent to the oral opening on the adoral side of the anal opening should probably be called the superdeltoid, instead of epideltoid.

Ambulacra five, linear, each 15 mm. long by 1.25 mm. wide, recurved below, lancet exposed along the middle one-third of its width except at the aboral end. The side plates are normally disposed with 30 side plates in a space of 10 mm. length along an ambulacrum. Four cover-plate sockets to each side plate are seen along the main food groove and three side cover-plate sockets to each side plate along side food grooves. Two hydrospire folds occur on each side of an ambulacrum, with a hydrospire plate on each side, and more pores than side plates (approximately two to each side plate) along the radial margins. The surfaces of the calyx plates are ornamented with fine granules aligned parallel to plate margins.

The above description is based on the newly selected holotype.

*Remarks.*—The original holotype was destroyed in a fire at Indiana University in 1883, where the Owen collection was housed. The neotype, or new holotype, here selected, is that figured by ETHERIDGE & CARPENTER, 1886, pl. 7, fig. 14.

*Occurrence.*—Lower Mississippian, lower part of Burlington Limestone, Burlington, Iowa (neotype).

*Type.*—Neotype (new holotype), S4,959, one specimen, old number S3,766, Springer collection, U. S. National Museum, Washington. This is also the type-species of *Cryptoblastus*.

## CRYPTOBLASTUS SHUMARDI (Meek &amp; Worthen)

Plate 38, figure 4

*Granatocrinus shumardi* MEEK & WORTHEN, 1866, p. 257.

*Description.*—The specimen is 36 mm. long by 17 mm. wide and is here illustrated to show the shape of the specimen with brachioles attached.

*Occurrence.*—Lower Mississippian, lower part of Burlington Limestone, Burlington, Iowa.

*Types.*—Topotypes, S3,765, 10 specimens, Springer collection, U. S. National Museum, Washington.

## Genus DEVONBLASTUS Reimann, 1935

*Type-species*, by subsequent designation (Reimann, 1942).—*Pentremites leda* HALL, 1862.

*Generic diagnosis.*—Spiraculate blastoids with five spiracles, or four spiracles in addition to an anispiracle, with anispiracle between a superdeltoid and hyperdeltoid and with two hidden cryptodeltoids, approximately five hydrospire folds on each side of an ambulacrum, lancet covered by side plates except at adoral end, with one pore between side plates along radial and part of deltoid margins; deltoids visible in side view, overlapped by radials; calyx form elliptical, with conical pelvis. *Devonian*, New York, Ontario, ?Indiana.

*Remarks.*—The genus *Devonblastus* was probably derived from *Hyperblastus* by complete closure of the radial sinus, downward migration of the deltoid plates, and partial outward migration of the adoral end of the lancet plates.

## EXPLANATION OF PLATE 16

FIGURE	PAGE		
1-3. <i>Orophocrinus gracilis</i> (MEEK & WORTHEN), topotypes, S3,228, Springer coll., U.S. Natl. Mus.; Lower Mississippian, Lower Burlington Limestone, Burlington, Iowa; 1, oral view of specimen ( $\times 4.4$ ); 2, 3, aboral and "D" ambulacral views of another specimen ( $\times 3.6$ )	37	5, "B" ambulacral view, ( $\times 2.8$ ); 6, aboral view, ( $\times 3.7$ )	37
4-6. <i>Orophocrinus orbignyanus</i> (DE KONINCK), topotype, S3,229, Springer coll., U.S. Natl. Mus.; Lower Carboniferous limestone, Tournai, Belgium; 4, oral view, ( $\times 3.5$ );		7-9. <i>Orophocrinus verus</i> (CUMBERLAND), plesiotype, S3,237, Springer coll., U.S. Natl. Mus.; Lower Carboniferous limestone, Lancashire, England; oral, "D" ambulacral, aboral views (all $\times 3.5$ )	39
		10-12. <i>Orophocrinus puzos</i> (MÜNSTER), topotype, S3,230, Springer coll., U.S. Natl. Mus.; Lower Carboniferous limestone, Tournai, Belgium; oral, "D" ambulacral, aboral views (all $\times 6.6$ )	38

## DEVONBLASTUS LEDA (Hall)

Plate 24, figures 1-2, 6

*Pentremites leda* HALL, 1862, p. 149, pl. 1, fig. 11.*Devonblastus leda* REIMANN, 1935, p. 31.

*Description.*—A detailed description of the syntypes has been submitted for publication in another work. The syntypes are not well preserved and most of the generic information is taken from the description of specimens of *Devonblastus whiteavesi*. The syntypes are figured on Plate 24. This species differs from *D. whiteavesi* in that the maximum width (or periphery) of *D. leda* is low, at or near the radial lips, in contrast to its higher, more median position in *D. whiteavesi*.

*Occurrence.*—Devonian, Hamilton Shale, western New York.

*Types.*—Syntypes, 451 (figures 1, 6), and 452 (figure 2), two specimens, Hall collection, New York State Museum, Albany, New York.

## DEVONBLASTUS WHITEAVESI Reimann

Plate 24, figures 3-5; plate 25, figures 1-12; text-figs. 101-112

*Devonblastus whiteavesi* REIMANN, 1935, p. 32, pl. 1, fig. 8.*Granatocrinus leda* WHITEAVES, 1889, p. 108, pl. 14, fig. 14.

*Description.*—The description is mainly on specimen 35,036, supplemented by information from other specimens. The calyx is calcitic, oval in side view, with short conical pelvis, 16 mm. long by 10.5 mm. wide, pentagonal in top view, with periphery near mid-height, and vault 14 mm. long, pelvis 2 mm. long, pelvic angle on basals 85 degrees and on radial bodies 130 degrees. The stem is round, crenellar, 1.5 mm. in diameter, with approximately 45 crenellae extending inward radially from the margin one-third of the distance to the small round lumen. The stem is attached to the basal cirlet, which has a hexagonal raised area at the aboral ends of the basal plates. Basal cirlet pentagonal in aboral view, widely conical in side view, 2 mm. long by 5 mm. wide, with strongly rounded medial ridge on each basal. Radials five, elongate hexagonal, each 14.5 mm. long by 5.5 mm. wide, with long, narrow, shallow sinus 13 mm. long by 2 mm. wide; radials overlapping deltoids. The surfaces of the radials and basals are ornamented by fine growth striae parallel to plate margins.

Deltoids four, lancet-shaped, each 3.5 mm. long by 2 mm. wide, visible in side view, with one large oval spiracle notched in the adoral end of each, separating the deltoid into two parts, the deltoid lip located adjacent to the oral opening and the deltoid body adjacent to the radial limbs. The surfaces of the deltoid bodies are ornamented by coarse growth ridges parallel to plate margins, especially parallel to the radiodeltoid sutures. On the anal side four anal deltoid plates seem to be present. The small pentagonal superdeltoid is adjacent to the oral opening and forms the external border on the adoral part of the

large oval anispiracle. Internally the two cryptodeltoids rest on the aboral face of the superdeltoid and separate the anal opening from the adjacent hydrosphere canals. The cryptodeltoids are infolded to form hydrospheres on the anal side, and are overlapped by the radial limbs. The cryptodeltoids are covered externally by the hypodeltoid plate and are not visible from the exterior. The pentagonal hypodeltoid is visible in side view and is homologous with the deltoid body of each of the other four deltoids. Five hydrosphere folds are seen on each side of an ambulacrum.

Ambulacra five, linear, slightly recurved below periphery, each 16 mm. long by 2 mm. wide, with lancet covered by side plates except at the adoral end, 24 side plates in a space of 10 mm. along an ambulacrum. The side plates are normally disposed, with four main cover-plate lobes to each side plate along the main food groove. A single large pore is observed between adjacent side plates along the radial ambulacral margins, and one or two pores occur along the deltoid ambulacral margins just above the radiodeltoid sutures. Each spiracle is bordered by a deltoid lip, two lancet stipes, two side plates, and a deltoid body.

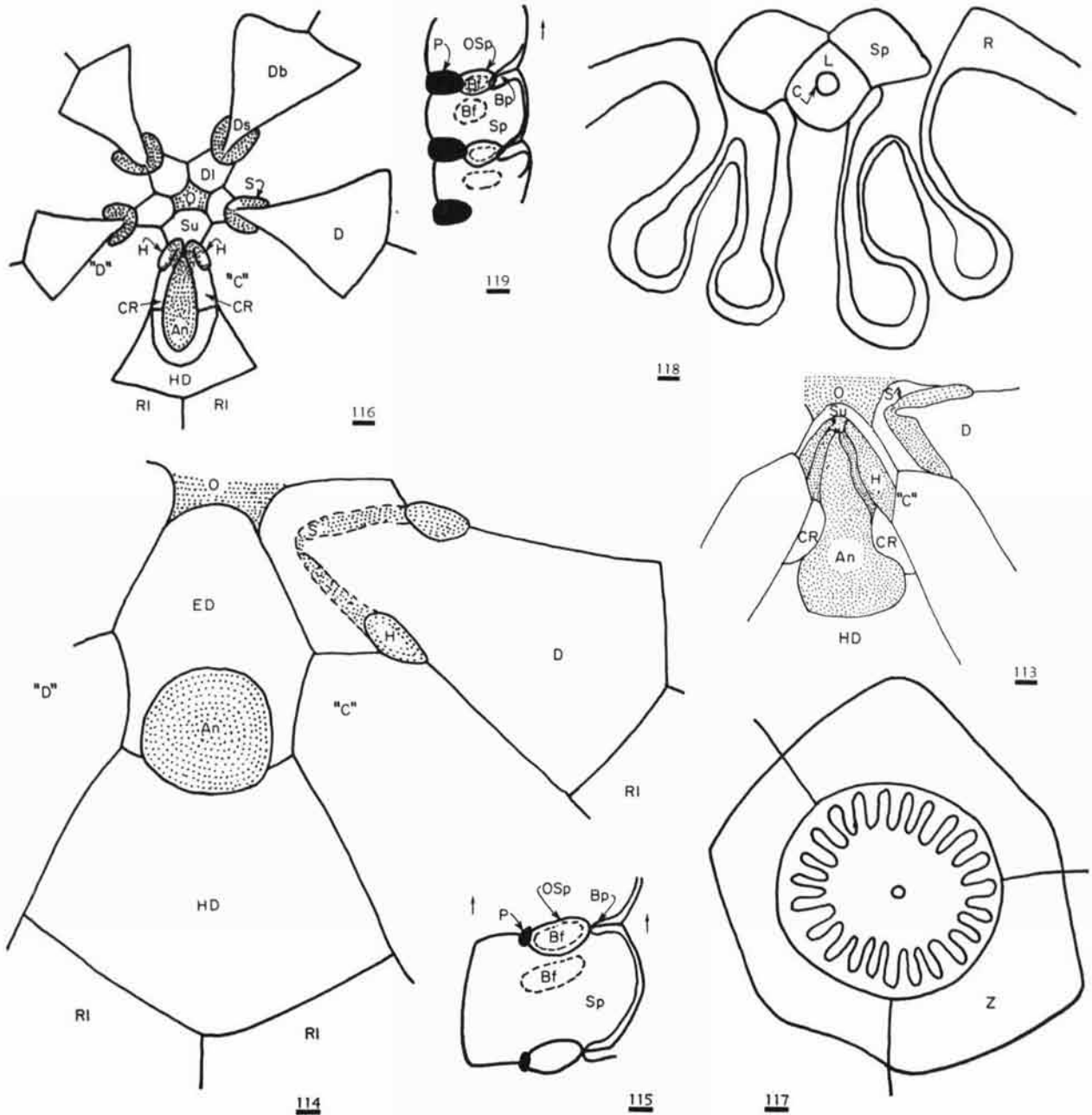
*Occurrence.*—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, Thedford and Arkona areas, Ontario. Shale layer of Tichenor Limestone, Cazenovia Creek, Springbrook, Erie County, New York.

*Types.*—Topotype, 35,036, one specimen, Charles Southworth collection, from Ausable River valley, 2.5 miles northeast of Arkona; University of Michigan, Ann Arbor. Plesiotype, 34,467, one specimen, from tile yard 0.5 mile north of Thedford, Ontario, Charles Southworth collection (June, 1954), University of Michigan. Plesiotypes, E13,065, three specimens, Charles Southworth collection (1941), from area near Thedford, Ontario, Buffalo Society of Natural Sciences, Buffalo, New York. Hypotype, 3,661, one specimen, from Thedford area, described by WHITEAVES (1889) as *Granatocrinus leda*, Geological Survey of Canada, Ottawa, Ontario, Canada. Plesiotypes, S4,648, two specimens, Springer collection, from Ausable River valley, 2 miles east of Arkona, Ontario, collected by Charles Southworth; S4,144, one specimen, Springer collection, from Marsh's Mill, Arkona, Ontario, lower Widder beds; and 142,025, one specimen, labelled *Devonblastus leda*, Tichenor Limestone, New York, all in U. S. National Museum, Washington.

## Genus DIPLOBLASTUS Fay, n. gen.

*Type-species*, by original designation (herein).—*Granatocrinus glaber* MEEK & WORTHEN, 1869.

*Generic diagnosis.*—Spiraculate blastoids with five paired spiracles, or four paired spiracles in addition to a paired anispiracle, with superdeltoid, two cryptodeltoids, and hypodeltoid on anal side; two hydrosphere folds on each side of an ambulacrum; lancet covered



FIGURES 113-119. *Diploblastus glaber* (MEEK & WORTHEN), Upper Mississippian, St. Louis Limestone, Illinois (Univ. Illinois, nos. X-363, E1,498), and Ste. Genevieve Limestone, Kentucky (Univ. Kentucky, no. 1,303).

113. Anal area (no. X-363),  $\times 15$ .—114. Anal area (no. E1,498),  $\times 45$ .—115. Part of "C" ambulacrum, showing side plates (no. E1,498),  $\times 90$ .—116. Summit area, (no. 1,303),  $\times 15$ .—117. Stem impression (no. 1,303),  $\times 45$ .—118. Cross section of "C" ambulacrum, aboral view (no. 1,303),  $\times 45$ .—119. Part of "C" ambulacrum, showing side plates (no. 1,303),  $\times 45$ .

[Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); CR, cryptodeltoid; "D," amb.; D, deltoid; Db, deltoid body; DI, deltoid lip; Ds, deltoid septum; ED, epideltoid; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; R, radial; RI, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]

by side plates at aboral end and gradually exposed to one-third of its width near the adoral end, with one pore between side plates along deltoid and radial margins; radials overlapping deltoids; calyx subglobular. *Mississippian*, Illinois, Missouri, Kentucky, Alabama.

*Remarks.*—The genus *Diploblastus* was probably derived from a form similar to *Schizotremites* in which the lancet plates extended downward and the form became subglobular. There should be more intermediate forms.

#### DIPLOBLASTUS GLABER (Meek & Worthen)

Plate 48, figures 1-12; plate 49, figures 1-9; text-figs. 113-119

*Granatocrinus glaber* MEEK & WORTHEN, 1869, p. 91.

*Granatocrinus glaber* MEEK & WORTHEN, 1873, p. 537, pl. 20, fig. 11.

*Description.*—Observations here recorded are based mainly on one of the original syntypes. Calyx calcitic, worn, flattened spheroidal in side view, rounded pentagonal in top view, 5 mm. long by 6 mm. wide, with periphery at mid-height. The stem is round, crenellar, attached to a raised hexagonal base in the middle of the basal circllet, with small round central lumen. Basal circllet pentagonal in basal view, flat, 2.75 mm. in diameter, with three normally disposed basals. In one specimen from Kentucky the azygous basal is in the "DE" instead of "AB" position, but this specimen may belong to another species. Radials five, pentagonal in side view, recurved below, each 4.5 mm. long by 3.25 mm. wide, with long, narrow, shallow sinus 4.5 mm. long by 1 mm. wide. Radials overlap deltoids.

Deltoids four, short, each 2 mm. long by 2 mm. wide, broadly lanceolate, each with a paired spiracle at the adoral tip. Four deltoid plates are present on the anal side—a superdeltoid, two cryptodeltoids, and a hypodeltoid. The V-shaped superdeltoid is adjacent to the oral opening and has two deltoid septa that are continuous in position with the cryptodeltoids. The adoral end of the paired anispiracle is excavated in the superdeltoid. Immediately aboral to the two septa and aligned with them are two subquadrangular cryptodeltoids, located on either side of the anal opening. The broad pentagonal hypodeltoid rests on the cryptodeltoids and

covers the aboral part of the anal opening. The anal opening is partly fused with the adjacent hydrospire canals, thus forming a paired anispiracle on the anal side. Therefore, five spiracles surround the oral opening—four paired spiracles and a paired anispiracle. In weathered specimens these openings are separate and a variable number appear to be present from specimen to specimen. There are two hydrospire folds on each side of an ambulacrum, without a hydrospire plate.

Ambulacra five, linear, recurved below, each 7.5 mm. long by 0.75 mm. wide, with the median one-third of the lancet exposed near the adoral end, but near the aboral end the lancet is covered by the side plates. There are 45 side plates in a space of 10 mm. along an ambulacrum. The primary side plates are dumbbell-shaped with one large pore between adjacent plates at the abmedial margin of the lens-shaped outer side plate, with pores located along radial and deltoid ambulacral margins. The surfaces of the basal and radial plates are ornamented with fine growth lines parallel to plate margins and the deltoids have aligned granules along growth ridges.

*Remarks.*—There is regional and stratigraphic variation among various specimens assigned to this species. The basal circllet is convex, flat, or slightly concave in different specimens, and on this basis alone one may distinguish various species. The object of the present work is to define genera, and therefore this problem will have to be considered by later investigators. The variation in shape of specimens from the St. Louis Group of Illinois and the Ste. Genevieve Limestone of Kentucky should be called to attention.

*Occurrence.*—Mississippian, St. Louis Limestone, Hardin County, Illinois (syntypes, X-363) and Brown County, Illinois (E1,498). Ste. Genevieve Limestone, Crittenden County, Kentucky (1,303). Gasper Formation, Huntsville, Alabama (71,650). Warsaw Formation, Florence, Alabama (S3,782).

*Types.*—Syntypes, X-363, three specimens, one 4-sided, A. H. Worthen collection, old Illinois State Museum no. 10,096, now in Department of Geology, University of Illinois, Urbana. Plesiotype, E1,498, one specimen, labelled *Mesoblastus kirkwoodensis*, A. H. Worthen collection, University of Illinois. Plesiotypes, 1,303, seven specimens, one polished section, one thin section, and five

#### EXPLANATION OF PLATE 17

FIGURE	PAGE	
1-3, 7-9. <i>Astrocrinus benniei</i> (ETHERIDGE), plesiotypes, 362, Harvard Mus. Comp. Zoölogy, Lower Carboniferous Limestone Group (shale above no. 2 limestone), Carlops Quarry, Peebleshire, Scotland; 1, 3, oral and aboral views with "A" ambulacrum toward top of page in fig. 1 ( $\times 10.6$ ); 2, 9, "C" ambulacral and aboral views of another speci-		
		men (approximately $\times 14$ ), 7, 8, aboral and oral views of specimen with "D" side directed downward ( $\times 17.0$ ) .....
4-6. <i>Pleuroschisma ontario</i> REIMANN, topotype, 35,033, Southworth coll., Univ. Michigan; Devonian, Hungry Hollow Formation (coral bed), Ausable River valley northeast of Arkona, Ontario; oral, "D" ambulacral, aboral views (all $\times 9.1$ ) .....		21 42

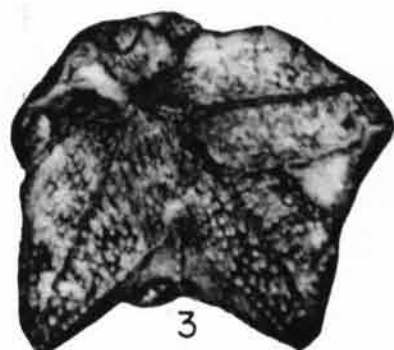




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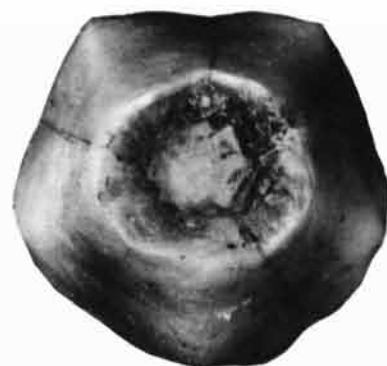
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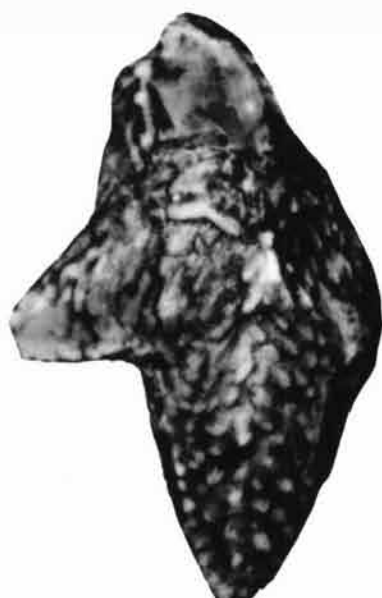
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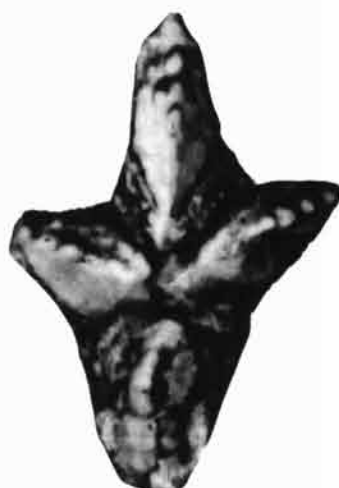
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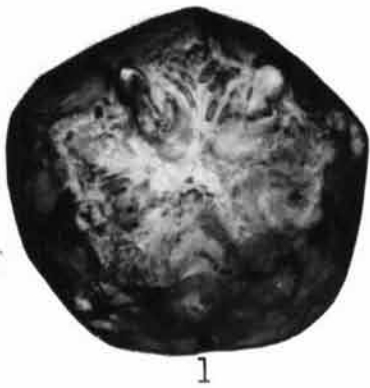
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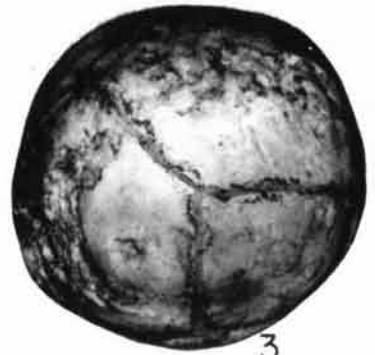
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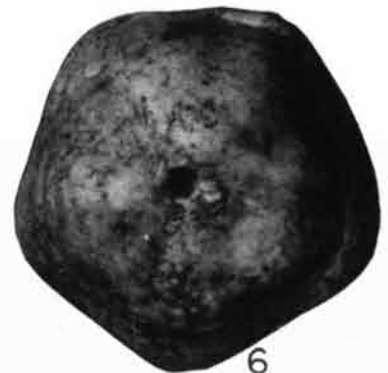
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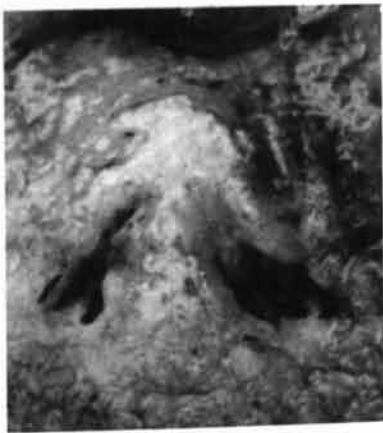
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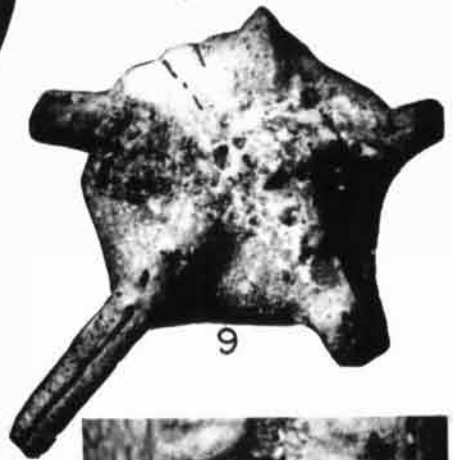
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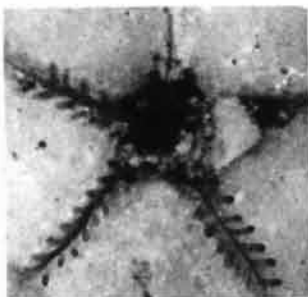
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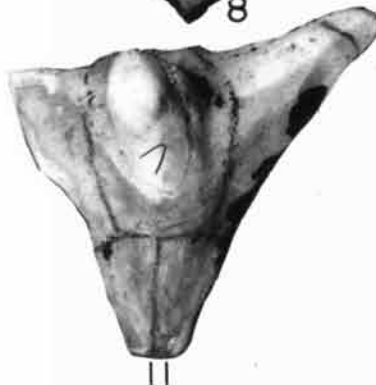
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complete specimens, University of Kentucky, Lexington. Plesiotypes, S3,782, 18 specimens, Springer collection, one illustrated, showing esophageal ring; 71,650, one specimen in rock figured by BUTTS, 1926, pl. 59, fig. 3, U. S. National Museum, Washington.

### Genus ELAEACRINUS C. F. Roemer, 1851

[=*Olivanites* (TROOST, 1849, *nom. nud.*) LYON, 1857; *Elaecrinus* ETHERIDGE & CARPENTER, 1883]

*Type-species*, by subsequent designation (Shumard, 1863).—*Elaecrinus verneuili* ROEMER, 1851 (= *Pentremites verneuili* TROOST, 1841, *nom. nud.*).

*Generic diagnosis*.—Spiraculate blastoids with 11 openings around oral opening, consisting of ten spiracles and anus separate, approximately 18-21 oral plates, one of which may not be an oral but an exposed superdeltoid plate, with three other exposed anal plates or two cryptodeltoids and hypodeltoid, one or two anal orals between adoral tips or cryptodeltoids; lancet covered by side plates, an inner side plate present, a single pore between side plates along deltoid and radial margins; deltoids long, overlapping radials, with two hydrospire folds on each side of an ambulacrum with medium-long hydrospire canal; form of calyx ellipsoidal, longer than wide. *Devonian*, Ohio, Indiana, Kentucky, Missouri.

*Remarks*.—The genus *Elaecrinus* was probably derived from a genus related to *Troosticrinus*, in which the small cryptodeltoids moved outward to the exterior, crowding the hypodeltoid between them, the superdeltoid began to migrate inward, the hydrospires became reduced to two on each side of an ambulacrum due to atrophy, the deltoids migrated downward, and many small oral plates coalesced to form a few large orals (18-21).

### ELAEACRINUS VERNEUILI C. F. Roemer

Plate 28, figures 7-10; text-figs. 120, 121

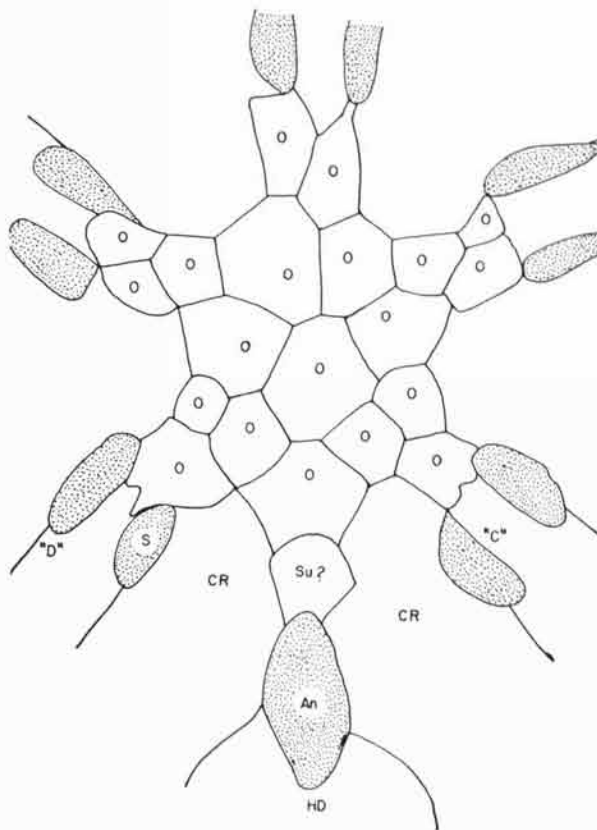
*Pentremites verneuili* TROOST, 1841, p. 14 (*nom. nud.*).

*Pentrematites verneuili* BRONN, 1848, p. 946 (*nom. nud.*).

*Olivanites verneuili* TROOST, 1849, p. 419 (*nom. nud.*); type-species of *Olivanites*.

*Elaecrinus verneuili* ROEMER, 1851, p. 379, pl. 8, figs. 1a-d (type-species of *Elaecrinus*).

*Description*.—Calyx calcitic, ellipsoidal in side view, subcircular in top view, 36 mm. long by 28 mm. wide,

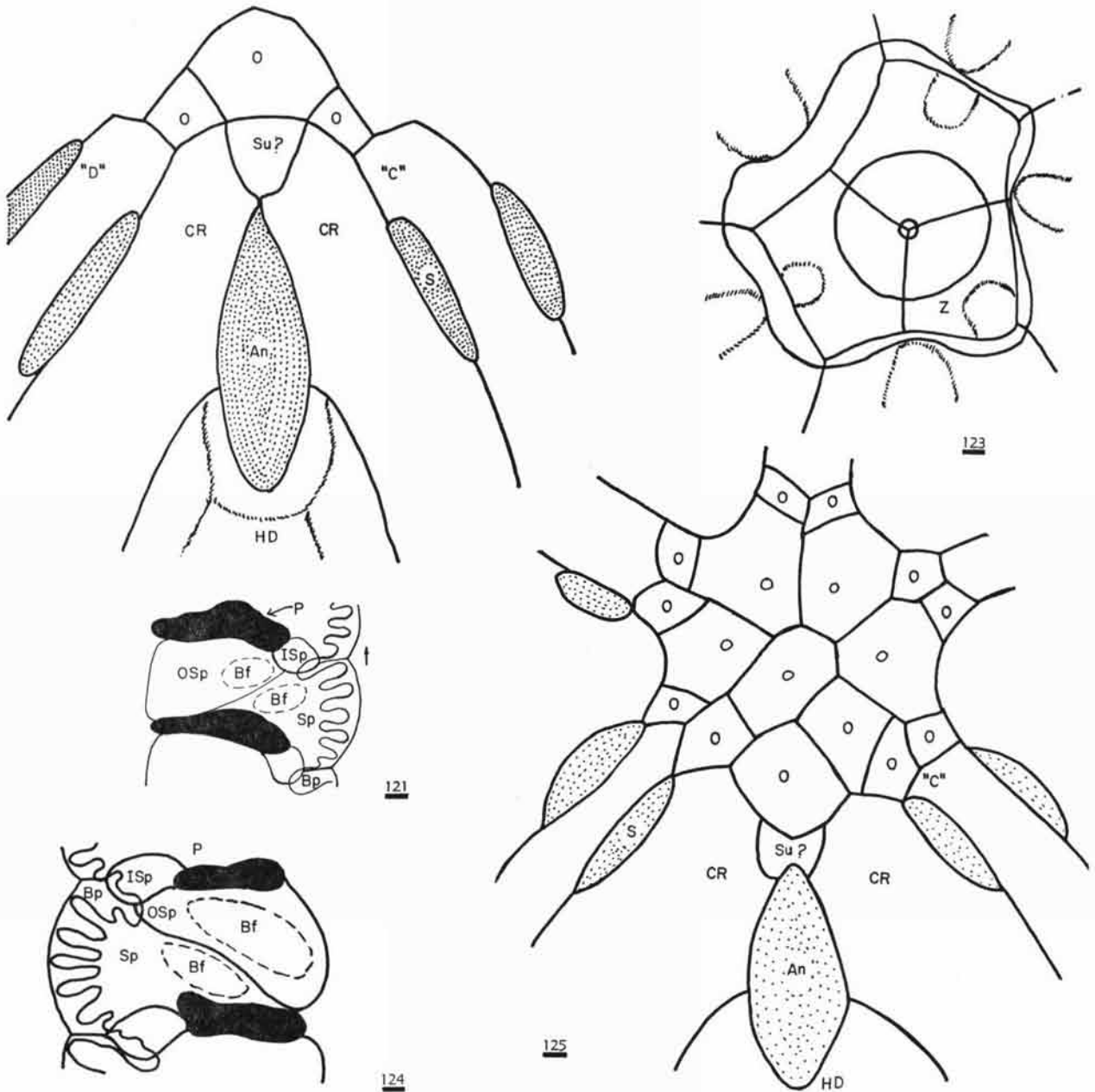


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FIGURE 120. *Elaecrinus verneuili* ROEMER, Middle Devonian, Jeffersonville Limestone, Jeffersonville, Indiana (Univ. Chicago, no. 9,956); summit area,  $\times 8$ . [Explanation.—An, anal opening; "C," amb.; CR, cryptodeltoid; "D," amb.; HD, hypodeltoid; O, oral plate; S, spiracle; Su, superdeltoid.]

### EXPLANATION OF PLATE 18

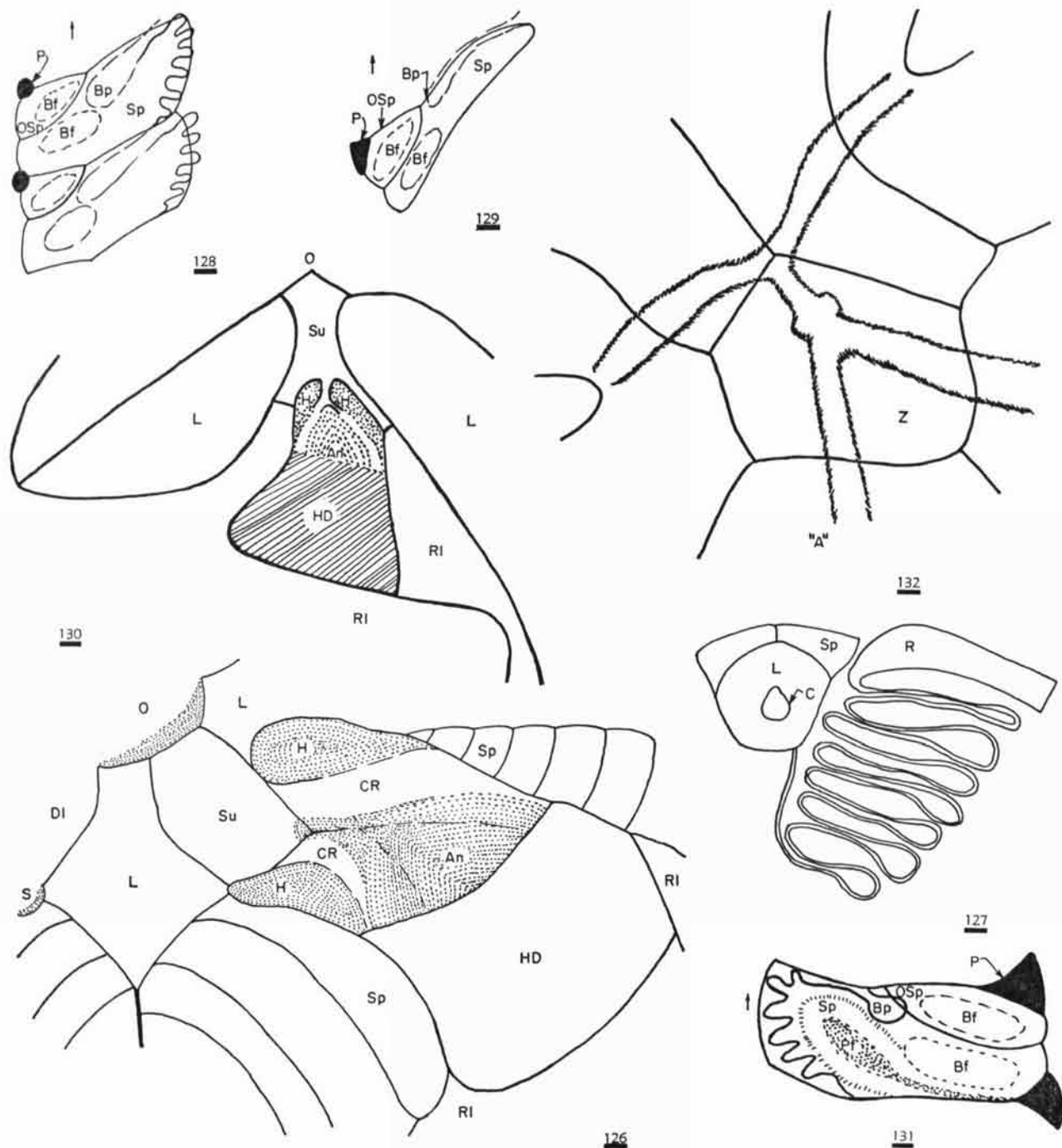
FIGURE	PAGE		
1-7. <i>Sagittoblastus wanneri</i> (YAKOVLEV), metatype, 102,187 (figs. 1-3), U.S. Natl. Mus., Permian, Krasnoufimsk, Urals, Russia; 1-3, oral, "D" ambulacral, aboral views of weathered specimen (all $\times 6.7$ ); metatype, 695, (figs. 4-7), Illinois Geol. Survey, Permian, Krasnoufimsk, Urals, Russia; 4-6, oral, "D" ambulacral, aboral views ( $\times 4.9$ ); 7, detail view of "AB" deltoid showing three hydrospire slits on each side in deep concavity ( $\times 20.6$ )	44		
8, 9. <i>Orophocrinus sirius</i> (WHITE), holotype, 379, Harvard Mus. Comp. Zoology; Lower Mississippian, Burlington			
		Limestone, Burlington, Iowa; oral and aboral views showing winglike radials ( $\times 4$ )	39
10, 11. <i>Pterotoblastus gracilis</i> WANNER, topotype, S4,035, Springer coll., U.S. Natl. Mus.; Permian, Basleo beds, from Tonino, Kioe Kilo, near Basleo, Timor Island, East Indies; 10, detail oral view of oral area (approximately $\times 5.5$ ); 11, "B" ambulacral view (approximately $\times 2.5$ )	44		
12. <i>Thaumatoblastus longiramus</i> WANNER, topotype, S4,053, Springer coll., U.S. Natl. Mus.; Permian, Basleo beds, Basleo, Timor Island, East Indies; oral view of radial fragment showing side plates ( $\times 7$ )	45		



FIGURES 121-125. Species of *Elaeacrinus* ROEMER, Middle Devonian, North America.

121. *E. verneuili* ROEMER, Jeffersonville Limestone, Jeffersonville, Ind. (Univ. Chicago, no. 9,956); part of "E" ambulacrum showing side plates,  $\times 27.5$ —122-125. *E. venustus* (MILLER & GURLEY), Columbus Limestone, Columbus, Ohio (Univ. Cincinnati, no. 1,317; Univ. Chicago, no. 6,114); 122, anal area (no. 1,317),  $\times 15$ ; 123, basal area (no. 1,317),  $\times 15$ ; 124, part of "B" ambula-

crum showing main, inner, and outer side plates (no. 1,317),  $\times 45$ ; 125, summit area (no. 6,114),  $\times 15$ . [Explanation.—An, anal opening; Bf, brachilar facet; Bp, brachiolar pit; "C," amb.; CR, cryptodeltoid; "D," amb.; HD, hypodeltoid; ISp, inner side plate; O, oral plate; OSp, outer side plate; P, pore; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, zygous basal.]



FIGURES 126-132. *Eleutherocrinus casedayi* SHUMARD & YANDELL, Middle Devonian, Louisville, Kentucky. (U.S. Natl. Mus., nos. S4,960, S4,963), and Hungry Hollow Formation, Thedford, Ontario (Geol. Survey Canada, no. 3,665; Buffalo Soc. Nat. Sci. no. E15,933).

126. Anal area and part of "D" ambulacrum (no. S4,960),  $\times 37.5$ .—127. Partial cross section of "A" ambulacrum (no. S4,963),  $\times 20$ .—128. Part of "B" ambulacrum, showing side plates (no. S4,960),  $\times 37.5$ .—129. Part of "D" ambulacrum, showing side plates (no. S4,960),  $\times 37.5$ .—130. Anal area, hypodeltoid absent (no. 3,665),  $\times 15$ .—131. Part of "E" ambulacrum showing side plates (no. 3,665),  $\times 15$ .—132. Basal

view (no. E15,933),  $\times 15$ . [Explanation.—"A," amb.; An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; C, canal (radial); CR, cryptodeltoid; Dl, deltoid lip; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral plate; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; RI, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]

periphery above mid-height, with flat summit and small deep basal concavity. Stem round, crenellar, 2 mm. in diameter, with small round lumen. Basal circlet pentagonal in aboral view, 3.5 mm. wide, concave, in deep basal concavity, with three normally disposed basals, each with a prominent central ridge. Radials five, pentagonal in side view, each 8.5 mm. long by 9 mm. wide, sharply recurved below, with body in basal concavity, with narrow, shallow sinus 5 mm. long by 1.25 mm. wide, and body flaring at radial lips. Deltoids overlap radials. The surfaces of the radials and basals are ornamented by fine growth striae subparallel to plate margins.

Deltoids four, broadly lenticular, each 32 mm. long by 15 mm. wide, with two hemielliptical spiracles notched in the adoral tip adjacent to the ambulacral margins. On the anal side there are at least three anal deltoid plates and possibly four exposed. The two cryptodeltoids extend around the sides of the anal opening and are separated by one or two oral plates on the adoral side of the anal opening. The plate adjacent to the anal opening may be a superdeltoid plate. The long quadrangular hypodeltoid, bordered on either side by the cryptodeltoids, is aboral to the elongate diamond-shaped anal opening, and has a low rounded anal lip that rapidly decreases in height aborally. The adoral tip of each cryptodeltoid has a hemielliptical spiracle in its ambulacral margin. Thus there are 11 openings around the oral aperture, consisting of ten spiracles and a separate anal opening. The ornamentation of the deltoids and anal deltoids is the same as in *Nucleocrinus*. There are two hydrospire folds on each side of an ambulacrum, with a moderately long hydrospire canal. On the inner surface of the hypodeltoid is an inward-projecting hornlike process. Summit covered by approximately 21 oral plates (Fig. 120).

Ambulacra five, linear, each 45 mm. long by 2 mm. wide, recurved below, with lancet covered by side plates, and 22 side plates in a space of 10 mm. along an ambulacrum. Inner side plate present, with approximately four cover-plate sockets to each side plate along the main food groove. Side plates disposed as in *Nucleocrinus*, with one large pore between adjacent side plates along the deltoid and radial margins.

*Occurrence*.—Middle Devonian, Onondaga Formation, Jeffersonville, Indiana.

*Types*.—Plesiotypes, 9,956, ten specimens, the largest of which is described above, Gurley collection, Walker Museum, University of Chicago.

#### ELAEACRINUS VENUSTUS (Miller & Gurley)

Plate 28, figures 1-6; text-figs. 122-125

*Nucleocrinus venustus* MILLER & GURLEY, 1894, p. 63, pl. 8, figs. 26-30.

*Description*.—The description is based on one of the syntypes (1,317). Calyx calcitic, ellipsoidal in side view, rounded pentagonal in top view, 16.5 mm. long by 12.5 mm. wide, with flat summit, concave constricted base, and periphery near mid-height. Stem round, crenellar, 1.25 mm. in diameter, in sharp basal concavity. Basal circlet lobed-pentagonal in aboral view, 2.75 mm. in diameter, in sharp basal concavity, with three normally disposed basals. Radials five, pentagonal in oblique basal view, short, each 3.5 mm. long by 5 mm. wide, recurved below, with short, narrow, flat sinus 2 mm. long by 1.5 mm. wide, and broad M-shaped radiodeltoid suture formed at top of radial limbs. Deltoids overlap radials.

Deltoids four, long, bluntly lenticular, each 14 mm. long by 6 mm. wide, each with a smooth central triangular area with base equalling almost the full width of the radiodeltoid suture, bordered on either side by a granulo-striate lenticular area, with two slitlike spiracles notched in the adoral tip adjacent to the ambulacra. On the anal side there are at least three, possibly four, anal deltoid plates. A central smooth quadrangular hypodeltoid with raised adoral end is bordered on either side by two granulo-striate cryptodeltoids that extend adorally beyond the anal opening (one on each side) with one or two small plates between them adorally from the anal opening. One of these plates, slightly below the other, is adjacent to the anal opening and may represent a superdeltoid plate. The adoral tips of the two cryptodeltoids abut against three other oral plates on the anal side. Each cryptodeltoid has one slitlike spiracle on the adoral tip along the adjacent ambulacral margin. Thus there are 11 openings around the oral aperture, that is, ten spiracles

#### EXPLANATION OF PLATE 19

FIGURE	PAGE
1-5. <i>Troosticrinus reinwardti</i> (TROOST), holotype, 33,071 (now 139,105) (figs. 1-3), paratypes, 139,106 (figs. 4, 5), Troost coll., U.S. Natl. Mus.; Middle Silurian, Niagaran, Decatur County, Tennessee; 1, oral view ( $\times 6$ ); 2, "D" ambulacral view ( $\times 3.4$ ); 3, aboral view ( $\times 6$ ); 4, anal view showing superdeltoid, cryptodeltoids and hypodeltoid ( $\times 22$ ); 5, polished section with "A" ambulacrum directed upward, oral view ( $\times 4.5$ )	106
6-8. <i>Metablastus lineatus</i> (SHUMARD), neotypes, S4,958 (new holotype, figs. 7, 8); S4,957 (new paratype, fig. 6), Springer coll., U.S. Natl. Mus.; Lower Mississippian, Upper Burlington Limestone, Sagetown, Ill.; 6, aboral view of "C" ambulacrum ( $\times 10$ ); 7, anal view of holotype showing exposed cryptodeltoids where hypodeltoid is missing ( $\times 6.6$ ); 8, "CD" interambulacral view of holotype ( $\times 2.2$ )	79
9. <i>Metablastus varsouviensis</i> (WORTHEN), syntype, 1,885, A. H. Worthen coll., formerly Illinois State Mus., Springfield, now Illinois Geol. Survey, Urbana; Mississippian, Warsaw beds, Monroe County, Illinois; side view of one of two imperfect types, in rock ( $\times 7.1$ )	82



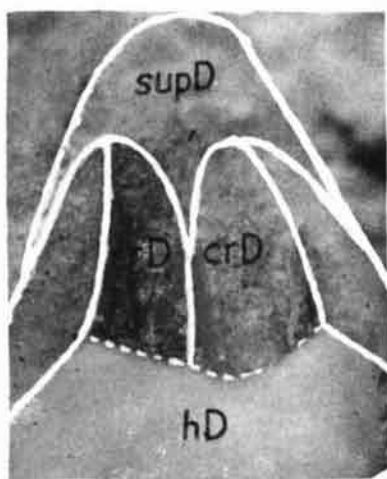
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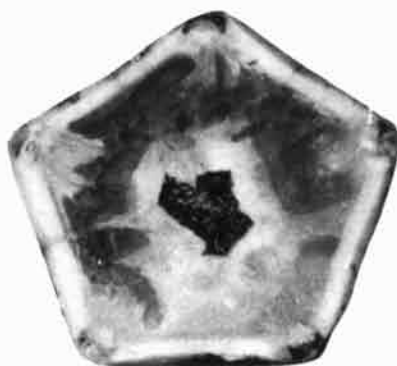
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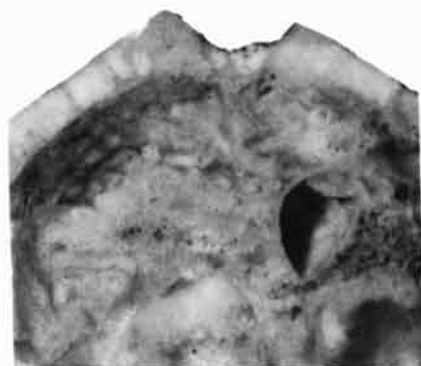
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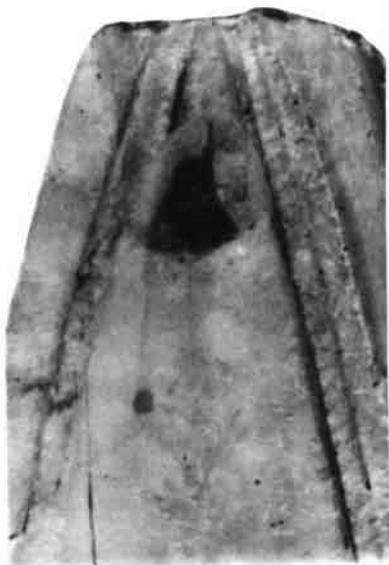
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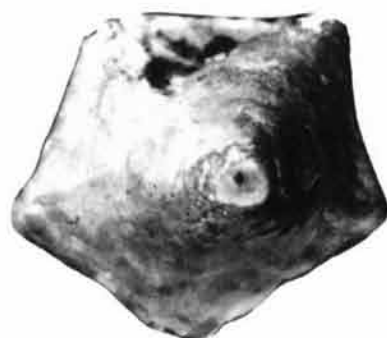
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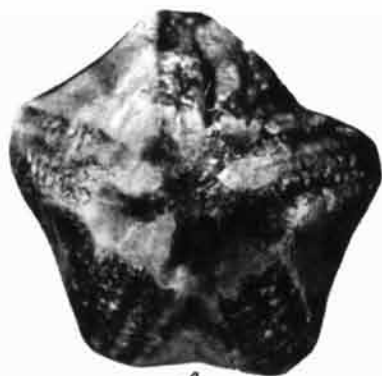
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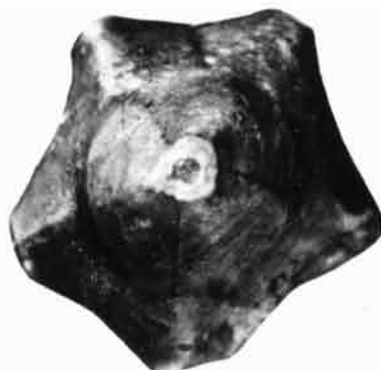
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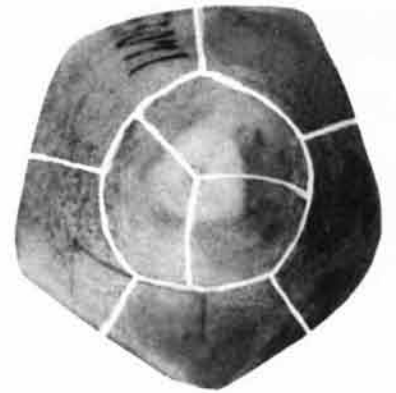




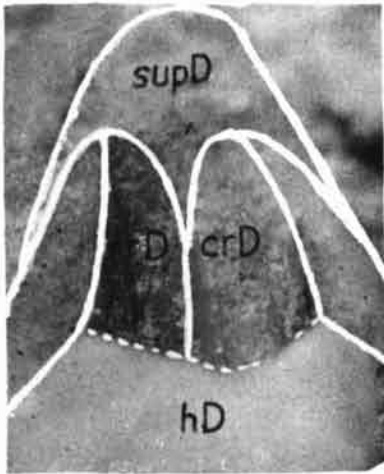
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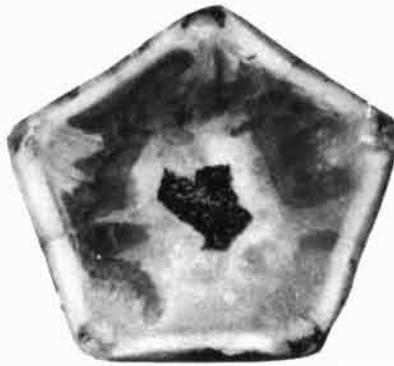
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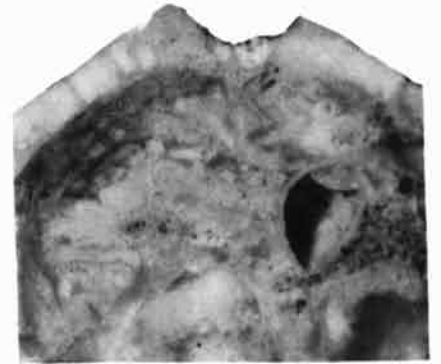
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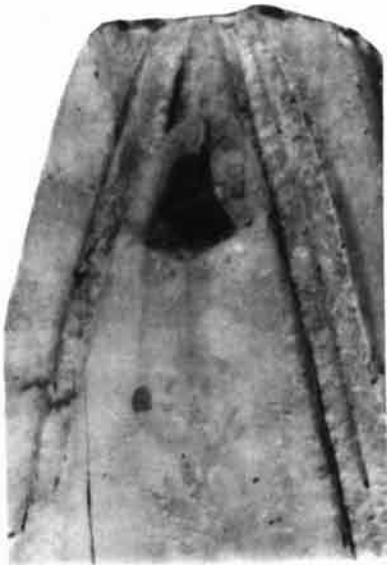
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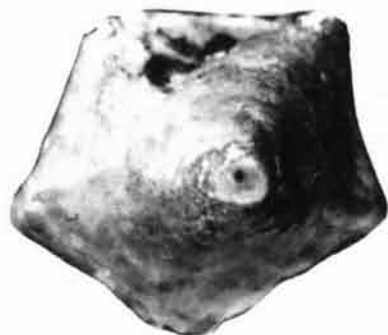
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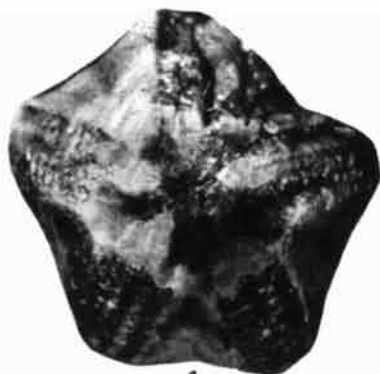
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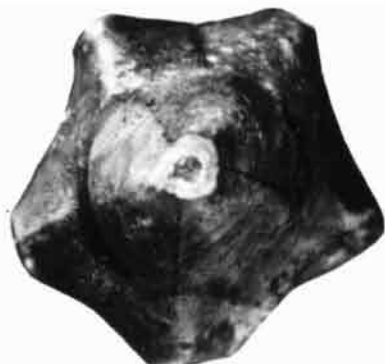
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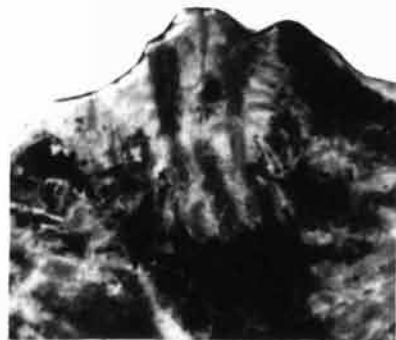
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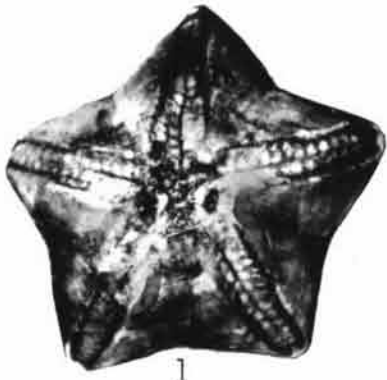
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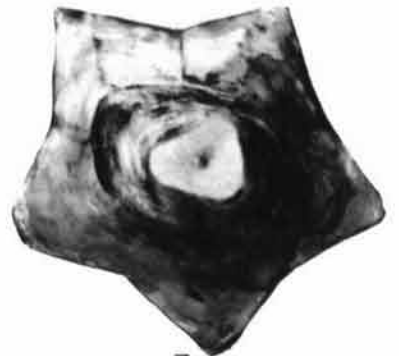
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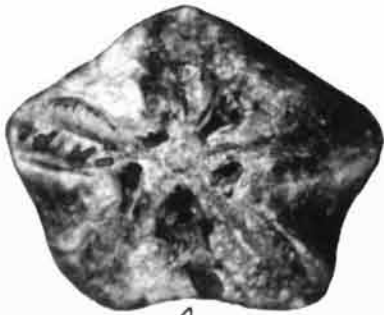
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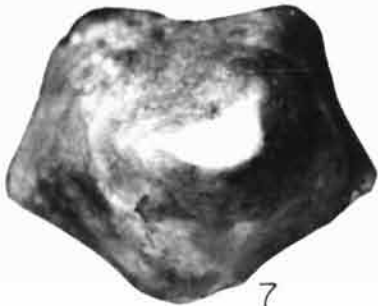
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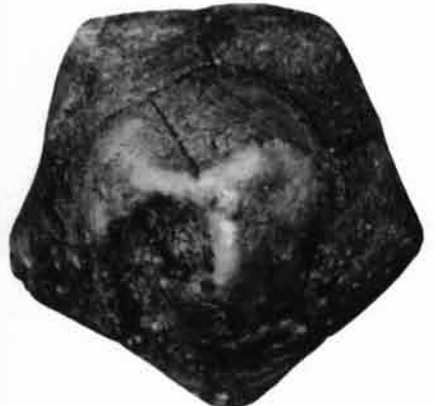
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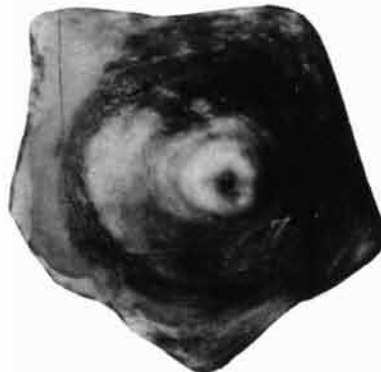
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and a separate anus. The oral area is covered by approximately 18 oral plates, consisting of five large orals in the center, each arrow-shaped and interambulacral in position, bordered aborally by 12 or 13 accessory orals. There are two accessory orals at the adoral end of each ambulacrum, and two or three (one of which may be a superdeltoid) on the anal side. It is assumed that two hydrospire folds occur on each side of an ambulacrum.

Ambulacra five, linear, raised, recurved below, each 19 mm. long by 1 mm. wide, with lancet covered by side plates, 26 side plates in a space of 10 mm. along an ambulacrum, and side plates disposed as in *Nucleocrinus*. There is one large pore between adjacent side plates along the deltoid and radial margins, and four cover-plate sockets to each side plate along the main food groove. Inner side plate present. The surfaces of the calyx plates are ornamented as in *Nucleocrinus* by fine growth striae parallel to plate margins, with small aligned granules or ridges on deltoid and cryptodeltoid ambulacral margins, each ridge corresponding in position to one pore, aligned at a high angle to ambulacral margins.

*Occurrence*.—Middle Devonian, Onondaga (Columbus) Limestone, Columbus, Ohio.

*Types*.—Syntypes, 1,317, two specimens, University of Cincinnati Museum. Syntypes, 6,114, two specimens, Gurley collection, illustrated by GURLEY (1894), p. 63, pl. 8, fig. 26-30, Walker Museum, University of Chicago.

### Genus ELEUTHEROCRINUS Shumard & Yandell, 1856

*Type-species*, by original designation (monotypy).—*Eleutherocrinus casedayi* SHUMARD & YANDELL, 1856.

*Generic diagnosis*.—Spiraculate blastoids with five spiracles, or four spiracles and an anispiracle, with superdeltoid, two cryptodeltoids, and a hypodeltoid on anal side, six or seven hydrospire folds on each side of an ambulacrum, lancet covered by side plates, with one pore between adjacent side plates along deltoid and radial margins, radials overlapping deltoids, calyx plates irregular because of shortened "D" ambulacrum; ellipsoidal in side view. *Devonian*, Kentucky, Indiana, New York, Ontario.

*Remarks*.—The genus *Eleutherocrinus* was prob-

ably derived from *Hyperblastus* by complete closure of the sinus areas, shortening of the (D) ambulacrum, and consequent shifting of calyx plates.

### ELEUTHEROCRINUS CASSEDAYI Shumard & Yandell, 1856

Plate 26, figures 1-8; plate 27, figures 1-11; text-figs. 126-137

*Eleutherocrinus casedayi* SHUMARD & YANDELL, 1856, p. 74, pl. 2, figs. 1-5.

*Description*.—The new holotype (neotype) is 18 mm. long by 9 mm. wide, vault 14 mm. long, pelvis 4 mm. long, pelvic angle 70 degrees in left anterior radial view and 85 degrees in anterior radial view. The basal circllet is irregular, with two equal long basals 9 mm. long by 3 mm. wide extending upward on the "D" ambulacral side, azygous basal confined to the base, 3 mm. long by 2 mm. wide. The base of the azygous plate has a smooth area about 0.5 mm. from the aboral tip, in which a seemingly round crenellar depression occurs, too ill-defined for positive identification. Apparently a stem is absent. A single prominent ridge extends downward on the middle face of each basal, that on the azygous basal splitting and extending to the lips of the "A" and "B" radials, whereas the other two extend to the "C" and "E" radial lips, respectively. The ridges on the two equal basals each branch and have an extension up the middle of the plate, parallel to the interbasal suture. Radials five, irregular in shape and length. The "A," "B," "C," and "E" radials are 16 mm. long, the "A" and "B" radials being symmetrical, 5 mm. wide, with sinus 13 mm. long, whereas the "C" and "E" radials are unsymmetrical, with narrow pointed limbs on the "D" side, each 6 mm. wide, with sinus 14 mm. long. The sinus areas are approximately 1 mm. wide. The "D" radial is short and wide, roughly subquadrangular, 9 mm. long and 7 mm. wide, with short, wide sinus confined to the summit; radials overlapping deltoids.

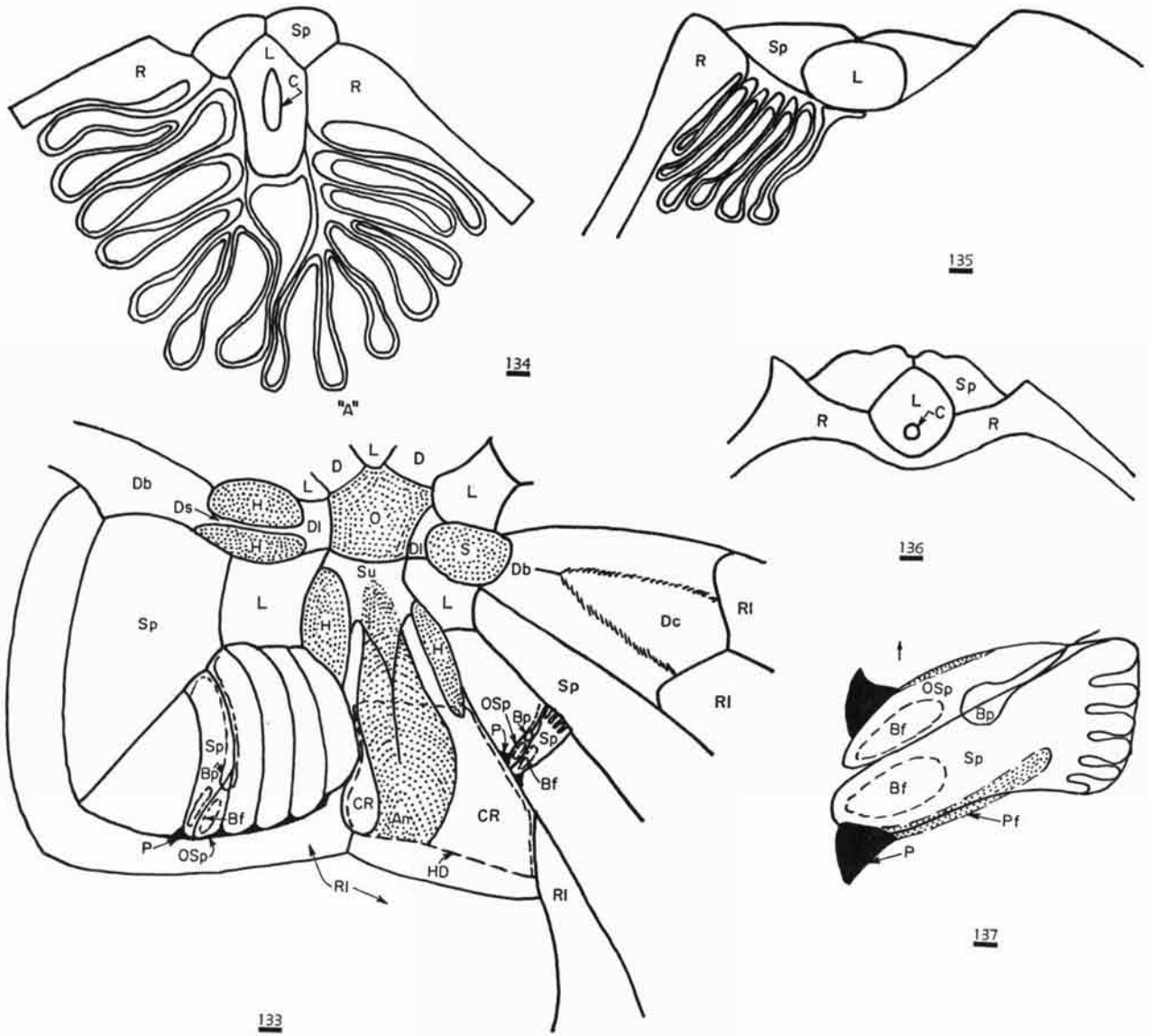
The "AB," "BC," and "EA" deltoids are short, visible in side view, 1 mm. long, triangular, with depressed deltoid septum, and each with a spiracle between the deltoid body and deltoid lip. The "DE" deltoid is short, quadrangular, confined to the summit, and smaller than the other deltoids, but with similarly formed spiracle. On the anal side there are four deltoid plates. The super-

### EXPLANATION OF PLATE 20

FIGURE	PAGE	
1-9. <i>Cordyloblastus clavatus</i> (SCHULTZE).—1-3, 8. Syntypes, 539, Schultze coll., Harvard Mus. Comp. Zoology; Devonian, near Kerpen, Nollenbach, Germany; 1-3, oral, "A" ambulacral, aboral views ( $\times 4.9$ ); 8, polished cross section of "E" ambulacrum looking aborally ( $\times 3$ ).—4-6, 9, plesiotype, 19,090, Gurley coll., Univ. Chicago;		Calizas de Arnao, León, Spain; 4-6, oral, "D" ambulacral, aboral views of specimen with polished summit ( $\times 5.2$ ); 9, enlarged view of fig. 4 ( $\times 7.7$ ).—7. Plesiotype, S3.613, Springer coll., U.S. Natl. Mus.; Lower Devonian, Calizas de Arnao, Sabero (León), Spain; "D" ambulacral view ( $\times 6.5$ )
		54

deltoid is adjacent to the oral opening and has two septa that separate the anal opening from the adjacent hydrospire canals internally. The two cryptodeltoids adjoin the septa internally and form broad platforms adjacent to the "C" and "D" radial limbs. The "C" radial limb con-

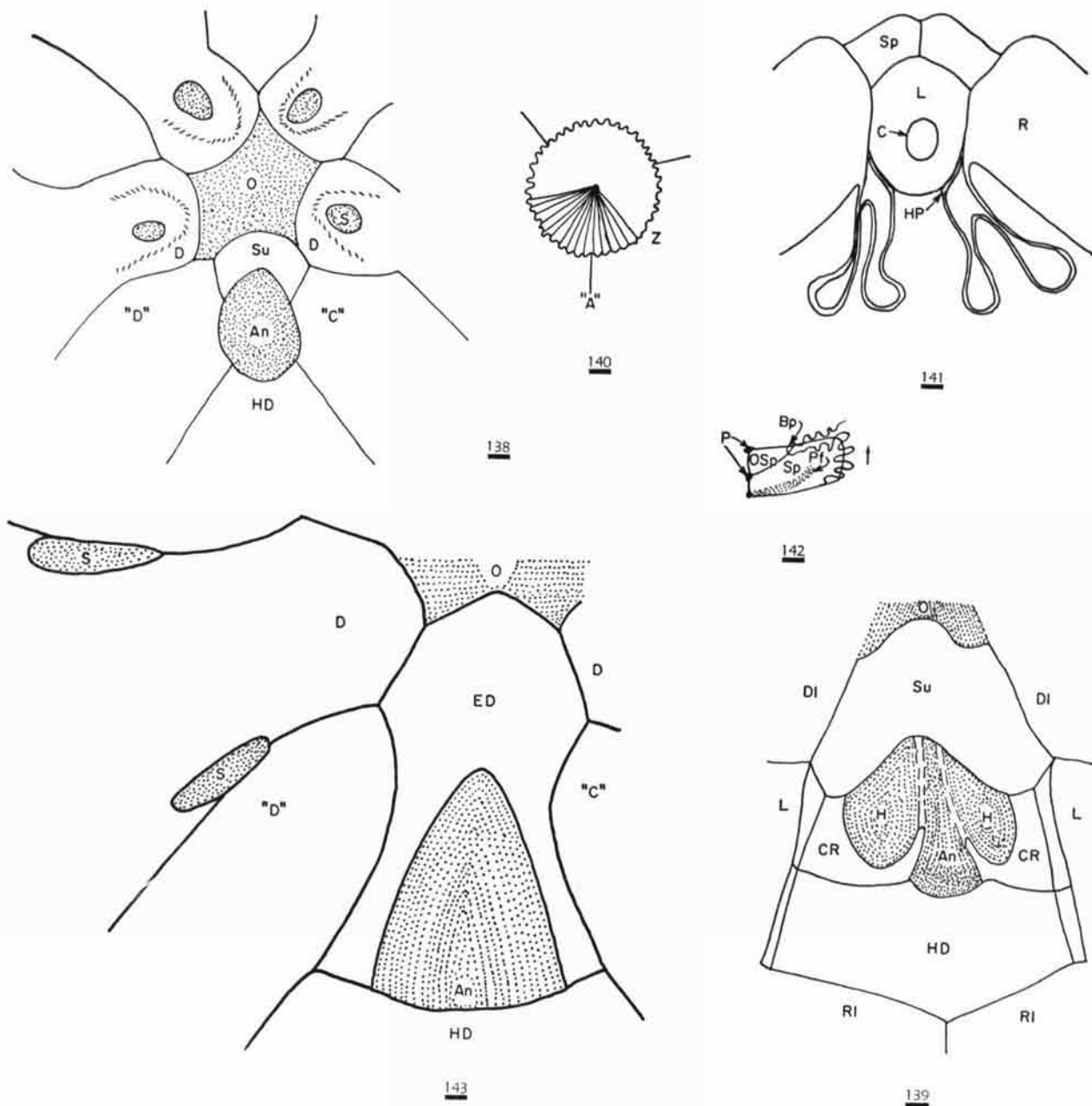
tinues adorally beyond the "D" limb, and the irregularly pentagonal hypodeltoid fits against the adoral ends of the "C" and "E" radial limbs, overlapping the cryptodeltoids. Thus, there are five spiracles around the oral opening, comprising four spiracles and anispiracle. There



FIGURES 133-137. *Eleutherocrinus casedayi* SHUMARD & YANDELL, Middle Devonian, Hungry Hollow Formation, Thedford, Ontario (Buffalo Soc. Nat. Sci., nos. E13,061, E15,933).

133. Summit area and parts of "BC" and "CD" interambulacra, and "D" ambulacrum (no. E15,933),  $\times 15$ .  
 —134. Oblique cross section of "E" ambulacrum (no. E13,061),  $\times 15$ .  
 —135. Partial cross section of "D" ambulacrum, aboral view (no. E13,061),  $\times 15$ .  
 —136. Aboral view of an ambulacrum near aboral end (no. E13,061),  $\times 15$ .  
 —137. Part of ambulacrum showing side plates (no. 13,061),  $\times 45$ . [Explanation.—"A," amb;

An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; C, canal (radial); CR, cryptodeltoid; D, deltoid; Db, deltoid body; Dc, deltoid crest; Dl, deltoid lip; Ds, deltoid septum; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; Rl, radial lip; S, spiracle; Sp, main side plate; Su, superdeltoid.]



FIGURES 138-143. Species of *Ellipticoblastus* FAY, *Globoblastus* HAMBACH, and *Granatocrinus* HALL, Lower Carboniferous, England, and Mississippian, North America.

138. *Ellipticoblastus orbicularis* (SOWERBY), Lower Carboniferous, England (Univ. Chicago, no. 13,877); summit area,  $\times 15$ .—139-142. *Globoblastus norwoodi* (OWEN & SHUMARD), Lower Mississippian, Burlington Limestone, Burlington, Iowa (U.S. Natl. Mus., nos. S4,955, S4,956); 139, anal area (no. S4,956),  $\times 17.5$ ; 140, basal area, showing stem impression (no. S4,956),  $\times 40$ ; 141, cross section of "E" ambulacrum, aboral view (no. S4,955),  $\times 20$ ; 142, part of ambulacrum, showing side plates (no. S4,956),  $\times 20$ .—143. *Granatocrinus ken-*

*tuckyensis* (CONKIN), Lower Mississippian, New Providence Formation, Jefferson County, Kentucky (U.S. Natl. Mus., paratype 1, no. 139,620); anal area,  $\times 15$ . [Explanation.—"A," amb.; An, anal opening; Bp, brachiolar pit; "C," amb.; C, canal (radial); CR, cryptodeltoid; "D," amb.; D, deltoid; Dl, deltoid lip; ED, epideltoid; H, hydrospire; HD, hypodeltoid; HP, hydrospire plate; L, lancet O, oral opening OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; Rl, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]

are seven hydrosfire folds on each side of a normal ambulacrum ("A," "B," "C," "E") and 6 hydrosfire folds on each side of the "D" ambulacrum.

The "D" ambulacrum is 3 mm. long by 3 mm. wide, the "A" and "B" ambulacra 15 mm. long by 1.25 mm. wide, and the "C" and "E" ambulacra 17 mm. long by 1.25 mm. wide, the widest part being adjacent to the deltoids. The lancet plate is covered by side plates, with 22 side plates in a space of 10 mm. along a normal ambulacrum. The "D" ambulacrum has seven side plates in all on each side, but these are similar to those of the other ambulacra except for being more elongate. The side plates are normally disposed, with one large pore between adjacent plates along the deltoid and radial margins, and five cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented with fine growth lines parallel to plate margins.

*Occurrence.*—Middle Devonian, Hamilton Group, Beargrass Creek, Jefferson County, Kentucky (S4,960). Hamilton Group, Louisville, Kentucky (S4,963). Coral zone of Widder beds, Hungry Hollow Formation, Thedford, Ontario (108; 3,665; E13,061; E15,933).

*Types.*—Neotypes, S4,960 (new holotype); S4,963 (new paratype), old numbers S3,666 and S3,665 respectively, Springer collection, S4,963 figured by ETHERIDGE & CARPENTER (1886), pl. 19, fig. 3, U. S. National Museum, Washington. Plesiotype, 108, one specimen, University of Illinois, Urbana. Plesiotype, 3,665, Geological Survey of Canada, Ottawa. Plesiotypes, E13,061, four fragmentary specimens, Charles Southworth collection (1941); and E15,933, one specimen, Charles Southworth collection (1943), Buffalo Society of Natural Sciences, Buffalo, New York.

### Genus ELLIPTICOBLASTUS Fay, 1960

*Type-species*, by original designation.—*Pentatremites orbicularis* SOWERBY, 1834.

*Generic diagnosis.*—Spiraculate blastoids with five spiracles, or four spiracles in addition to an anispiracle, with superdeltoid, two cryptodeltoids, and a hypo-

deltoid on anal side, a hydrosfire plate, approximately twice as many pores as side plates along the deltoid and radial margins, one long, curved hydrosfire fold on each side of an ambulacrum, radials overlapping deltoids, lancet exposed along middle one-third of its width, and calyx shape elliptical. *Lower Carboniferous*, England.

*Remarks.*—The genus *Ellipticoblastus* was probably derived from *Globoblastus* by reduction of the two hydrosfires on each side of an ambulacrum to one. The lancet plate migrated outward, thus exposing the middle portion.

### ELLIPTICOBLASTUS ORBICULARIS (Sowerby)

Plate 43, figures 7-9, 12; text-fig. 138

*Pentatremites orbicularis* SOWERBY, 1834, p. 456, pl. 33, fig. 5.

*Ellipticoblastus orbicularis* (SOWERBY) FAY, 1960, p. 315-317, pl. 1, fig. 7.

*Description.*—Calyx calcitic, flattened globular, 8.5 mm. long by 8 mm. wide, with periphery near mid-height at radiodeltoid suture. Stem round, crenellar, 1 mm. in diameter, with small, central, round lumen. Basal circlet pentagonal in basal view, 3 mm. in diameter, in slight basal concavity, with three normally disposed basal plates. Radials five, each pentagonal in side view, extending one-half of length of the calyx, with long, narrow, shallow sinus 5.5 mm. long by 1.25 mm. wide; radials overlapping deltoids at a high angle. The angle formed along the radiodeltoid suture, with center at junction of inter-radial sutures with radiodeltoid sutures is 95 degrees.

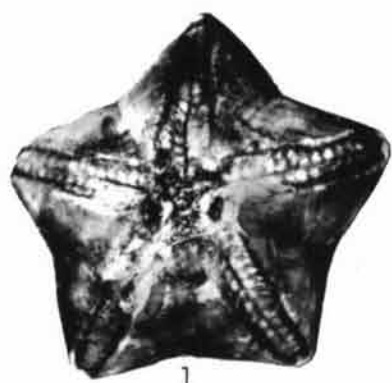
Deltoids four, long, lancet-shaped, each 6 mm. long by 3.5 mm. wide, each pierced in the adoral tip by one large oral spiracle. Each spiracle has a steep raised margin and each wide, short deltoid lip has approximately seven long cover-plate lobes along the aboral margin. On the anal side two external anal deltoids are seen, a superdeltoid and hypodeltoid, with anispiracle between. Anal opening filled with matrix. It is assumed that two small cryptodeltoids are present but covered, as seen in other specimens. One hydrosfire fold is present on each side of an ambulacrum, as in other specimens.

## EXPLANATION OF PLATE 21

FIGURE	PAGE
1-10. <i>Cordyloblastus eifelensis</i> (ROEMER).—1-3. Topotype, 213, Schultze coll., Harvard Mus. Comp. Zoölogy; Middle Devonian (Eifelian), Nollenbach, near Kerpen, Germany; oral, "D" ambulacral, aboral views (all $\times 3.7$ ).—4, 5, 7. Plesiotype, E21,087, Buffalo Soc. Nat. Sci.; Middle Devonian, Eifel, Germany; oral, "D" ambulacral, aboral views of an immature specimen (all $\times 13.1$ ).—6, 8. Plesiotype, 195, Schultze coll., Harvard Mus. Comp. Zoölogy; Middle Devonian, Eifel, Germany; oral and "DE"	

interambulacral views of an abnormal specimen showing development of a small sixth radial plate in "DE" interambulacrum ( $\times 3.8$ ).—9, 10. Topotypes, 305, Schultze coll., Harvard Mus. Comp. Zoölogy; Middle Devonian (Eifelian), Nollenbach, near Kerpen, Germany; 9, long, polished section of an ambulacrum showing hydrosfires ( $\times 13$ ); 10, oral view of polished section showing the two cryptodeltoids (slightly darker calcite) resting on lighter-colored superdeltoid near oral opening and extending aborally (downward) ( $\times 5$ ) ..... 56

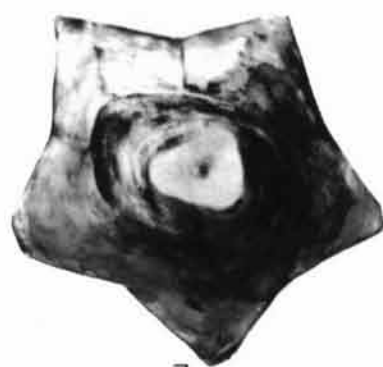




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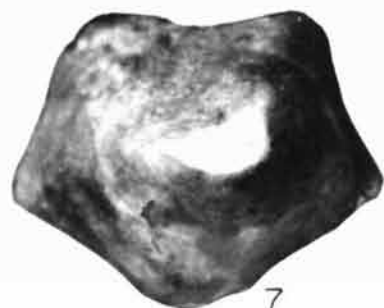
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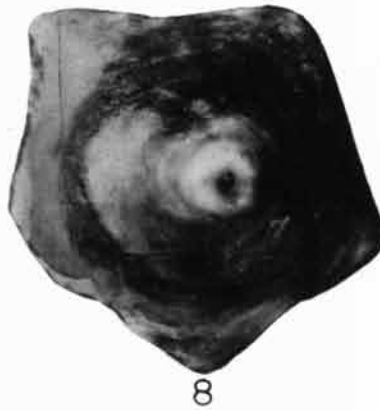
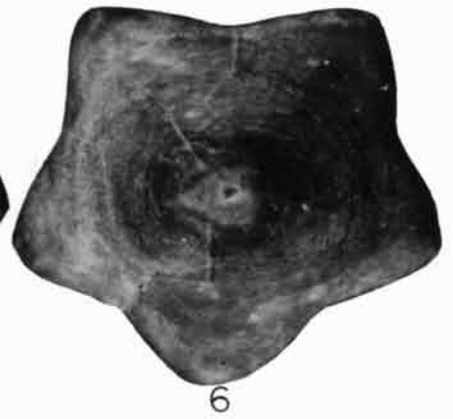
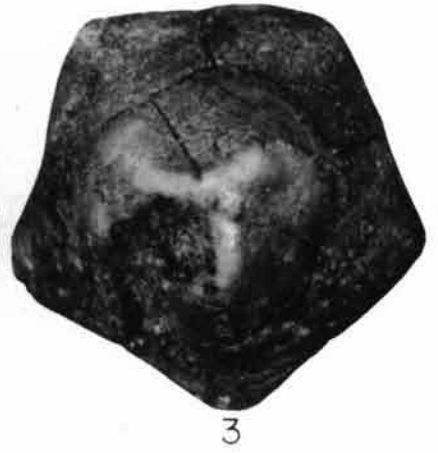
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9



10



Ambulacra five, linear, recurved below, each 11 mm. long by 1 mm. wide, with median one-third of width of lancet exposed and 25 side plates in 10 mm. length of an ambulacrum. The side plates are normally disposed, with approximately two pores to each side plate, a hydrospire plate present, and five or six main cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented by fine granules that are arranged along growth lines.

*Occurrence*.—Lower Carboniferous Limestone, Lancashire and Yorkshire, England.

*Types*.—Plesiotype, 13,877, one specimen, Gurley collection, Walker Museum, University of Chicago. Plesiotype, 241, one specimen, deKoninck collection, old no. 2,330, Carboniferous Limestone, Settle, Yorkshire, England, Harvard Museum of Comparative Zoölogy, Cambridge, Mass.

### Genus GLOBBLASTUS Hambach, 1903

*Type-species*, by original designation (monotypy), and by subsequent designation (Bassler, 1938).—*Pentremites norwoodi* OWEN & SHUMARD, 1850.

*Generic diagnosis* (*emend.* FAY, 1960).—Spiraculate blastoids with five spiracles, composed of four spiracles and an anispiracle, with superdeltoid, two cryptodeltoids, and a hypodeltoid on the anal side; lancet covered by side plates except near adoral end, radials overlapping deltoids, approximately two pores to each side plate along radial margins, hydrospire plate present, deltoids short; two hydrospire folds on each side of an ambulacrum; calyx subglobular in shape. *Mississippian*, Illinois, Iowa, Missouri.

*Remarks*.—The genus *Globblastus* was probably derived from a form similar to *Devonblastus* in which a hydrospire plate and infolded pores formed along the ambulacra, the hydrospires becoming reduced in number, and form of the calyx subglobular.

### GLOBBLASTUS NORWOODI (Owen & Shumard)

Plate 44, figures 1-7; text-figs. 139-142

*Pentremites norwoodi* OWEN & SHUMARD, 1850, p. 64, pl. 7, figs. 13a-c.

*Description*.—The new holotype (neotype) is ellipsoidal, 15 mm. long by 12 mm. wide, with concave base. Stem round, approximately 1 mm. in diameter, with about

40 crenellae extending toward center. Basal circlet small, in deep concavity, with three normally disposed basals. Radials each 15 mm. long by 7 mm. wide, recurved in basal concavity, with long narrow sinuses; radials overlapping deltoids.

Deltoids four, short, each 2 mm. long by 2 mm. wide, with a single spiracle at their adoral tips. On the anal side the superdeltoid is 1 mm. long by 2 mm. wide, and hypodeltoid 1 mm. long by 2 mm. wide, with anispiracle between. The two cryptodeltoids are covered over by the hypodeltoid, are infolded internally into hydrospires, and are overlapped by the radial limbs. Adorally the cryptodeltoids separate the anal opening from the adjacent hydrospire canals internally, and rest on the aboral surface of the superdeltoid. There are two hydrospire folds on each side of an ambulacrum, with a hydrospire plate present; approximately two pores to each side plate are excavated in the ambulacral margins of the radial plates. The oral opening is surrounded by the four deltoid lips and the superdeltoid, and by five spiracles, or four spiracles and an anispiracle.

Ambulacra five, linear, each 16 mm. long by 1.5 mm. wide, recurved below, with lancet covered by side plates along the aboral one-half of each ambulacrum but exposed one-third of its width near the oral opening. There are 30 side plates in a space of 10 mm. along an ambulacrum, with approximately two pores to each side plate (one aligned with side plate suture and one aligned approximately near middle of the ambulacral margin of each side plate), with secondary side plate normally disposed. There are four cover-plate sockets to each side plate along the main food groove and two or three side cover-plate sockets along each side of a side food groove. The interrarial sutures are depressed and the surfaces of the calyx plates are ornamented with finely granular growth lines parallel to plate margins.

*Remarks*.—The original types were probably destroyed in the fire at Indiana University in 1883 and therefore neotypes are here selected.

*Occurrence*.—Lower Mississippian, upper part of Burlington Limestone, Burlington, Iowa.

*Types*.—Neotypes, S4,956 (new holotype), S4,955 (new paratype), Springer collection, old no. S3,759, part of 31 specimens, U. S. National Museum, Washington.

## EXPLANATION OF PLATE 22

FIGURE	PAGE
1-3. <i>Cordyloblastus roemeri</i> (ETHERIDGE & CARPENTER), plesiotype, S3,615, Springer coll., U.S. Natl. Mus.; Lower Devonian, Calizas de Arnao, León, Spain; oral, "D" ambulacral, aboral views (all $\times 8.2$ ).	
4-9. <i>Cordyloblastus lusitanicus</i> (ETHERIDGE & CARPENTER). ——4-6. Plesiotype, S3,616, Springer coll., U.S. Natl. Mus.; Middle Devonian, Gerolstein, Eifel, Germany; oral, "D" ambulacral, aboral views (all $\times 9.8$ ).——7-9. Plesiotype, 19,091, Gurley coll., Univ. Chicago; Middle Devonian, Gerolstein, Germany; oral, aboral, "D" ambulacral views (all $\times 11.5$ ).....	57

**Genus GRANATOCRINUS Hall, 1862**

*Type-species*, by subsequent designation (Shumard, 1866).—*Pentatremites granulatus* ROEMER, 1851.

*Generic diagnosis*.—Spiraculate blastoids with eight spiracles in addition to an anispiracle, which occurs between epideltoid and hypodeltoid plates; lancet covered by side plates; hydrospire plate present; two pores to each side plate along margins of radials and deltoids, radials overlapping deltoids, one hydrospire fold on each side of an ambulacrum, deltoids moderately long, shape elliptical. *Mississippian*, Kentucky, Indiana, Tennessee.

*Remarks*.—The genus *Granatocrinus* was probably derived from a form similar to *Poroblastus* in which the marginal pores along the deltoids were infolded to form two sets of pores to each side plate, and the mature form had a tendency to increase in size.

**GRANATOCRINUS GRANULATUS (Roemer)**

Plate 39, figures 3-9

*Pentatremites granulatus* ROEMER, 1851, p. 363, pl. 13, fig. 13.

*Granatocrinites cidariformis* TROOST, 1849, p. 420 (*nomen nudum*).

*Cidaroblastus granularis* HAMBACH, 1903, pl. 3, fig. 2.

*Orbitremites oppelti* ROWLEY, 1902, p. 86, pl. 29, figs. 15-20.

*Description*.—A long description has been given by CONKIN (1957, pp. 139-140) but this should be altered slightly. There are eight spiracles in addition to an anispiracle around the oral opening, the anispiracle occurring between epideltoid and hypodeltoid plates. A hydrospire plate is present and approximately two pores to each side plate occur along the ambulacral margins of the deltoids and radials. A single long hydrospire fold is seen on each side of an ambulacrum, and radials overlap the deltoids. The base is deeply concave. Ornamentation consists of large rounded spines more or less arranged along growth lines.

*Remarks*.—This form would be placed in a new genus except that the name *Granatocrinus* is available, and therefore, the name is revived but restricted to forms that fit the above generic diagnosis.

*Occurrence*.—Lower Mississippian, Coral Ridge member of New Providence Formation, east quarry of Coral Ridge Brick Company yards, Coral Ridge, southwestern Jefferson County, Kentucky (127,323). New Providence Formation, Bedford County, Tennessee (33,080). New Providence Formation, headwaters of Medlock's Creek, 10 miles south of Lebanon, Marion County, Kentucky (S3,751).

*Types*.—Plesiotypes, S3,751, 19 specimens, Springer collection, filed under the name *Orbitremites granulatus*, and on label is "Keokuk, *Granulata Troosti?*, Marion Co., Ky., 10 miles south of Lebanon," from the New Providence Formation; 33,077, topotypes, two specimens of the

Troost collection, labelled *Granatocrinus globosus*, from the New Providence Formation, Bedford County, Tennessee; 33,078, topotypes, labelled *Granatocrinites granularis* Troost, from Shelbyville, Tennessee; 33,080, three topotypes, labelled *Granatocrinus cidariformis*, Troost collection, New Providence Formation, Bedford County, Tennessee; and 127,322, 127,323, two specimens from the Conkin collection, Coral Ridge, Kentucky, labelled *Orbitremites oppelti*. All of the above are in the U. S. National Museum, Washington, and are here considered to be conspecific. Plesiotype, S5,746, one specimen, from Mason County, Kentucky, University of Michigan, Ann Arbor.

**GRANATOCRINUS KENTUCKYENSIS (Conkin)**

Plate 40, figures 1-6; text-fig. 143

*Orbitremites kentuckyensis* CONKIN, 1957, pp. 135-137, pl. 13, figs. 1-20; text-figs. 1B, 1C, 1E.

*Description*.—CONKIN's unfigured paratype no. 1 is described. Calyx pyritic, flattened elliptical in side view, circular in top view, 15.5 mm. long by 19.5 mm. wide, with flattened summit, constricted concave base, and periphery at mid-height. Stem not preserved. Basal circlet 2 to 3 mm. in diameter, pentagonal in aboral view, not well preserved, in deep basal concavity that is 5 mm. wide. Radials five, pentagonal in side view, each 12 mm. long by 11 mm. wide, extending adorally beyond mid-height, strongly recurved below in basal concavity, with narrow, moderately deep sinus 12 mm. long by 2.5 mm. wide, with depressed radiodeltoid sutures; radials overlapping deltoids at a high angle.

Deltoids four, broadly arrow-shaped, long, extending to mid-height, each 11 mm. long by 9 mm. wide, notched in the adoral tip by two elongate slitlike spiracles along ambulacral margins. On the anal side, the broadly pentagonal V-shaped epideltoid is adjacent to the oral opening, with a triangular anispiracle between it and the elongate pentagonal hypodeltoid. The oral opening is surrounded by four deltoid lips and the epideltoid, and there are eight spiracles and anispiracle, or nine openings around the oral aperture.

Ambulacra five, linear, depressed, each 26 mm. long by 2.5 mm. wide, recurved below, with approximately 25 side plates in a space of 10 mm. along an ambulacrum. Detailed features of ambulacra obscure, but the lancet appears to be covered by side plates. Calyx plates with wide, high, granular growth ridges parallel to plate margins, termed chevrons on deltoids, and dalaths on radials.

*Occurrence*.—Lower Mississippian, lower New Providence Formation, upper part of Coral Ridge member, east quarry of Coral Ridge Brick & Tile Company, Coral Ridge, Jefferson County, Kentucky.

*Types*.—Paratypes, nos. 1 (139,620) and 2 (139,619) of CONKIN (1957) unfigured, two specimens, U.S. National Museum, Washington.

## Genus HETEROBLASTUS Etheridge & Carpenter, 1886

*Type-species*, by original designation.—*Heteroblastus cumberlandi* ETHERIDGE & CARPENTER, 1886.

*Generic diagnosis*.—Spiraculate blastoids with nine spiracles, or eight spiracles and anispiracle, apparently with anispiracle located between epideltoid and hypodeltoid, lancet covered by side plates, probably more than one fold on each side of an ambulacrum, with one pore between side plates, radials overlapped by deltoids, deltoids long, with high coronal processes, and calyx form elliptical in side view. *Lower Carboniferous*, England.

*Remarks*.—The genus *Heteroblastus* may have been derived from a form similar to *Crioblastus*, in which the deltoids migrated aborally and overlapped the radial limbs.

### HETEROBLASTUS CUMBERLANDI Etheridge & Carpenter

Plate 39, figures 1-2; text-figs. 144-146

*Heteroblastus cumberlandi* ETHERIDGE & CARPENTER, 1886, pp. 141, 237, pl. 6, figs. 1-6.

*Description*.—Calyx calcitic, fragmentary, crushed, 10 mm. long by 7 mm. wide, with base destroyed. Radials each 4 mm. long by 3 mm. wide, deltoids each 7 mm. long by 2.5 mm. wide, overlapping radials. Ambulacra five, long, linear, each 9 mm. long by 1.5 mm. wide, with lancet covered by side plates, 30 side plates in space of 10 mm. along an ambulacrum, and one pore between plates. Two small spiracles are excavated in the adoral tips of each deltoid, one spiracle on either side of the base of the high coronal process. Side plates appear to be normally disposed, with an outer side plate on the ab-medial-adoral corner of each primary side plate, and pores present along deltoid and ambulacral margins. The remainder of the generic diagnosis was taken from ETHERIDGE & CARPENTER (1886).

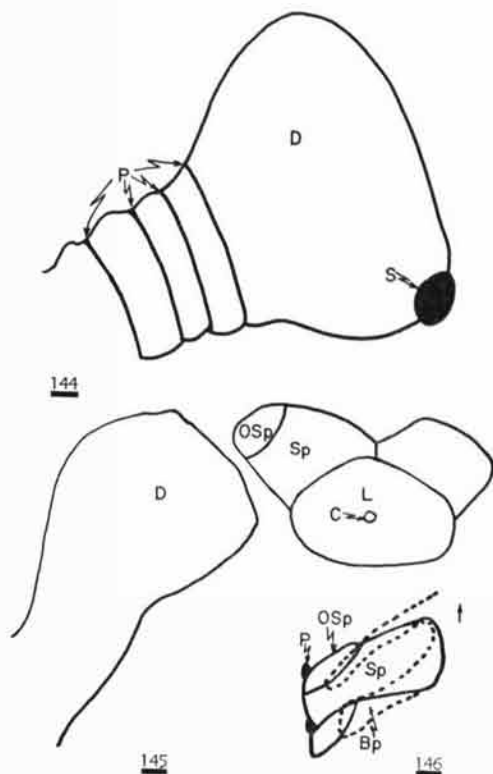
*Occurrence*.—Lower Carboniferous, Yoredale Shale, near Hexham, Northumberland, England.

*Type*.—Topotype, S3,776, one specimen, Springer collection, U. S. National Museum, Washington.

### Genus LOPHOBLASTUS Rowley, 1901

*Type-species*, by original designation.—*Codonites inopinatus* ROWLEY & HARE, 1891.

*Generic diagnosis*.—Spiraculate blastoids with nine spiracles, or eight spiracles and an anispiracle which is located between an epideltoid and hooded hypodeltoid, two cryptodeltoids may be present, three hydrosphere folds on each side of an ambulacrum, lancet exposed one-third of its width, with one pore between adjacent side plates along deltoid and radial margins, deltoids overlapping radials; shape ellipsoidal. *Mississippian*, Missouri.



FIGURES 144-146. *Heteroblastus cumberlandi* ETHERIDGE & CARPENTER, Lower Carboniferous, England (U.S. Natl. Mus. no. S3,776).—144. Adoral tip of deltoid, side view showing elongate pores,  $\times 37.5$ .—145. Cross section of ambulacrum,  $\times 37.5$ .—146. Part of ambulacrum, showing side plates,  $\times 37.5$ . [Explanation.—Bp, brachiolar pit; C, canal (radial); D, deltoid; L, lancet; OSp, outer side plate; P, pore; S, spiracle; Sp, main side plate.]

*Remarks*.—The genus *Lophoblastus* may have been derived from a form similar to *Schizotremites* that became elliptical in shape and developed nine definite spiracular openings, with reduction of hydrosphere folds to three.

### LOPHOBLASTUS INOPINATUS (Rowley & Hare)

Plate 45, figures 1-9; text-figs. 147-150

*Codonites inopinatus* ROWLEY & HARE, 1891, p. 100, pl. 2, figs. 11-12; p. 118, pl. 3, fig. 17.

*Description*.—Calyx subellipsoidal, 8.5 mm. long by 6.5 mm. wide, with rounded summit, convex base, periphery at mid-height, vault 7 mm. long, pelvis 1.5 mm. long, and pelvic angle 120 degrees. Stem round, small, crenellar, about 1 mm. in diameter, attached to a raised pentagonal area of the basal circlet, which is convex, pentagonal in basal view, 1 mm. long by 2.5 mm. wide, with azygous basal broadly quadrangular and other two basals pentagonal, each with fine growth striae parallel to plate mar-

gins. Radials five, each hexagonal in side view, 5 mm. long by 3.5 mm. wide, with shallow sinus 4 mm. long by 1.5 mm. wide, with growth striae subparallel to margins. Deltoids overlap radials.

Deltoids four, lancet-shaped, each 3 mm. long by 2 mm. wide, notched at the adoral tip by two spiracles along ambulacral margins. On the anal side there are two deltoids; a horseshoe-shaped or V-shaped epideltoid adjacent to the oral opening, curving around the adoral part of the anal opening on three sides, and a large lancet-shaped hypodeltoid on the aboral side of the anal opening, extended ventrally into a hood or coronal process. Two cryptodeltoids may be present. The anal spiracles or hydrospire canals are separated internally from the anal opening by deltoid septa, but externally only one anispiracle is visible. Thus there are nine openings around the oral opening, consisting of eight spiracles and the anispiracle. There are three hydrospire folds on each side of an ambulacrum.

Ambulacra five, broadly linear, each 7.5 mm. long by 1.5 mm. wide, each lancet plate being exposed one-third or more of its width along the middle of each ambulacrum. The side plates are normally disposed, with 30 side plates in a space of 10 mm. along an ambulacrum, one pore between adjacent side plates notched in the deltoid and radial ambulacral margins, and three main cover-plate sockets to each side plate along the main food groove. In addition to fine growth striae, the calyx plates are ornamented by coarse ridges subparallel to the plate margins.

*Remarks.*—The type specimens are grouped together in two glass vials and it has not been possible to find all of the figured specimens. There are 37 specimens in all, including the holotype; the above description applies to specimen RX-134h. The other specimens resemble this one closely and all belong to the same species.

*Occurrence.*—Lower Mississippian, lower Burlington Limestone, in chert, Louisiana, Missouri.

*Types.*—Holotype, RX-134; paratypes, RX-134a-i (36 specimens). Holotype unfigured but almost same as 134h, herein figured on pl. 45, figs. 1-3. RX-134a, ROWLEY (1901), pl. 28, fig. 8, herein figured on pl. 45, figs. 4, 6, 8. RX-134b, polished section showing hydrospires.

RX-134c shows area of stem attachment. RX-134d, ROWLEY & HARE (1891), pl. 3, fig. 17, refigured by ROWLEY (1901), pl. 28, fig. 5, herein figured on pl. 45, fig. 7. RX-134e, ROWLEY (1900), pl. 2, fig. 18. RX-134f, ROWLEY (1901), pl. 28, figs. 6-7. RX-134g, 18 unfigured types. RX-134h was provisionally selected as lectotype until recently when the holotype was found. RX-134i, 11 specimens in a glass vial, with the holotype. Rowley collection, Department of Geology, University of Illinois.

### Genus MESOBLASTUS Etheridge & Carpenter, 1886

*Type-species*, by original designation.—*Pentatremitites crenulatus* ROEMER, 1851.

*Generic diagnosis.*—Spiraculate blastoids with nine spiracles or eight spiracles and an anispiracle, with superdeltoid, two cryptodeltoids, and hypodeltoid on the anal side, and three hydrospire folds on each side of an ambulacrum; thick hydrospire plate present; approximately five hydrospire pores to each side plate infolded into a double row; lancet covered by side plates except at adoral end; pores absent along deltoid margins; radials overlapping deltoids; calyx form subglobular. *Lower Carboniferous*, Belgium, England, Germany.

*Remarks.*—The genus *Mesoblastus* may have been derived from a form similar to *Pentremitella*, but until the latter is better understood this is only a guess. *Pentremitella* appears to have characters similar to *Schizotremites* but the latter is not well understood at present.

### MESOBLASTUS CRENULATUS (Roemer)

Plate 47, figures 1-13; text-figs. 151-157

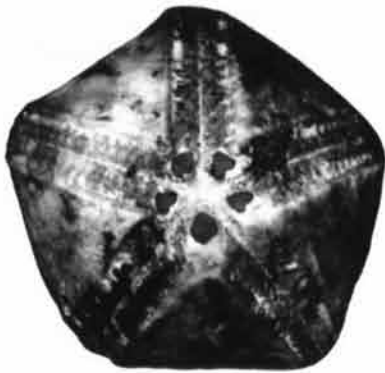
*Pentatremitites crenulatus* ROEMER, 1851, p. 366, pl. 4, figs. 15a-d.

*Description.*—Calyx calcitic, subglobular in side view, rounded pentagonal in top view, 6 mm. long by 7.5 mm. wide, with flattened summit, flat to slightly convex base, and periphery below mid-height. Stem round, 0.75 mm. in diameter, on raised hexagonal area of basals, with about 30 crenellae extending almost to central round lumen. Basal cirlet pentagonal in aboral view, slightly

## EXPLANATION OF PLATE 23

FIGURE	PAGE
1-3. <i>Cordyloblastus gilbertsoni</i> (ETHERIDGE & CARPENTER), plesiotype, 313, Schultze coll., Harvard Mus. Comp. Zoölogy; Middle Devonian, Pelm, Germany; oral, "D" ambulacral, aboral views of a specimen that closely resembles calyx figured by Schultze (1867, pl. 13, fig. 7c)	57
4-8. <i>Cordyloblastus acutangulus</i> (SCHULTZE), holotype, 325, Schultze coll. (labelled type), Harvard Mus. Comp. Zoölogy; Middle Devonian, Eifel, Pelm, Germany; 4-6,	

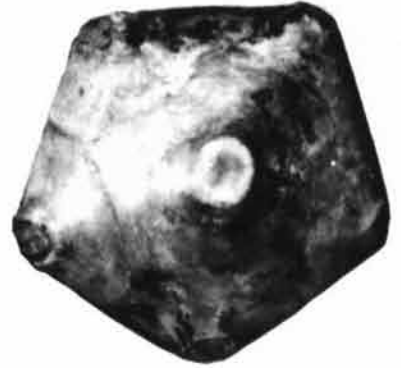
oral, "D" ambulacral, aboral views of a specimen exactly like type figured by Schultze (1867, pl. 13, fig. 6) ( $\times 2.5$ ) [another specimen in the same tray is identical with SCHULTZE's, fig. 6c; the summit of this specimen is ground and polished]; 7, detail view of oral area of specimen shown in fig. 4 ( $\times 10.5$ ); 8, detail view of "B" ambulacrum showing pores between plates along raised ambulacral margins and lancet completely covered by side plates ( $\times 10.6$ )



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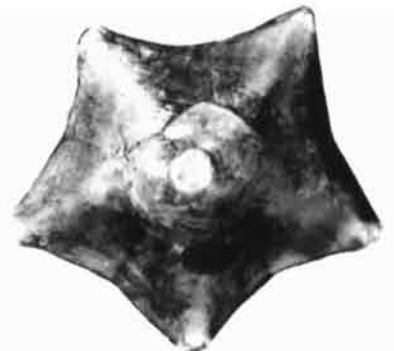
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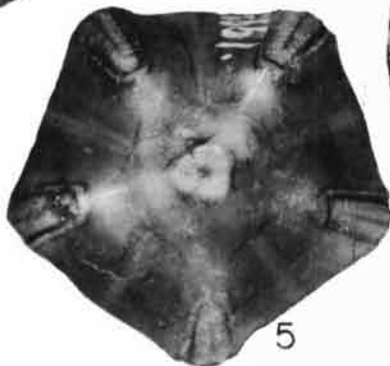
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convex, 4 mm. wide, with three normally disposed basals, each with a prominent central rounded ridge. Radials five, elongate subquadrangular, recurved below, each 5.5 mm. long by 4 mm. wide, with long, wide, shallow sinus 5 mm. long by 1.5 mm. wide; radials overlapping deltoids.

Deltoids four, short, lancet-shaped, barely visible in side view, each 1.75 mm. long by 1.5 mm. wide, the adoral tip of each notched by two large elliptical spiracles with a flat, wide median septum between. Each deltoid lip has approximately 14 prominent cover-plate sockets on its oral and lancet margins. On the anal side there are four deltoid plates, a superdeltoid, two cryptodeltoids, and a hypodeltoid. The V-shaped superdeltoid is adjacent to the oral opening and together with the other four deltoid lips helps to surround the oral opening. The two bluntly lenticular cryptodeltoids, adjacent to the side plates and below the hypodeltoid, separate the anal opening internally from the anal spiracles. Internally the cryptodeltoids are overlapped by the adjacent radial limbs. The pentagonal hypodeltoid abuts against the radial limbs and covers the aboral end of the anal opening and adjacent hydropsire canals. Thus nine orifices surround the oral opening—eight spiracles and the anispiracle. Three hydrospire folds are present on each side of an ambulacrum, ending admedially in a thick hydrospire plate. Approximately five hydrospire pores to each side plate are seen, three almost hidden being adjacent to the side plate, and two others between but slightly abmedial to the first three, visible, and slightly outward from them. The latter two pores appear to branch from the former three, forming a more or less connected system. Pores are absent along the deltoid margins.

Ambulacra five, broadly linear, recurved below, each 7 mm. long by 1.5 mm. wide, with lancet covered by side plates from mid-height downward but fully exposed at adoral end. Side plates are normally disposed, with 26 in a space of 10 mm. along an ambulacrum; a triangular outer side plate occurs on the bevelled abmedial-adoral corner of each primary side plate, with six main cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented by fine growth striae parallel to plate margins, except on the deltoids. The deltoids have coarse granules arranged along growth lines.

*Occurrence.*—Lower Carboniferous, Tournaisian, Tournai, Belgium.

*Types.*—Topotypes?, 5,196, two specimens, Krantz collection, one specimen fragmentary, one almost perfect; 19,083, four specimens labelled *Orophocrinus puzos*, Gurley collection, University of Chicago. The above description is mainly based on specimen 5,196. Topotypes?, 536, 23 specimens, old no. 2,326, deKoninck collection, Harvard Museum of Comparative Zoölogy, Cambridge, Mass. Topotypes?, S3,775, 24 specimens, Springer collection, from Lower Carboniferous shale of the "Mountain Limestone" of Tournai, Belgium; sent by Dr. A. Krantz of Bonn, Germany, to U. S. National Museum, Washington.

### Genus METABLASTUS Etheridge & Carpenter, 1886

*Type-species*, by original designation.—*Pentremites lineatus* SHUMARD, 1858.

*Generic diagnosis.*—Spiraculate blastoids with five paired spiracles, or four paired spiracles in addition to a paired anispiracle, with superdeltoid, two cryptodeltoids, and a hypodeltoid plate on the anal side, lancet covered by side plates, one pore between adjacent side plates along deltoid and radial margins, radials overlapping deltoids, four or five hydrospire folds on each side of an ambulacrum, radial plates thin, pelvis long, conical, deltoids not visible in side view but large hypodeltoid visible in side view; calyx form conical, with aborally directed ambulacra. *Mississippiian*, Illinois, Iowa, Indiana, Missouri, Kentucky.

*Remarks.*—The genus *Metablastus* was probably derived from a form similar to *Troosticrinus* in which the pelvis became elongate and ambulacra moved downward. The type species occurs in the Burlington Limestone (Osagian) and is different from the Keokuk (Osagian), Warsaw, and Salem (Meramecian) species. The latter group have flaring radial bodies, whereas the type does not. The latter group probably represents intermediate stages between *Metablastus* and *Tricoelocrinus* but are here classed with *Metablastus* because the radial plates of this group are thin and there are four or five hydrospire folds on each side

## EXPLANATION OF PLATE 24

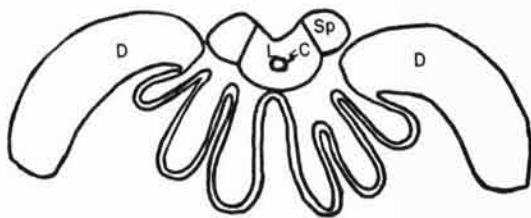
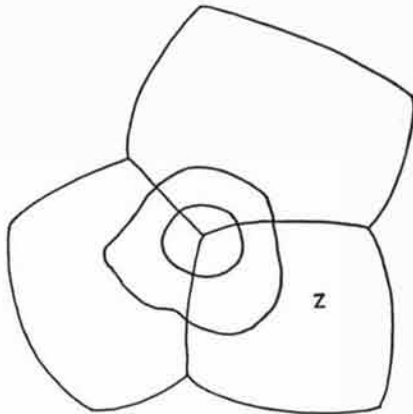
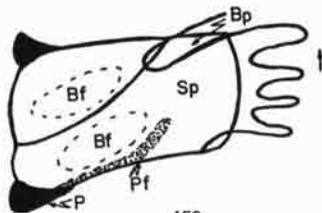
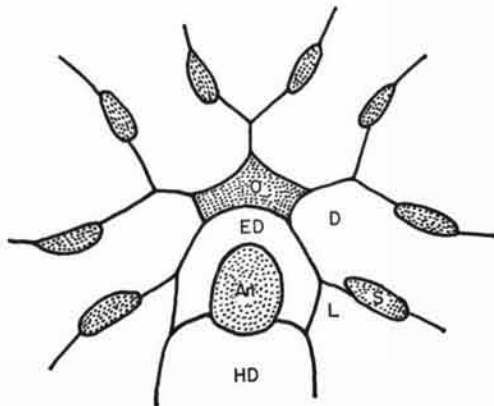
FIGURE	PAGE
1-2, 6. <i>Devonoblastus leda</i> (HALL), syntypes, 451 (figs. 1, 6), 452 (fig. 2), New York State Mus., Albany; Middle Devonian, Hamilton Shale, western New York; 1, aboral view ( $\times 8.4$ ); 2, ambulacrum showing side plates ( $\times 56.5$ ); 6, side view of calyx ( $\times 6.4$ )	62
3-5. <i>Devonoblastus whiteavesi</i> REIMANN, plesiotype, 3,661, Geol. Survey Canada, figured by WHITEAVES (1889, pl. 14, figs. 3a-d,f); Middle Devonian, Hamilton Group, near Thedford, Ontario oral, "D" ambulacral aboral views of nearly perfect specimens (all $\times 3.3$ )	62

of an ambulacrum, extending a long distance down the sides of the radial limbs.

**METABLASTUS LINEATUS (Shumard)**

Plate 19, figures 6-8; text-figs. 158-160

*Pentremites lineatus* SHUMARD, 1858, p. 241, pl. 9, figs. 3a-b.



*Description.*—The new holotype (neotype) is 33 mm. long by 12 mm. wide, vault 13 mm. long, pelvis 20 mm. long, pelvic angle 25 degrees, and shape of calyx in side view elongate conical, with truncated summit. Pentagonal in top view. Basal circlet conical in side view, 10.5 mm. long, with three normally disposed basals. Radials 22 mm. long, overlapping deltoids. Deltoids not visible in side view except where seen along ambulacral margins.

Deltoids four, triangular, confined to summit, each with a paired spiracle at its adoral tip. On the anal side there are four deltoid plates, a superdeltoid occurring next to the oral opening with two elongate cryptodeltoids, each 2 mm. long resting on it and adjacent radial limbs projecting over them. The pentagonal hypodeltoid, 4 mm. long by 3 mm. wide, rests on the cryptodeltoids and abuts against the adjacent radial limbs. A paired anispiracle is present on the anal side; thus five paired spiracles occur on the summit (or four spiracles in addition to a paired anispiracle). Four hydrospire folds are seen on each side of an ambulacrum.

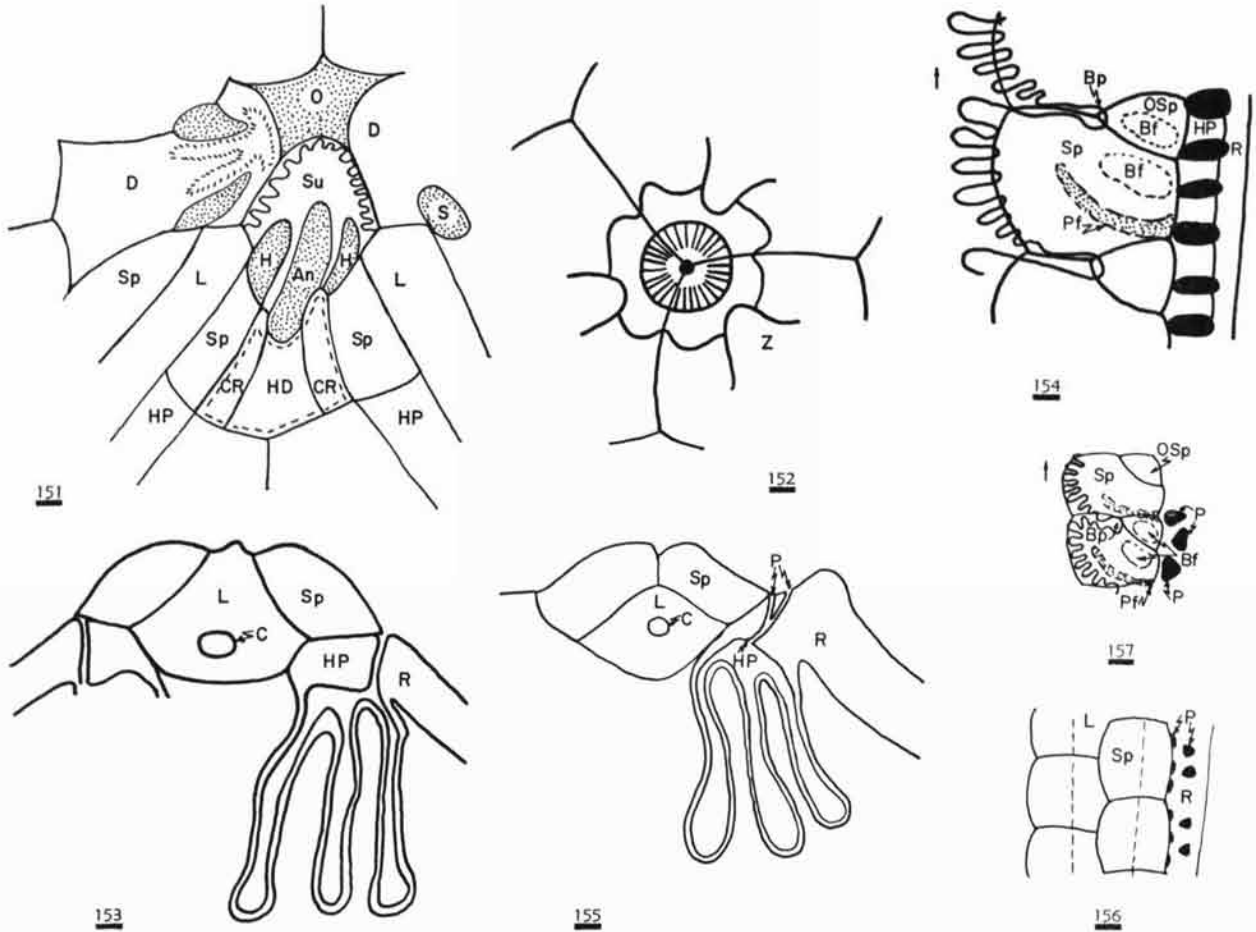
Ambulacra five, linear, each 13 mm. long by 1 mm. wide, with lancet covered by side plates, and 24 side plates in a length of 10 mm. along an ambulacrum, with four cover-plate sockets to each side plate along ambulacral groove. The ambulacra are set deep within narrow sinus walls. The side plates are normally disposed, with one pore between adjacent side plates along the deltoid and radial margins. The radial plates are thin, and the hydrospires extend almost the length of the ambulacra. The surfaces of the calyx plates are ornamented by fine growth lines parallel to plate margins.

*Remarks.*—The type specimen was probably destroyed and therefore a new holotype and paratype have been herein selected, described above.

*Occurrence.*—Lower Mississippian, upper part of Burlington Limestone, Sagetown, Illinois.

*Types.*—Neotypes, S4,958 (new holotype), and S4,957 (new paratype), Springer collection, old no. S3,628 (holotype in slab and paratype a cut section), U. S. National Museum, Washington.

FIGURES 147-150. *Lophoblastus inopinatus* (ROWLEY & HARE), Lower Mississippian, Burlington Limestone, Louisiana, Missouri (Univ. Illinois, no. RX-134h).—147. Summit area,  $\times 15$ .—148. Basal area,  $\times 15$ .—149. Cross section of ambulacrum,  $\times 15$ .—150. Part of "A" ambulacrum, showing side plates,  $\times 45$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; C, canal (radial); D, deltoid; ED, epideltoid; HD, hypodeltoid; L, lancet; O, oral opening; P, pore; Pf, pore furrow; S, spiracle; Sp, main side plate; Z, azygous basal.]



FIGURES 151-157. *Mesoblastus crenulatus* (ROEMER), Lower Carboniferous, Tournaisian, Tournai, Belgium (U.S. Natl. Mus., no. S3,775; Univ. Chicago, nos. 5,196, 19,083).

151. Anal area (no. 5,196),  $\times 15$ .—152. Basal area, showing stem impression (no. 5,196),  $\times 15$ .—153. Partial cross section of "C" ambulacrum, aboral view (no. 19,083),  $\times 15$ .—154. Part of "E" ambulacrum, showing side plates (no. 5,196),  $\times 45$ .—155. Partial cross section of "B" ambulacrum, aboral view (no. S3,775)  $\times 30$ .—156. Part of ambulacrum showing side plates, edges of subjacent lancet indicated by broken lines (no.

S3,775),  $\times 17.5$ .—157. Part of ambulacrum, showing side plates (no. S3,775),  $\times 17.5$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; C, canal (radial); CR, cryptodeltoid; D, deltoid; H, hydrospire; HD, hypodeltoid; HP, hydrospire plate; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pfw, pore furrow; R, radial S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]

### METABLASTUS BIPYRAMIDALIS (Hall)

Plate 51, figure 6

*Pentremites bipyramidalis* HALL, 1858, p. 607, pl. 15, fig. 2 (type species of *Saccoblastus* Hambach, 1903).

**Description.**—This species may be distinguished from others by comparing the length of the pelvis against the width and length of the specimen and noting that the radial bodies flare. The pelvis is short and the specimen is wide. This combination is not seen in other species.

**Occurrence.**—Mississippian, Keokuk Limestone, Boonville, Missouri.

**Type.**—Holotype, 7,226/1, American Museum of Natural History, New York, N. Y.

### METABLASTUS NITIDULUS (Miller & Gurley)

Plate 51, figures 3-4, 7

*Troostocrinus nitidulus* MILLER & GURLEY, 1890, 1891, p. 373, pl. 9, figs. 14-15; pl. 10, fig. 14.

**Description.**—The description is based on one of the syntypes. Calyx silicified, bipyramidal in side view, with flat summit and base, pentagonal in top view, 10.5 mm. long by 4 mm. wide, vault 3 mm. long, pelvis 7.5 mm. long, pelvic angle on radial bodies 15 degrees, with

periphery well above mid-height at radial lips. The stem impression appears to be round, 0.75 mm. in diameter, in slight concavity. Basal circling short, flattened conical in side view, triangular in basal view, 3 mm. long by 3 mm. wide, with flat triangular aboral base each side of which is 1.5 mm. wide. Radials five, hexagonal in side view, each 8.5 mm. long by 2.5 mm. wide, with short, wide, deep sinus 3 mm. long by 1.75 mm. wide by 0.5 mm. deep, with limbs shorter on anal side than on other sides; radials overlapping deltoids. Radials and basals flare.

Deltoids four, short, triangular, barely visible in side view, each 1.5 mm. long by 1 mm. wide, with a paired spiracle at adoral ends of each. On the anal side there are four deltoid plates—a superdeltoid adjacent to the oral opening, homologous with the deltoid lip of each of the other four deltoids, two cryptodeltoids resting on the aboral surface of the superdeltoid, internally separating the anal opening from the adjacent hydrospire canals, and a hypodeltoid that covers the cryptodeltoids and abuts against the adjacent radial limbs. A paired anispiracle is present on the anal side; thus five paired spiracles occur around the oral opening, that is, four paired spiracles and a paired anispiracle.

Ambulacra five, short, linear, each 4 mm. long by 1 mm. wide, with lancet covered by side plates, and 40 side plates in space of 10 mm. along an ambulacrum. Side plates not well preserved but appearing to be normally arranged. Surfaces of calyx plates ornamented by fine growth lines subparallel to plate margins.

*Occurrence.*—Upper Mississippian, Salem Limestone, Lanesville, Indiana.

*Types.*—Syntypes, 6,284, two specimens, Gurley collection, Walker Museum, University of Chicago.

#### METABLASTUS VARSOUVIENSIS (Worthen)

Plate 19, figure 9; plate 50, figures 1-3; plate 52, figure 6

*Pentremites (Tricoelocrinus) varsouviensis* MEEK & WORTHEN, 1875, p. 521, pl. 31, figs. 8-9.

*Description.*—The types are fragmentary. The small syntype is 11.5 mm. long by 6 mm. wide, with vault 6.5

mm. long, pelvis 5 mm. long, and pelvic angle 65 degrees. The large syntype is 15 mm. long by 9 mm. wide, with basals destroyed. The above proportions serve to distinguish this species from all others. Radial bodies and basals slightly flared.

*Occurrence.*—Upper Mississippian, Warsaw beds, Monroe County, Illinois.

*Types.*—Syntypes, 1,885 (old no. of the Illinois State Museum), two specimens, Worthen collection, Illinois Geological Survey, Urbana.

#### METABLASTUS WACHSMUTHI (Gurley)

Plate 51, figures 1-2, 5

*Troostocrinus wachsmuthi* GURLEY, 1884, p. 1.

*Description.*—Calyx calcitic, poorly preserved, bipyramidal in side view, 42 mm. long by 16 mm. wide, with vault 13.5 mm. long, pelvis 28.5 mm. long, pelvic angle 25 degrees, periphery at radial lips above mid-height, and with flat wide triangular base 5 mm. wide on each side. Stem impression not well preserved. Basal circling long, flattened basally, conical in side view, pentagonal in basal view at basiradial sutures, gradually tapering to an equilateral triangle at base. Radials five, long, hexagonal in side view, each 28 mm. long by 8.5 mm. wide, with short, wide, deep sinus 12 mm. long by 4 mm. wide by 2 mm. deep; radials overlapping deltoids. Radial bodies and basals slightly flaring.

Deltoids four, short, not visible in side view, triangular, each 4 mm. long by 2 mm. wide, with adoral tips notched by a V-shaped paired spiracle. On the anal side are four anal deltoids, a superdeltoid, two cryptodeltoids, and a hypodeltoid. The short, wide, curved superdeltoid is adjacent to the oral opening, overlapped on its aboral surface by the two cryptodeltoids which internally separate the anal opening from the adjacent hydrospire canals. The pentagonal hypodeltoid is missing but the facets for its reception are present. The adoral ends of the radial limbs on the anal side overlap the cryptodeltoids, and the hypodeltoid covers the cryptodeltoids on the

### EXPLANATION OF PLATE 25

#### FIGURE

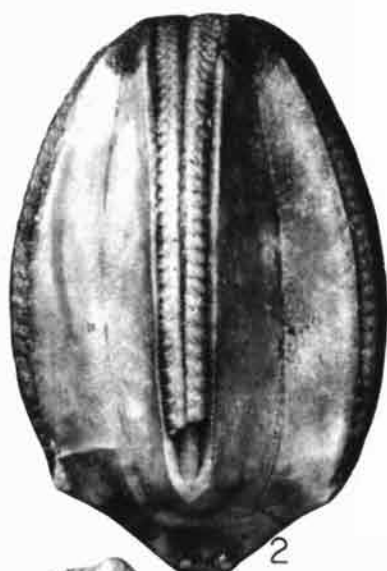
1-12. *Devonoblastus whiteavesi* REIMANN, Middle Devonian, Hungry Hollow Formation (coral zone) Ontario, (except fig. 6).—1-3, 7. Topotype, 35,036, Charles Southworth coll. Univ. Michigan; Hungry Hollow of Ausable River Valley, 2.5 miles northeast of Arkona, Ontario; 1-3, oral, "D" ambulacral, aboral views ( $\times 4.6$ ); 7, detail oral view of same specimen ( $\times 17$ ).—4. Plesiotype, 34,467, Charles Southworth coll. Univ. Michigan; tileyard about 0.5 mile north of Thedford, Ontario; oral view of polished summit showing anal opening (black) with cryptodeltoids on either side and superdeltoid on adoral side ( $\times 13.2$ ).—5, 9. Plesiotype, E13,065, Charles Southworth coll.

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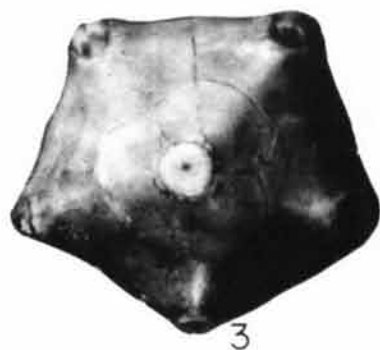
Buffalo Soc. Nat. Sci.; near Thedford, Ontario; 5, hydrospires from interior side ( $\times 8$ ); 9, aboral view of thin section with "E" ambulacrum directed upward ( $\times 8.2$ ).—6. Plesiotype, (accession no.) 142,025, U.S. Natl. Mus.; Middle Devonian, Tichenor Limestone (shaly layer), Cazenovia Creek, Springbrook, Erie County, New York; detail ambulacral view ( $\times 11$ ).—8. Plesiotype, S4,648, Springer coll., U.S. Natl. Mus.; Ausable River area, 2 miles east of Arkona, Ontario; oral view of polished section with "C" ambulacrum directed downward ( $\times 5.6$ ).—10-12. Plesiotype, S4,144, Springer coll., U.S. Natl. Mus.; Marsh's Mill, Arkona, Ontario; aboral, "D" ambulacral, oral views ( $\times 4.4$ )



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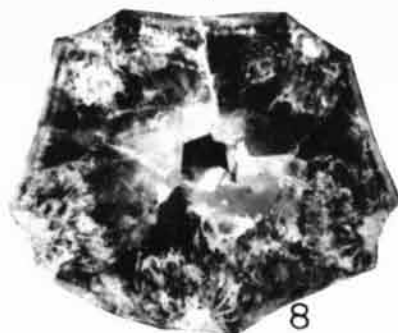
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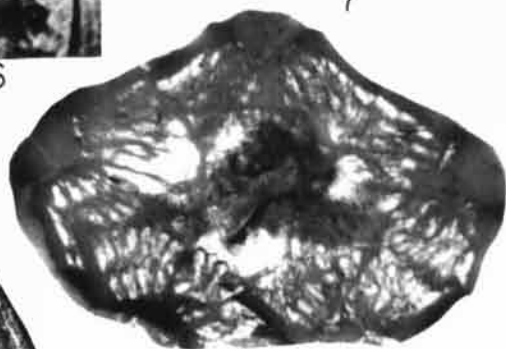
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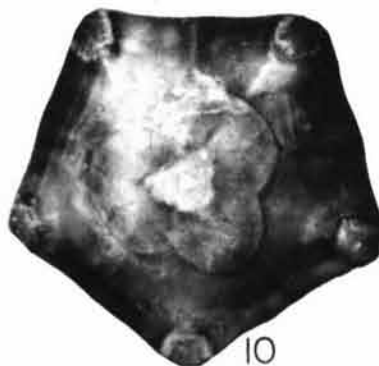
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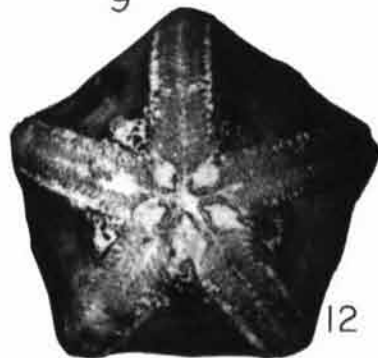
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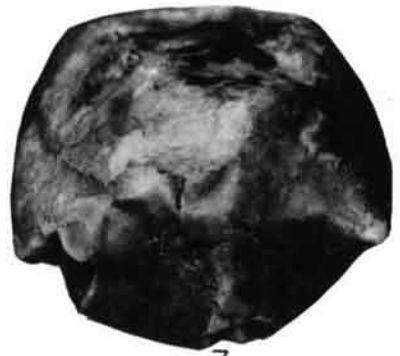
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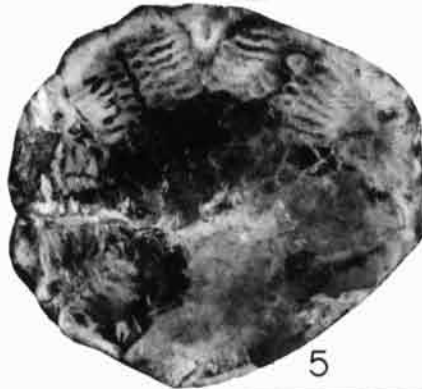
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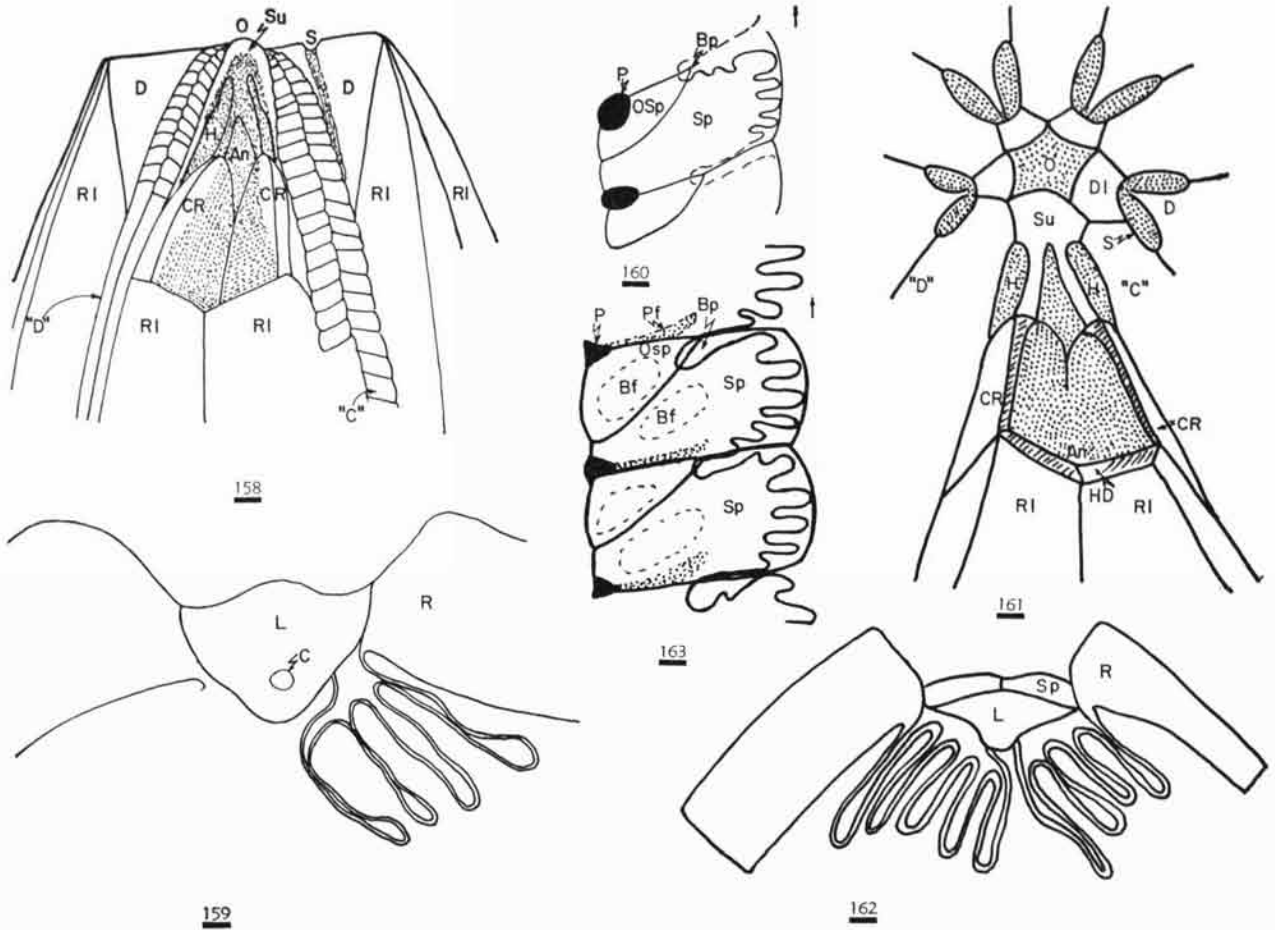
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FIGURES 158-163. Species of *Metablastus* ETHERIDGE & CARPENTER, Mississippian, Illinois, Missouri.

158-160. *M. lineatus* (SHUMARD), Burlington Limestone Sagetown, Ill. (U.S. Natl. Mus., nos. S4,957, S4,958); 158, anal side of holotype (S4,958),  $\times 7.5$ ; 159, partial cross section of "C" ambulacrum (S4,957),  $\times 20$ ; 160, part of "C" ambulacrum, showing side plates (S4,958),  $\times 40$ .  
 —161-163. *M. wortheni* (HALL), Warsaw Limestone, Boonville, Mo. (Buffalo Soc. Nat. Sci., unnumbered specimens); 161, summit and anal areas,  $\times 15$ ; 162, cross

section of "C" ambulacrum,  $\times 15$ ; 163, part of "B" ambulacrum, showing side plates,  $\times 45$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); CR, cryptodeltoid; "D," amb.; D, deltoid; DL, deltoid lip; H, hydrospire; HD, hypodeltoid; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; RI, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid.]

EXPLANATION OF PLATE 26

FIGURE	PAGE	
1-8. <i>Eleutheroocrinus casedayi</i> SHUMARD & YANDELL.—1-4, 6. Neotype (new holotype), S4,960, Springer coll., U.S. Natl. Mus.; Middle Devonian, Hamilton Group, Beargrass Creek, Jefferson County, Kentucky; 1-4, oral, "A" ambulacral, aboral, "D" ambulacral views ( $\times 4.3$ ); 6, detail view of "B" ambulacrum ( $\times 8$ ).—5. Neotype (new paratype), S4,963, Springer coll., U.S. Natl. Mus.; Middle Devonian, Hamilton Group, Louisville, Kentucky; oral view of polished section with "A" ambulacrum directed upward (figured by ETHERIDGE & CARPENTER, 1886, pl. 19, figure 3) ( $\times 7.2$ ).—7, 8. Plesiotype, 108, Univ. Illinois; Middle Devonian, Hamilton Group, Thedford, Ontario; 7, oral view of "D" ambulacrum ( $\times 20.8$ ); 8, side view of azygous basal plate ( $\times 22.1$ )		72

aboral side of the anal opening and abuts against the adjacent radial limbs. The cryptodeltoids are partially exposed externally and therefore a paired anispiracle occurs on the anal side. Thus, one paired anispiracle and four paired spiracles are recognized, a total of five paired spiracles around the oral opening.

Ambulacra five, short, linear, each 15 mm. long by 1.5 mm. wide, with lancet covered by side plates, and 22 side plates in a space of 10 mm. along an ambulacrum. Side plates poorly preserved but appearing to be normally disposed. The surfaces of calyx plates are worn but the ornamentation appears to consist of fine growth lines subparallel to plate margins.

*Occurrence.*—Upper Mississippian, Salem Limestone, Ellettsville, Indiana.

*Type.*—Holotype, 6,323, one specimen, Gurley collection, Walker Museum, University of Chicago.

#### METABLASTUS WORTHENI (Hall)

Plate 50, figures 4-9; text-figs. 161-163

*Pentremites wortheni* HALL, 1858, p. 606, pl. 15, fig. 1.

*Description.*—Calyx calcitic, 16 mm. long by 7.5 mm. wide, bipyramidal in side view, with flat summit and flat triangular base, pentagonal in oral view, with periphery well above mid-height at radial lips. Vault 6.5 mm. long, pelvis 9.5 mm. long, and pelvic angle 30 degrees. Stem impression appears to be round, about 1 mm. in diameter, crenellar, with small round lumen, resting on the flat triangular aboral surface. Basal circlet long, rounded pentagonal in basal view, 5 mm. long by 5 mm. wide, triangular at base, with three normally disposed basals, each of which has a high, wide ridge extending down the mid-line from the aboral end. The ridge on the azygous basal bifurcates at half the distance upward adorally, each resulting ridge extending to the radial lips of the "A" and "B" ambulacra, respectively. The ridge on each of the other two basals trifurcates, with the median ridge of each extending to the radial lips of the "C" and "E" ambulacra, respectively, and the lateral ridges extending to the lips of the "A," "B," and "D" ambulacra, respectively. These broad ridges give a bulge or flare to the pelvis in the region of the basiradial sutures, and are prevalent in the specimens of various species of *Metablastus* that occur in the Keokuk, Warsaw, and Salem formations. Radials five, each 10 mm. long by 3.5 mm. wide, broadly quadrangular in side view, with narrow, deep sinus 5 mm. long by 2 mm. wide; radials overlapping deltoids.

Deltoids four, short, not visible in side view, each notched at the adoral end by a V-shaped paired spiracle, with deltoid lips and lancet stipes adjacent to oral opening. On the anal side there are four deltoids—a superdeltoid, two cryptodeltoids, and a hypodeltoid. The superdeltoid is adjacent to the oral opening, with two internal

septa on its aboral surface separating the hydrosfire canals or anal spiracles from the anal opening. Resting on these two septa are the two cryptodeltoids, which are overlapped by the adoral ends of the adjacent radial limbs. The pentagonal hypodeltoid abuts against the radial limbs, covers the cryptodeltoids, and covers the aboral part of the anal opening. The cryptodeltoids are partially exposed and therefore a paired anispiracle is formed on the anal side. Thus, the oral opening is surrounded by five openings, consisting of four paired spiracles and an anal paired spiracle or paired anispiracle.

Ambulacra five, linear, each 7 mm. long by 1 mm. wide, with lancet completely covered by side plates, one pore between side plates along deltoid and radial margins, and 34 side plates in a space of 10 mm. along an ambulacrum. Side plates normally disposed. There are four or five hydrosfire folds on each side of an ambulacrum. The surfaces of the calyx plates are ornamented by fine growth lines subparallel to plate margins.

*Occurrence.*—Upper Mississippian, Warsaw Limestone, Boonville, Missouri.

*Types.*—Plesiotypes, four specimens, purchased from Wards 6-21-41, Buffalo Society of Natural Sciences, Buffalo, New York.

#### Genus MONADOBLASTUS Fay, n. gen.

*Type-species*, by original designation.—*Monadoblastus granulatus* FAY, n. sp.

*Generic diagnosis.*—Spiraculate blastoids with nine spiracles, or eight spiracles and an anispiracle, with anispiracle between epideltoid and hypodeltoid plates, with hydrosfire plates bearing approximately two pores to each side plate along radial margins, pores absent along deltoids, lancet covered by side plates except near adoral end, one hydrosfire fold on each side of an ambulacrum, radials overlapping deltoids, base concave, and form of calyx elliptical. *Mississippian*, New Mexico.

*Remarks.*—The genus *Monadoblastus* was probably derived from *Tanaoblastus* by reduction of the hydrosfires to one and invagination of the basal circlet.

#### MONADOBLASTUS GRANULOSUS Fay, n. sp.

Plate 37, figures 1-3, 10; text-figs. 164-167

*Description.*—Calyx calcitic, suboval in side view, subpentagonal in oral view, 5 mm. long by 4 mm. wide, with flat summit, concave base, and periphery at mid-height. Stem round, about 0.5 mm. in diameter, impression poorly preserved. Basal circlet pentagonal in aboral view, 1.25 mm. in diameter, with three normally disposed basal plates. Radials five, each broadly pentagonal in side view, recurved in basal concavity, 4 mm. long by 2.5 mm. wide, with radial sinus 4 mm. long by



1 mm. wide; radials overlapping deltoids. Each plate has growth lines subparallel to the margins except along the adoral half of ambulacral margins of the radial limbs where there are many aligned nodes or granules. There are five nodes along the adoral end of each radial limb, aligned parallel to the radiodeltoid suture, even with adjacent side plates. Approximately 14 parallel similar rows occur below the first, with diminishing number of nodes, each successive row even with a successive side plate, forming a triangular area of nodes along the ambulacral margins of each radial limb. Radials overlap deltoids.

Deltoids four, arrow-shaped, each 2 mm. long by 1.25 mm. wide, with exposed median septum on adoral end of each, thus forming two spiracles in the adoral end of each deltoid. On the anal side there appear to be two anal deltoids—a short hexagonal epideltoid adjacent to the oral opening and a long pentagonal hypodeltoid aboral to the anal opening. The anal spiracles are confluent with the anal opening, thus forming an anispiracle. Therefore, nine openings surround the oral aperture; they consist of eight spiracles and an anispiracle. The oral opening is surrounded by the four deltoid lips and the epideltoid.

Ambulacra five, each 6 mm. long by 1 mm. wide, linear, with lancet exposed along the middle one-third of its width near the adoral end and covered by the side plates at the aboral end of the lancet. Side plates normally disposed, with approximately two hydrosphere pores to each side plate between the hydrosphere plate and radial margins. Pores are absent along the deltoid margins. There are approximately 35 side plates in a space of 10 mm. along an ambulacrum. One hydrosphere fold is present on each side of an ambulacrum.

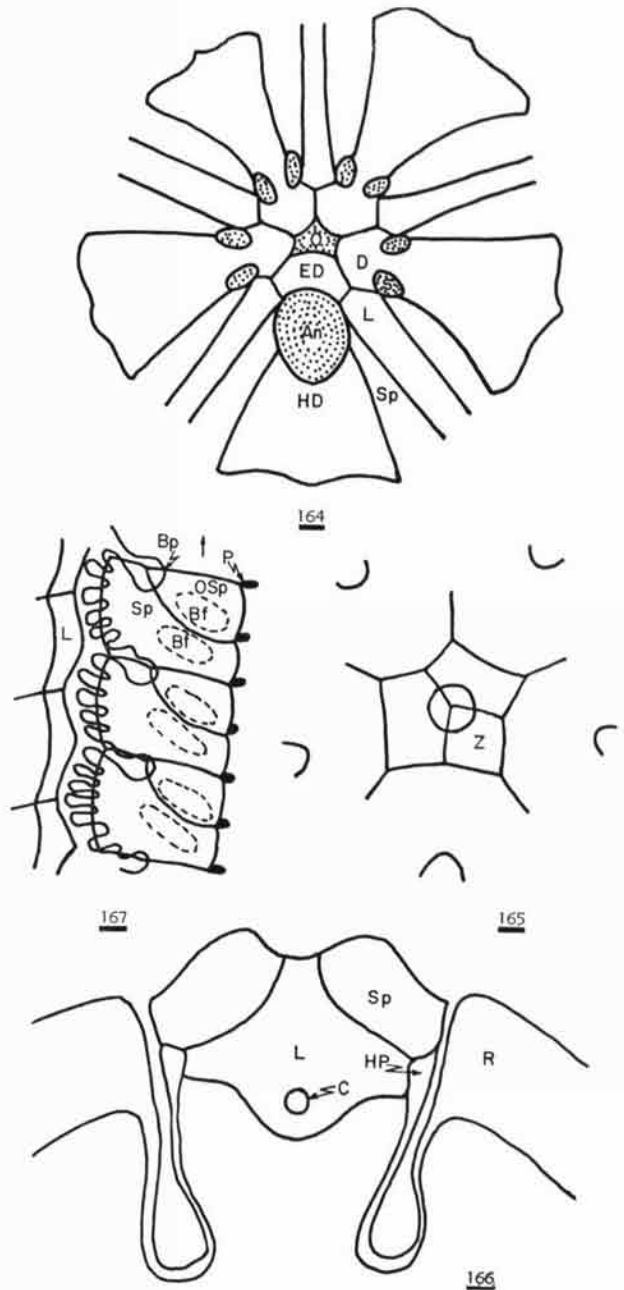
*Occurrence*.—Lower Mississippian, Lake Valley beds (?Nunn member), Lake Valley, New Mexico.

*Types*.—Holotype, E14,750, one small specimen described above; paratypes, E14,750, one cut section and one large specimen, Reimann collection (1941), Buffalo Society of Natural Sciences, Buffalo, New York.

### Genus NUCLEOCRINUS Conrad, 1842, emend.

*Type-species*, by original designation (monotypy).—*Nucleocrinus elegans* CONRAD, 1842.

*Generic diagnosis*.—Spiraculate blastoids with 11 openings around oral aperture, consisting of ten spiracles and anus separate, five large oral plates, three exposed anal plates or two cryptodeltoids and hypodeltoid, with hidden superdeltoid, anal oral abutting against cryptodeltoids, lancet covered by side plates, an inner side plate present, one pore between side plates along deltoid and radial margins, deltoids long, overlapping radials, with two hydrosphere folds on each



FIGURES 164-167. *Monadoblastus granulatus* FAY, n. sp., Lower Mississippian, Lake Valley beds, Lake Valley, N. Mexico (Buffalo Soc. Nat. Sci., no. E14,750).—164. Summit area,  $\times 15$ .—165. Basal area,  $\times 15$ .—166. Cross section of "A" ambulacrum, aboral view,  $\times 15$ .—167. Part of "B" ambulacrum, showing side plates,  $\times 45$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; C, canal (radial); D, deltoid; ED, epideltoid; HD, hypodeltoid; HP, hydrosphere plate; L, lancet; O, oral opening; OSp, outer side plate; P, pore; R, radial; S, spiracle; Sp, main side plate; Z, azygous basal.]

side of an ambulacrum with short hydrospire canal; form of calyx widely elliptical. *Devonian*, New York, Iowa, Ontario, Michigan.

*Remarks.*—The genus *Nucleocrinus* was probably derived from *Elaeocrinus* by suppression of the superdeltoid plate internally and reduction in the number of oral plates to five.

#### NUCLEOCRINUS ELEGANS Conrad

Plate 29, figures 4-6, 9; text-fig. 168

*Nucleocrinus elegans* CONRAD, 1842, p. 280, pl. 15, fig. 17.

*Description.*—Calyx calcitic, subglobular in side view, rounded pentagonal in top view, 8.5 mm. long by 11 mm. wide, with concave summit and concave base, and periphery above mid-height. Stem round, crenellar, 0.75 mm. in diameter, in basal concavity, with small central round lumen. Basal cirlet pentagonal in basal view, 1.5 mm. wide, in basal concavity, with three normally arranged basals. Radials five, short, pentagonal in side view, each 2.5 mm. long by 3.5 mm. wide, mostly on aboral surface, recurved below in basal concavity, with short, shallow sinus 1 mm. long by 1 mm. wide, and long flaring lips projected aborally into rounded ridges. Deltoids overlap radials. The surfaces of the basals and radials are ornamented by fine growth striae subparallel to plate margins.

Deltoids four, flattened lenticular, each 8 mm. long by 6 mm. wide, each with a broadly curved V-shaped radiodeltoid suture at the base, and with two hemielliptical spiracles at the adoral tip along ambulacral margins. The ornamentation of the deltoids consists of two parts, a central triangular portion with apex at adoral end, and two bordering lenticular portions. The central part has fine growth ridges parallel to the radiodeltoid suture and the marginal portions have narrow nodes that are aligned with the adjacent side plates at a high angle to the ambulacra. On the anal side three deltoids are visible, one deltoid being hidden. The visible deltoids are the two lenticular cryptodeltoids marginal to the ambulacra, with a central hypodeltoid that is subquadrangular in shape. The hypodeltoid, on the aboral side of the diamond-shaped anal opening has growth striae parallel

to the radiodeltoid suture and lateral margins, the central adoral portion being raised. The lenticular cryptodeltoids extend from the adoral and lateral sides of the anal opening to the radiodeltoid suture and have aligned nodes similar to those of the other four deltoids. The adoral tips of the cryptodeltoids abut against a large anal oral plate and each tip has a hemielliptical spiracle along its ambulacral margin. Thus, ten spiracles in addition to the anal opening occur around the oral aperture, which is covered by five large arrow-shaped oral plates, interambulacral in position. Internally, beneath the anal oral and between the adoral tips of the cryptodeltoids it is assumed that a suppressed superdeltoid is present. Hydrospire folds presumably two on each side of an ambulacrum, with a short hydrospire canal.

Ambulacra five, linear, recurved below, raised above calyx surface, each 12 mm. long by 1 mm. wide, with lancet covered by side plates, and 30 side plates in a space of 10 mm. along an ambulacrum. The side plates consist of a large raised subquadrangular primary side plate, with a large triangular secondary side plate on the adoral-abmedial bevelled corner of the primary side plate, and an inner side plate on the admedial side of each pore, broadly lenticular in shape. Approximately four main cover-plate sockets to each side plate occur along the main food groove, and one pore is present between adjacent side plates along the radial and deltoid margins.

*Occurrence.*—Middle Devonian, Hamilton beds, Moscow, New York.

*Type.*—Topotype, 19,049, one of two specimens, one of which is *Placoblastus lucina*, Gurley collection, Walker Museum, University of Chicago.

#### NUCLEOCRINUS MELONIFORMIS (Barris)

Plate 29, figures 1-3, 7-8; plate 30, figures 1-9; plate 32, figure 9; text-figs. 169-178

*Elaeocrinus meloniformis* BARRIS, 1883, p. 361; 1885-86, p. 91, pl. 1, fig. 3.

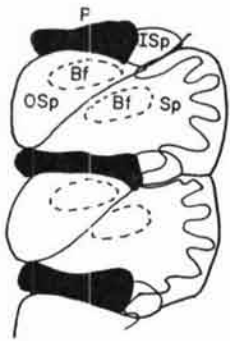
*Nucleocrinus meloniformis* THOMAS, 1924, p. 428, pl. 36, figs. 10-11.

*Description.*—Calyx calcitic, 10 mm. long by 7.5 mm. wide, with periphery above mid-height, vault 10 mm. long, pelvis 2 mm. long in oblique basal view, with pelvic

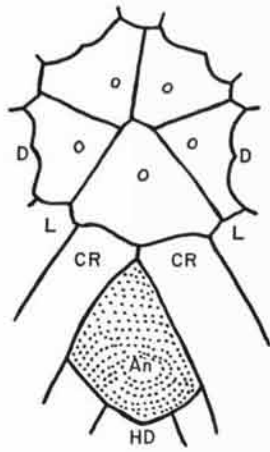
#### FIGURES 168-177. Species of *Nucleocrinus* CONRAD, Middle Devonian, New York, Ontario.

168. *N. elegans* CONRAD, Hamilton Group, Moscow, N.Y. (Univ. Chicago, no. 19,049); part of "B" ambulacrum showing main, inner, and outer side plates,  $\times 45$ .—169-177. *N. meloniformis* (BARRIS), Hungry Hollow Formation, Thedford and Arkona, Ont. (Geol. Survey Canada, no. 3,662a; Buffalo Soc. Nat. Sci., nos. E148, E15,939, E21,120); 169, summit and anal areas (no. 3,662a),  $\times 15$ ; 170, basal area (no. 3,662a),  $\times 15$ ; 171, stem impression (no. 3,662a),  $\times 45$ ; 172, cross section of "E" ambulacrum (no. E21,120),  $\times 15$ ; 173, summit area drawn from polished section showing hidden superdeltoid (no. E148),

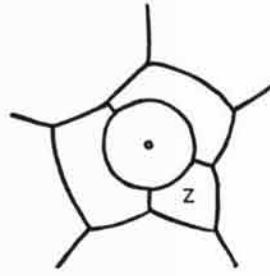
$\times 15$ ; 174, part of weathered "E" ambulacrum, showing side plates (E15,939),  $\times 45$ ; 175, part of "E" ambulacrum, showing side plates (no. E15,939),  $\times 45$ ; 176, anal area, oral plates lacking (no. E21,120),  $\times 15$ ; 177, part of "B" ambulacrum, showing main, inner, and outer side plates (no. 3,662a),  $\times 75$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; CR, cryptodeltoid; "D," amb.; D, deltoid; HD, hypodeltoid; ISp, inner side plate; L, lancet; O, oral plate; OSp, outer side plate; P, pore; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]



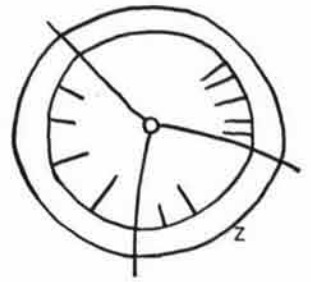
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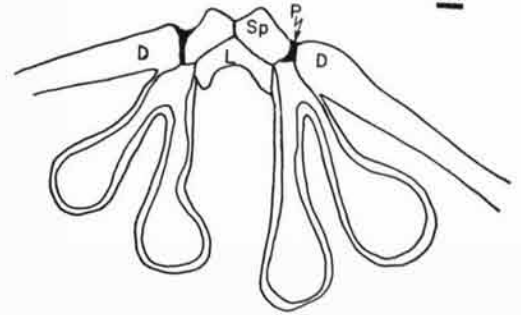
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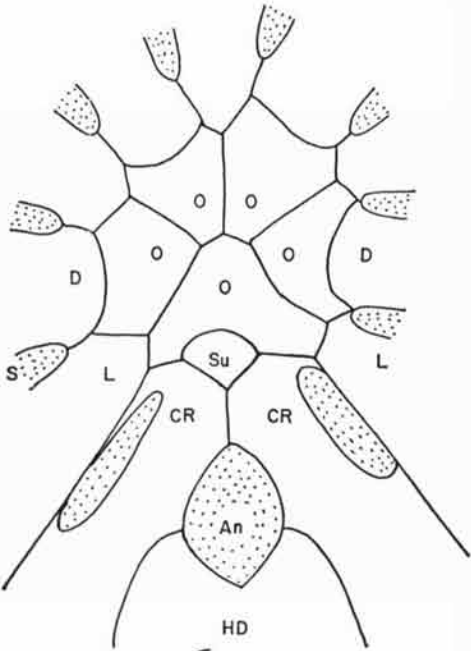
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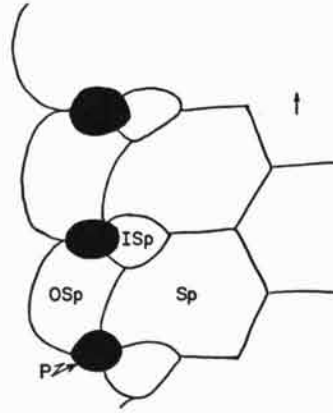
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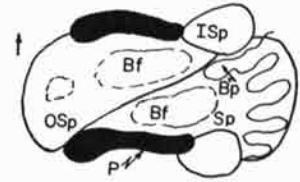
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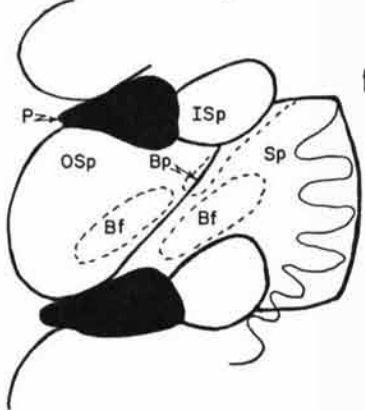
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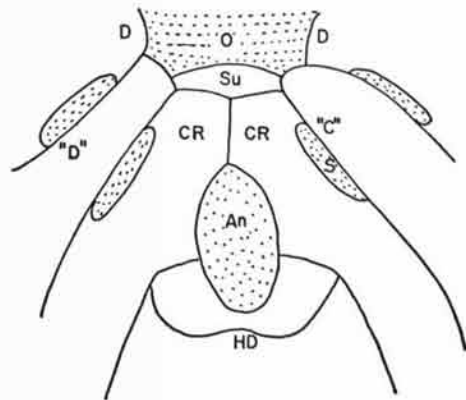
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angle 180 degrees, base flat, and summit flat. Stem round, 0.75 mm. in diameter, crenellar, with small round central lumen. Basal cirlet 1.5 mm. in diameter, pentagonal in aboral view, confined to small aboral surface, with three normally disposed basals. Radials five, each 2.5 mm. long by 2.5 mm. wide, recurved onto aboral surface, with short sinus 1 mm. long by 1 mm. wide. Deltoids overlap radials.

Deltoids four, each 9 mm. long by 4 mm. wide, with smooth triangular middle portion 2.5 mm. wide at base along radiodeltoid suture, bordered on either side by lenticular portions that have aligned lobes even with each side plate, each row slanting at an angle of about 100 degrees, measured from the mouth as origin and the line of the food groove as base. The disposition of the anal plates are the same as in *Nucleocrinus elegans*. In two specimens, one polished, one with orals removed, the hidden superdeltoid was seen. There are two hydrospire folds on each side of an ambulacrum, with a short hydrospire canal.

Ambulacra five, linear, recurved below, each 11 mm. long by 1 mm. wide, with lancet covered by side plates, and 36 side plates in a space of 10 mm. along an ambulacrum. Side plates disposed as in *Nucleocrinus elegans*. Orals five, subtriangular, covering peristome, interambulacral in position, and arranged as in *Nucleocrinus elegans*.

*Occurrence*.—Middle Devonian, coral zone of Widder beds, Hungry Hollow Formation, near Thedford and Arkona, Ontario.

*Types*.—Plesiotypes, 3,662, 3,662a (used for above description), two specimens, from Thedford, Geological Survey of Canada, Ottawa; 102,707, one specimen, from tile yard, Thedford, Charles Southworth collection, U. S. National Museum, Washington; E148, three specimens, one polished, from Thedford, and E8,244, one specimen, from tile yard, Thedford (identified as *N. lucina*), Southworth collection (1933), E15,939, two specimens, from tile yard, Thedford, Southworth collection (1943), and E21,120, nine specimens, from tile yard, Thedford and Hungry Hill, Arkona, Southworth collection, Buffalo

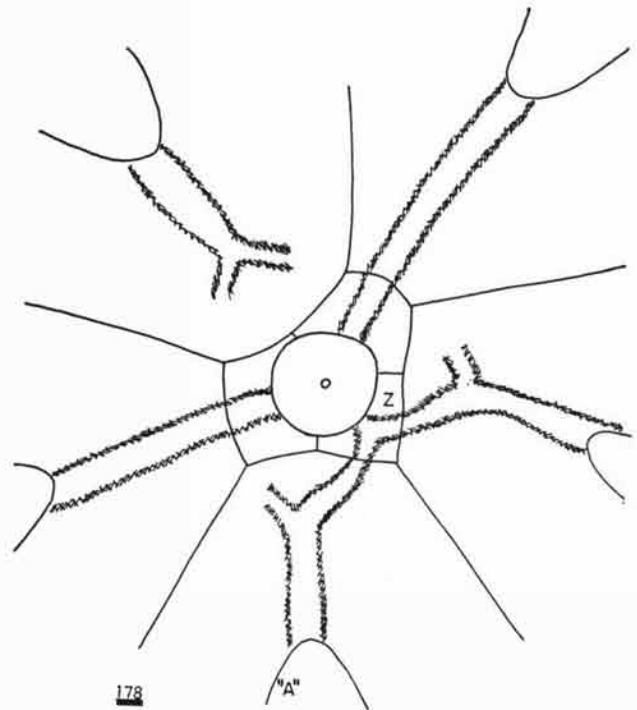


FIGURE 178. *Nucleocrinus meloniformis* (BARRIS), Middle Devonian, Hamilton Group, Moscow, New York (Buffalo Soc. Nat. Sci., no. E8,244); aboral view of basals and adjoining plates, showing ridges,  $\times 15$ . [Explanation.—“A,” amb.; Z, azygous basal.]

Society of Natural Sciences, Buffalo, New York. All these specimens, except one, have been labelled as *Nucleocrinus elegans* and obviously are misidentified.

#### Genus ORBITREMITES Austin & Austin, 1842

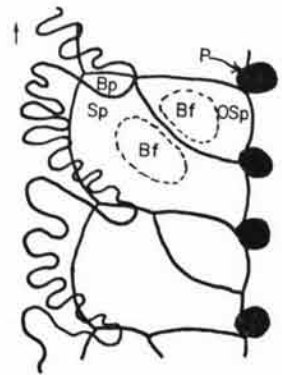
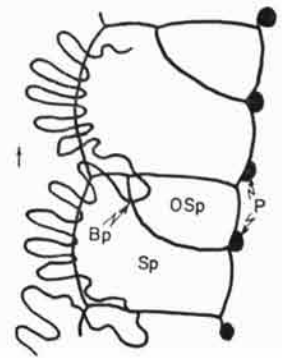
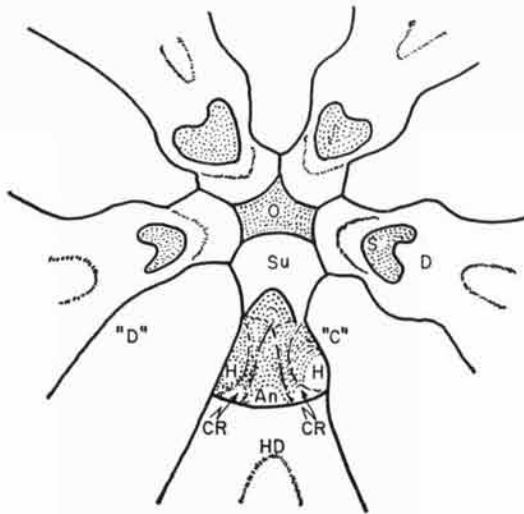
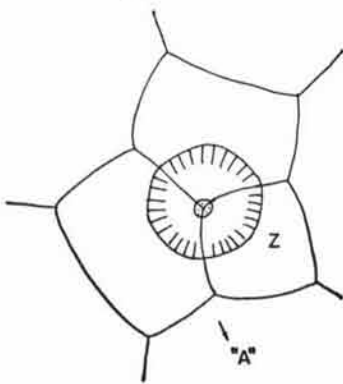
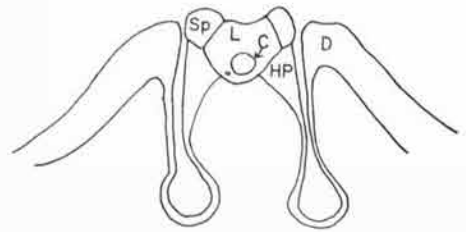
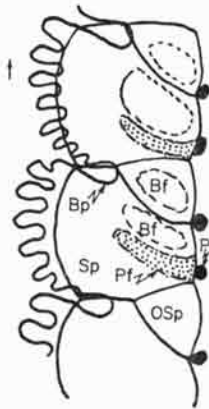
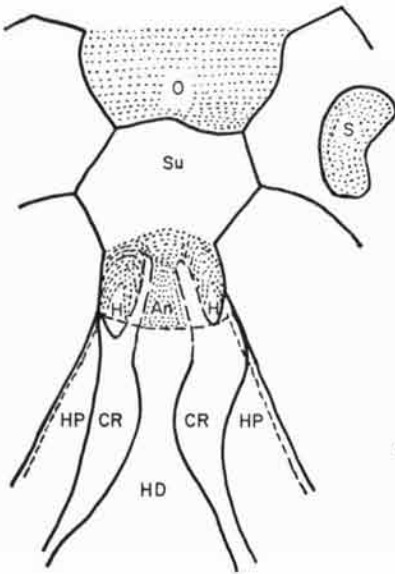
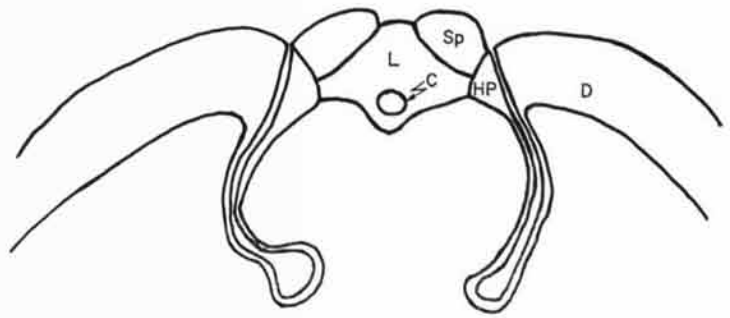
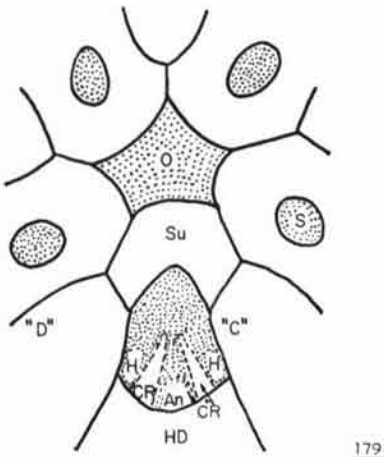
*Type-species*, by subsequent designation (Bather, 1899).—*Pentremites derbiensis* SOWERBY, 1825.

*Generic diagnosis (emend. FAY, 1960)*.—Spiraculate blastoids with five spiracles, or four spiracles in addition to an anispiracle, with a superdeltoid, two

#### FIGURES 179-187. Species of *Orbitremites* AUSTIN & AUSTIN, Lower Carboniferous, England.

179-182. *O. derbiensis* (SOWERBY), Middle Limestone, Yorkshire (H. H. Beaver coll., nos. 4, 328); 179, summit and anal areas (no. 328),  $\times 15$ ; 180, anal area of acid-etched specimen,  $\times 15$ ; 181, cross section of “E” ambulacrum, oral view (no. 4),  $\times 15$ ; 182, part of “E” ambulacrum, showing side plates (no. 4),  $\times 45$ .—183-185. *O. campanulatus* (M’COY), “Devonshire [?Derbyshire], England (Univ. Chicago, no. 1,633); 183, basal area,  $\times 15$ ; 184, cross section of “D” ambulacrum, oral view,  $\times 15$ ; 185, part of “E” ambulacrum, showing side plates,

$\times 45$ .—186, 187. *O. ellipticus* (SOWERBY), Clitheroe Limestone, Yorkshire (H. H. Beaver coll.); 186, summit area,  $\times 15$ ; 187, part of “A” ambulacrum, showing side plates,  $\times 45$ . [Explanation.—“A,” amb.; An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; “C,” amb.; C, canal (radial); CR, cryptodeltoid; “D,” amb.; D, deltoid; H, hydrospire; HD, hypodeltoid; HP, hydrospire plate; L, lancet; O, oral opening; OSP, outer side plate; P, pore; Pf, pore furrow; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]



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cryptodeltoids, and a hypodeltoid on anal side; hydrospire plate present; approximately twice as many pores as side plates along the deltoid and radial margins, one curved or straight hydrospire fold on each side of an ambulacrum; deltoids overlap radials, lancet exposed along middle one-third of its width; shape of calyx elliptical. *Lower Carboniferous*, England.

*Remarks.*—The genus *Orbitremites* was probably derived from *Ellipticoblastus* by overlap of radials by the deltoids.

#### ORBITREMITES DERBIENSIS (Sowerby)

Plate 44, figures 8-12; text-figs. 179-182

*Pentremites derbiensis* SOWERBY, 1825, pl. 11, fig. 3.

*Description.*—Calyx calcitic, flattened ellipsoidal in side view, circular in top view, 7.5 mm. long by 7.5 mm. wide, with periphery at mid-height. Stem impression round, 1 mm. in diameter, moderately deep concavity. Basal cirlet pentagonal in basal view, 1.5 mm. in diameter, in basal concavity, with three normally disposed basals. Radials five, short, wide, pentagonal in side view, recurved below, each 4 mm. long by 3.5 mm. wide, with short, flat, narrow sinus 3 mm. long by 0.75 mm. wide, and 110 degree angle of radial limbs at radiodeltoid suture, with center at interradial suture. Deltoids overlap radials.

Deltoids four, long, broadly lancet-shaped, each 6 mm. long by 3.5 mm. wide, pierced in the adoral tip by one oval spiracle, with deltoid lip adjacent to oral opening. On the anal side the anispiracle is between the V-shaped small epideltoid and large elongate pentagonal hypodeltoid, with the two small cryptodeltoids (hidden beneath the hypodeltoid) on either side of the anal opening, internally separating the anal opening from the adjacent hydrospire canals. The cryptodeltoids are infolded to form the hydrospires and hydrospire plate on the anal side. The oral opening is surrounded by four deltoid lips and the superdeltoid, and is surrounded by five spiracles, or four spiracles and an anispiracle. One long curved hydrospire fold occurs on each side of an ambulacrum, ending admedially in a hydrospire plate.

Ambulacra five, linear, each 9 mm. long by 0.75 mm. wide, recurved below, with lancet exposed along the median one-third of its width almost to the aboral tip, and approximately 30 side plates in a space of 10 mm. along an ambulacrum. The side plates are normally disposed, with a subtriangular outer side plate resting on the abmedial-adoral bevelled corner of each primary side plate, two pores to each side plate along the deltoid and radial margins, and five cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented by minute granules arranged along growth lines subparallel to plate margins.

*Occurrence.*—Lower Carboniferous, Cockleshell beds of the Middle Limestone of Yarnbury, near Grassington, Yorkshire, England.

*Types.*—Plesiotypes, 328, 4, 5, one unnumbered (four specimens), Harold Beaver collection, sent by DR. JOYSEY, from Cambridge; Humble Oil & Refining Co., Houston, Texas. The description is mainly that of specimen 328.

#### ORBITREMITES CAMPANULATUS (M'Coy)

Plate 43, figures 4-6; text-figs. 183-185

*Pentremites campanulatus* M'COY, 1849, p. 249; 1854, p. 123, pl. 3-D, fig. 9.

*Description.*—Calyx calcitic, fragmentary, 7.5 mm. wide, with flat base, and periphery just above base. Stem round, crenellar, 1 mm. in diameter, with approximately 30 crenellae, and a small central round lumen. Basal cirlet pentagonal in aboral view, 2 mm. wide, in broad basal concavity. Radials five, pentagonal in side view, presumably reaching to one-half the height of the calyx, each 5.5 mm. long by 4 mm. wide, recurved below, with a long, narrow, shallow sinus 5 mm. long by 1.25 mm. wide. Upper portion of calyx destroyed but presumably like *O. ellipticus*, with four deltoids, and a superdeltoid, two cryptodeltoids, and hypodeltoid, and five spiracles. Hydrospire plate present along deltoid and radial margins, with two pores to each side plate and one long straight hydrospire fold on each side of an ambulacrum. Deltoids overlap radials. An angle of 115 degrees is formed by the radial limbs at the radiodeltoid suture,

### EXPLANATION OF PLATE 27

#### FIGURE

1-11. *Eleutheroocrinus casedayi* SHUMARD & YANDELL, Middle Devonian, Hungry Hollow Formation (coral zone of Widder beds), near Thedford, Ontario.—1-5. Plesiotype, E15,933, Charles Southworth coll., Buffalo Soc. Nat. Sci.; old quarry on Frank Hunniford farm near Thedford, Ontario; 1, oral view (×4.5); 2, "D" ambulacral view (×4.1); 3, aboral view (×4.3); 4, "B" ambulacral view (×4.3); 5, "C" ambulacral view (×5)—6-8. Plesio-

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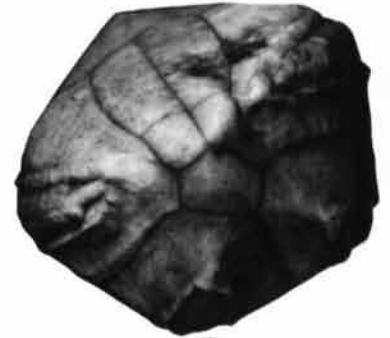
types, E13,061, Charles Southworth coll., Buffalo Soc. Nat. Sci.; 6, aboral view of polished section of "E" ambulacrum (×10); 7, view looking adorally of polished section of "D" ambulacrum of another specimen (×11); 8, aboral view of an ambulacrum near aboral end of another specimen, showing thick radial plate beneath lancet (×15).—9-11. Plesiotype, 3,665, Geol. Survey Canada; 9, "D" ambulacral view (×3.7); 10, 11, oral and aboral views (×4.1) ..... 72



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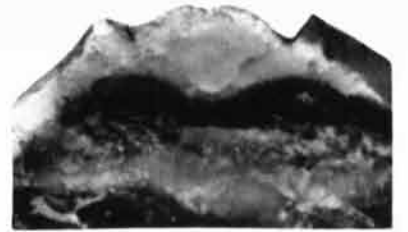
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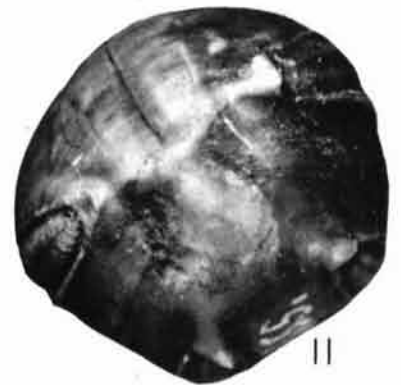
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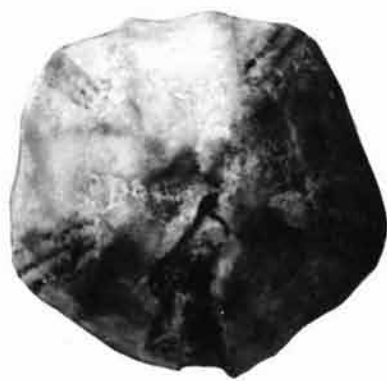
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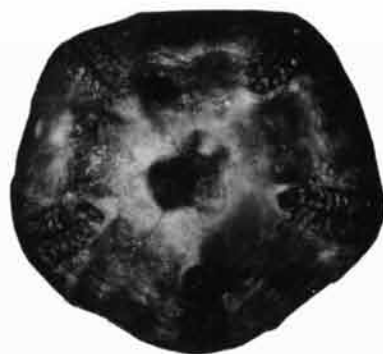
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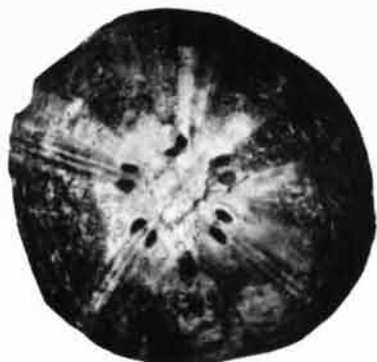
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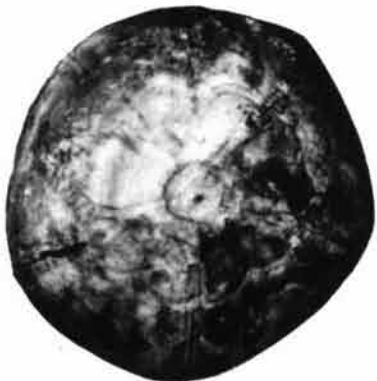
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with center at junction of interrarial suture with the radiodeltoid suture.

Ambulacra five, linear, with lancet exposed along the median one-third of its width almost to the aboral end of each ambulacrum. Side plates normally disposed, with approximately five cover-plate sockets to each side plate along main food groove, and two pores to each side plate, one of which is almost even with a side plate suture and the other about midway between the side plate sutures. Surfaces of calyx plates ornamented by fine granules arranged subparallel to plate margins along growth lines.

*Occurrence*.—Lower Carboniferous, recorded as Devonshire (may mean Derbyshire), England.

*Type*.—Plesiotype, 1,633, one specimen, James collection, labelled *Granatocrinus ellipticus*, Walker Museum, University of Chicago.

### ORBITREMITES ELLIPTICUS (Sowerby)

Plate 43, figures 1-3, 10-11; text-figs. 186, 187

*Pentremites elliptica* SOWERBY, 1825, p. 317, pl. 11, fig. 4.

*Elaeocrinus ellipticus* SHUMARD, 1863, p. 112.

*Description*.—Calyx calcitic, fragmentary, 12.5 mm. long by 12 mm. wide, ellipsoidal in side view, rounded pentagonal in top view, with flat summit, and periphery above mid-height. Stem and basals destroyed. Radials five, elongate hexagonal in side view, reaching adorally to periphery with narrow, shallow sinus 10 mm. long by 1.5 mm. wide. Deltoids overlap radials. The angle of the radial limbs at the radiodeltoid suture, with center at interrarial suture is 85 degrees.

Deltoids four, large, broadly rhombic, reaching below periphery, each 8 mm. long by 5.5 mm. wide, with one large triangular spiracle in the middle of the depressed adoral tip. On the anal side the triangular anispiracle is located between a pentagonal superdeltoid and a pentagonal hypodeltoid, with two hidden cryptodeltoids. Thus, five openings occur around the oral aperture, consisting of four spiracles and an anispiracle. There is one hydrospire fold on each side of an ambulacrum, terminating admedially in a hydrospire plate.

Ambulacra five, linear, raised, each 16 mm. long by 1.5 mm. wide, with lancet exposed along the middle one-

third of its width almost to the aboral end, and 26 side plates in a space of 10 mm. along an ambulacrum. There are two pores to each side plate along the deltoid and radial margins. The surfaces of the calyx plates are almost smooth, with fine growth striae subparallel to plate margins, and granular raised ridges immediately aboral to each spiracle and anispiracle.

*Occurrence*.—Lower Carboniferous, upper part of Clitheroe Limestone (C<sub>2</sub>) of Salt Hill Knoll, Clitheroe, Lancashire, England (Beaver collection), and Carboniferous limestone, Yorkshire, England (deKoninck collection).

*Types*.—Plesiotypes, 245, 11 specimens, deKoninck collection, old numbers, 2,324 and 467, Harvard Museum of Comparative Zoölogy, Cambridge, Mass.; one unnumbered specimen, Beaver collection, sent by DR. JOYSEY from Cambridge, England, Humble Oil & Refining Co., Houston, Texas. The above description is based on the specimen in the Beaver collection.

### Genus PENTREMITES Say, 1820

*Type-species*, by subsequent designation (ETHERIDGE & CARPENTER, 1886).—*encrina Godonii* DEFRANCE, 1819.

*Generic diagnosis*.—Spiraculate blastoids with five spiracles or four spiracles and an anispiracle, with the anispiracle excavated in one anal deltoid plate, ?two, three to seven or more hydrospire folds on each side of an ambulacrum, oral and anal areas covered by many imbricate plates, one pore between side plates along deltoid and radial margins, lancet almost completely exposed, ambulacra petaloid, radials overlap deltoids, and shape of calyx in side view rounded obconical or club-shaped. *Mississippian-Pennsylvanian*, Alabama, Tennessee, Kentucky, Indiana, Illinois, Missouri, Iowa, Oklahoma, Arkansas, Mississippi, Montana, Alberta, ?Alaska.

*Remarks*.—The genus *Pentremites* was probably derived from *Devonoblastus* by fusion of the anal deltoid plates into one, and continued downward migration of the deltoid plates, and outward migration of the lancet plates. A detailed description of the neotype (new holotype) of *P. godoni* is reserved for another paper to appear in the *Journal of Paleontology*.

## EXPLANATION OF PLATE 28

FIGURE	PAGE	
1-6. <i>Elaeocrinus venustus</i> (MILLER & GURLEY).—1-3. Syn- type, 6,114, Univ. Chicago; Devonian, Columbus, Ohio; oral, "D" ambulacral, aboral views of figured type (Miller & Gurley, 1894, pl. 8, fig. 26-30) (all $\times 4.1$ ).—4-6. Syntype, 1,317, Univ. Cincinnati; Devonian, Columbus,		Ohio; oral, "D" ambulacral, aboral views (all $\times 3.7$ ) ..... 69
		7-10. <i>Elaeocrinus verneuili</i> ROEMER, plesiotype, 9,956, Gurley coll., Univ. Chicago; Devonian, Jeffersonville Limestone, Jeffersonville, Ind., 7-9, oral, aboral, "D" ambulacral views ( $\times 1.7$ ); 10, enlarged oral view of summit ( $\times 4.3$ ) ..... 68

**PENTREMITES GODONI (Defrance)**

Text-fig. 188

*encrina Godonii* DEFRANCE, 1819, p. 467.*Asterial fossil* PARKINSON, 1808, p. 235, pl. 13, figs. 36-37.

*Description.*—The new holotype is 17 mm. long by 15 mm. wide, with vault 15 mm. long, pelvis 2 mm. long, and pelvic angle 145 degrees. The shape of the calyx is subrounded in side view, and rounded pentagonal in top view. Stem round, 2 mm. wide. Basal circling pentagonal in aboral view, 8 mm. in diameter, with three normally disposed basals. Radials each 10 mm. long by 7 mm. wide, overlapping deltoids, with petaloid sinus areas. There are five hydrospire folds on each side of an ambulacrum.

Deltoids five, each 8 mm. long by 4 mm. wide, with one oval spiracle excavated in the adoral tips of each, including the anispiracle excavated in the anal deltoid. Oral opening surrounded by five deltoid lips and five lancet stipes, and each spiracle bordered by a deltoid lip, lancet stipe, side plates, and deltoid body if side plates are removed. On the anal side the deltoid lip is attached to the deltoid body by two anal septa that separate the anal opening from the adjacent hydrospire canals internally. The septa are infolded to form hydrospires.

Ambulacra five, broadly petaloid, with lancet exposed its full width, and 32 side plates in a space of 10 mm. along an ambulacrum. A single pore occurs between side plates along the deltoid and radial margins, and the outer side plates rest on the bevelled abmedial-adoral corners of each side plate. The specimen is silicified but on others the ornamentation consists of fine growth lines subparallel to plate margins.

*Remarks.*—The original suite of specimens of PARKINSON, MITCHILL, SAY, WOODWARD, DEFRANCE, and FEATHERSTONEHAUGH have been destroyed and therefore neotypes are herein erected.

*Occurrence.*—Upper Mississippian (Chesteran), Gasper Formation (?upper part), Bowling Green, Kentucky. The original type specimen probably came from Mammoth Cave, Kentucky, but the above specimen agrees well with the figure of the type, and it is possible that the type actually came from the Bowling Green area.

*Types.*—Neotypes, 139,103 (new holotype), 139,104 (new paratype, a polished section), old no. 8,437, identified by HAMBACH as typical of the type, U. S. National Museum, Washington.

**PENTREMITES BURLINGTONENSIS**

Meek &amp; Worthen

Plate 54, figures 4-5

*Pentremites burlingtonensis* MEEK & WORTHEN, 1870, p. 33; 1873, p. 461, pl. 8, fig. 7.

*Description.*—The illustrated specimen is here selected to show form of the calyx with attached brachioles. Of

importance also is the fact that one specimen in the collection of the Philadelphia Academy of Science apparently has two hydrospire folds on each side of an ambulacrum. This is the minimum number of folds reported in any species of *Pentremites*.

*Types and occurrence.*—Plesiotypes, S3,634, two specimens of four labelled *Metablastus lineatus*, Springer collection, from Lower Mississippian, lower part of Burlington Limestone, Burlington, Iowa, U. S. National Museum, Washington.

**PENTREMITES PYRIFORMIS Say**

Plate 54, figures 1-3

*Pentremites pyriformis* SAY, 1825, p. 294; 1825, p. 314.

*Description.*—The specimens here illustrated show the form of the calyx with attached brachioles.

*Occurrence.*—Upper Mississippian (Chesteran), Huntsville, Alabama.

*Types.*—Plesiotypes, three unnumbered specimens on a card, U. S. National Museum, Washington.

**Genus PETALOBLASTUS Fay, n. gen.**

*Type-species*, by original designation (herein).—*Pentremites ovalis* GOLDFUSS, 1829.

*Generic diagnosis.*—Spiraculate blastoids with five spiracles, or four spiracles and an anispiracle, with anispiracle between an epideltoid and hypodeltoid, radials overlapping deltoids but radiodeltoid suture inverted V-shaped opposite that of *Pentremites*, lancet exposed its full width, with petaloid ambulacra, one pore between side plates along deltoid and radial margins, at least four hydrospire folds on each side of an ambulacrum, and shape oval in side view. *Lower Carboniferous* (Etröungian) Germany.

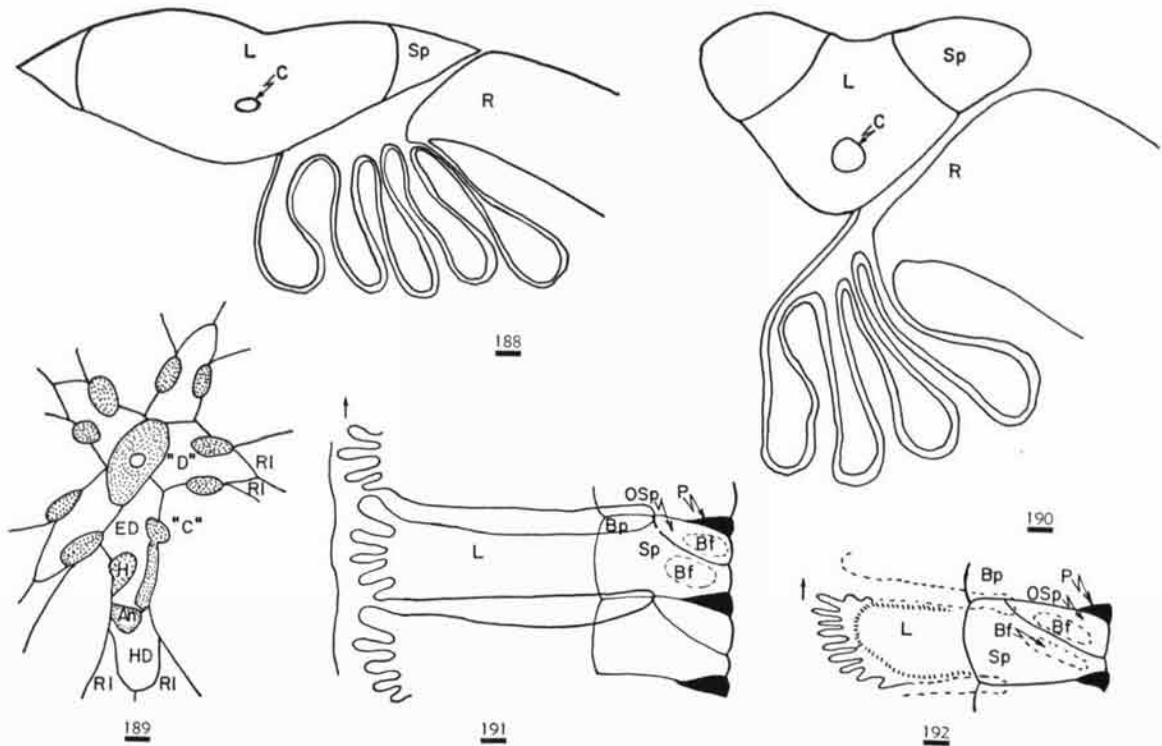
*Remarks.*—The genus *Petaloblastus* was probably derived from *Cordyloblastus* by fusion of the superdeltoid and cryptodeltoids into an epideltoid, and downward migration of the deltoid plates, together with outward migration of the lancet plate.

**PETALOBLASTUS OVALIS (Goldfuss)**

Plate 35, figures 1-8; text-figs. 189-192

*Pentremites ovalis* GOLDFUSS, 1829, p. 161, pl. 50, figs. 1a-c.

*Description.*—Calyx calcitic, oval in side view, pentagonal in top view, slightly crushed, 6.5 mm. long by 4 mm. wide, with vault 4 mm. long, pelvis 2.5 mm. long, pelvic angle on supplementary basals 10 degrees and on radial bodies 145 degrees, with periphery above mid-height. The stem is round, crenellar, 0.5 mm. in diameter, with small round lumen. Basal circling conical in side view, pentagonal in aboral view, 2 mm. long by 2.5 mm. wide, with three normally disposed basals and three low ex-



FIGURES 188-192. Species of *Pentremites* SAY and *Petaloblastus* FAY, n. gen.

188. *Pentremites godoni* (DEFrance), Upper Mississippian, Gasper Formation, Bowling Green, Ky. (U.S. Natl. Mus., no. 139,104); partial cross section of "A" ambulacrum, oral view,  $\times 17.5$ .—189-192. *Petaloblastus ovalis* (GOLDFUSS), Lower Carboniferous, Etroeungtian, Cromford bei Rättingen, Germany (Harvard Mus. Comp. Zoölogy, no. 316); 189, summit and anal areas, drawn from polished section,  $\times 15$ ; 190, partial cross section of

"?C" ambulacrum, oral view,  $\times 45$ ; 191, part of ambulacrum, showing lancet and side plates,  $\times 45$ ; 192, part of ambulacrum,  $\times 30$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); D, deltoïd; ED, epideltoïd; H, hydrospire; HD, hypodeltoïd; L, lancet; OSp, outer side plate; P, pore; R, radial; RI, radial limb; Sp, main side plate.]

panded supplementary basals immediately above the stem and overlapping the basals. Radials five, each elongate hexagonal in side view, 4.5 mm. long by 2.5 mm. wide, with long wide, shallow sinus 2.5 mm. long by 3.75 mm. wide, and prominent bluntly pointed radial lip. The radials overlap deltoïds so that the V-shaped radiodeltoïd suture has its apex pointed adorally, which is opposite that of most blastoids. This opposite relationship is due to the fact that the radial limbs meet at a point along the midline of each adjacent deltoïd and the suture is seen along the wide sloping sinus.

Deltoïds four, visible in side view, each 1.5 mm. long by 0.75 mm. wide, V-shaped with apex directed adorally, each notched adorally by a large oval spiracle that separates the deltoïd lip from the deltoïd body externally. Internally these two parts are connected by a deltoïd septum. On the anal side there appear to be two anal deltoïds, an epideltoïd adjacent to the oral opening, and a V-shaped hypodeltoïd on the aboral side of the anispiracle.

The superdeltoïd has two thick deltoïd septa on its aboral face that separate the anal opening from the adjacent hydrospire canals internally. The hypodeltoïd overlaps these septa, thus covering the adoral part of the anal opening. Therefore, five openings surround the oral aperture, consisting of four spiracles in addition to the anispiracle. There are four hydrospire folds on each side of an ambulacrum.

Ambulacra five, broad, petaloid, with lancet exposed its full width along each ambulacrum, and 40 side plates in a space of 10 mm. along an ambulacrum. The exposed lancet is approximately 1 mm. wide, the side plates 0.5 mm. wide on the sides, and the ambulacra are each 4.5 mm. long by 2 mm. wide. The side plates are normally disposed, with a subtriangular outer side plate resting on the bevelled abmedial-adoral corner of each primary side plate, one pore between adjacent side plates along the deltoïd and radial margins, and approximately four cover-plate lobes to each side plate along the main food groove

on the lancet plate. The surfaces of the calyx plates are ornamented by coarse raised ridges subparallel to plate margins, each ridge with low, aligned, round pustules.

*Occurrence.*—Lower Carboniferous, Uebergangskalke or transition limestone, Etroeungtian, Cromford bei Rättingen, Germany.

*Types.*—Topotypes, 151, four specimens, deKoninck collection, old no. 2,331, one specimen of which was used for the above description; 316, four specimens, Bronn or Brown collection, old no. 2,351, Harvard Museum of Comparative Zoölogy, Cambridge, Mass.

**Genus PLACOBLASTUS Fay, n. gen.**

*Type-species*, by original designation (herein).—*Elaeacrinus obovatus* BARRIS, 1883.

*Generic diagnosis.*—Spiraculate blastoids with 11 openings around oral aperture, consisting of ten spiracles and anus separate, six or seven large oral plates, one of which may be a superdeltoid exposed between the adoral ends of the two cryptodeltoids, with a hypodeltoid between two exposed cryptodeltoids, at least one anal oral between adoral tips of the two cryptodeltoids, lancet covered by side plates, an inner side plate present, one pore between side plates along deltoid and radial margins, deltoids long, overlapping radials, with two hydrospire folds on each side of an ambulacrum bearing a long hydrospire canal; form of calyx elongate elliptical. *Devonian*, Iowa, Michigan, New York, Indiana, Ohio.

*Remarks.*—The genus *Placoblastus* was probably derived from *Elaeacrinus* by reduction in the number of the oral plates and elongation of the hydrospire canals.

**PLACOBLASTUS OBOVATUS (Barris)**

Plate 31, figures 1-9; text-figs. 193-196

*Elaeacrinus obovatus* BARRIS, 1883, p. 358, fig. 3; 1885-86, p. 88, text-fig. 3, pl. 1, figs. 1-2.

*Nucleocrinus obovatus* CLELAND, 1911, p. 43, pl. 3, fig. 2.

*Nucleocrinus obovatus* THOMAS, 1924, p. 423, pl. 36, figs. 1, 6-9, 16-17, text-fig. 65.

*Description.*—Calyx calcitic, 47.5 mm. long by 25 mm. wide, deformed, and another specimen is 48 mm. long by 30 mm. wide, undeformed. The former specimen is elongate, oval in side view, with deeply concave base and periphery above mid-height. Basal circling small, within basal concavity, approximately 3 mm. in diameter. Radials

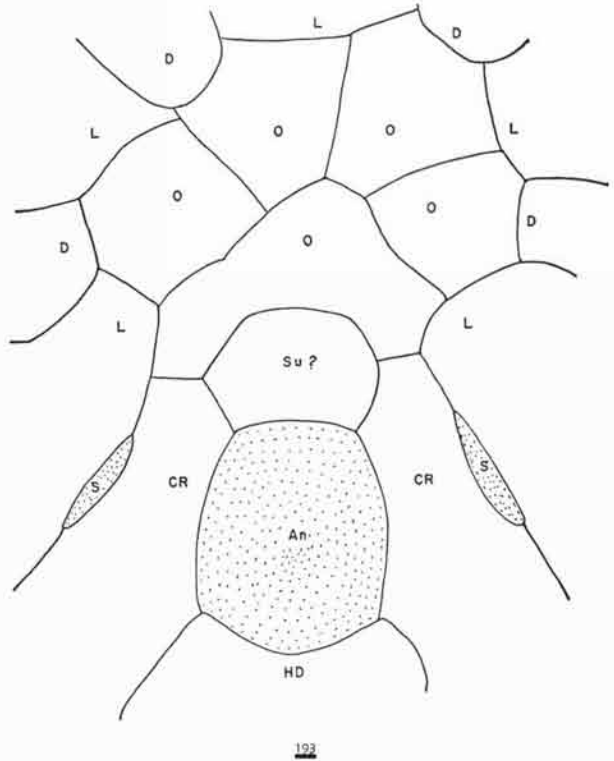


FIGURE 193. *Placoblastus obovatus* (BARRIS), Middle Devonian, Thunder Bay Limestone, near Alpena, Michigan (Buffalo Soc. Nat. Sci., no. E21,115); summit area,  $\times 11.7$ . [Explanation.—An, anal opening; CR, cryptodeltoid; D, deltoid; HD, hypodeltoid; L, lancet; O, oral plate; S, spiracle; Su, superdeltoid.]

EXPLANATION OF PLATE 29

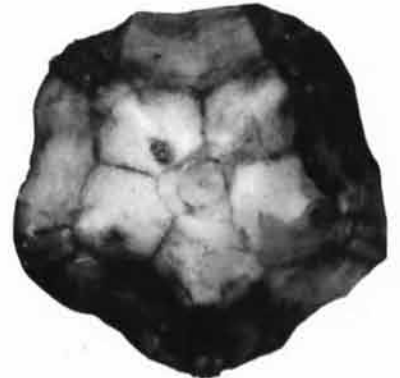
FIGURE	PAGE		
1-3, 7-8.		<i>Nucleocrinus meloniformis</i> (BARRIS), plesiotype, E21,120, Charles Southworth coll., Buffalo Soc. Nat. Sci.; Middle Devonian, Hungry Hollow Formation (coral zone of Widder beds), tile yard, Thedford and Hungry Hill, Arkona, Ontario; 1-3, oral, "D" ambulacral, aboral views ( $\times 7.1$ ); 7, oral view of specimen shown in fig. 1, oral plates removed to show small superdeltoid hidden adjacent to oral opening ( $\times 17.8$ ); 8, oral view of another specimen with oral plates in place, showing adoral tips of	
		cryptodeltoids abutting against one large oral plate on anal side, four other orals covering mouth ( $\times 15$ )	86
4-6, 9.		<i>Nucleocrinus elegans</i> CONRAD, topotype, 19,049, Gurley coll., Univ. Chicago, one of two specimens, other probably belonging to <i>Placoblastus lucina</i> (HALL); Middle Devonian, Hamilton Group, Moscow, N.Y.; 4-6, oral, "D" ambulacral, aboral views ( $\times 4.4$ ); 9, oral view showing five large oral plates, that on anal side abutting against adoral tips of cryptodeltoids ( $\times 2.6$ )	84



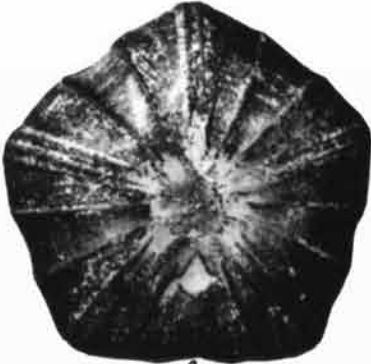
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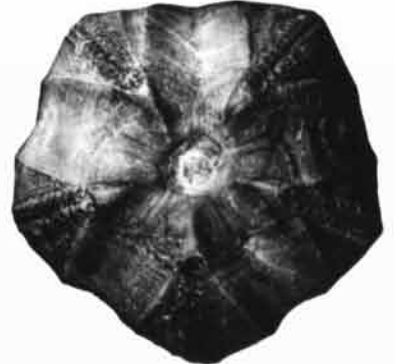
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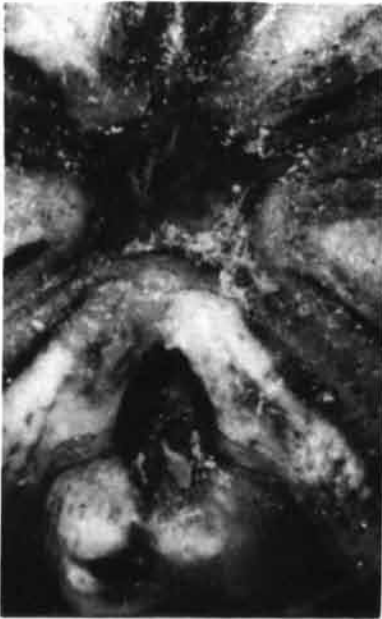
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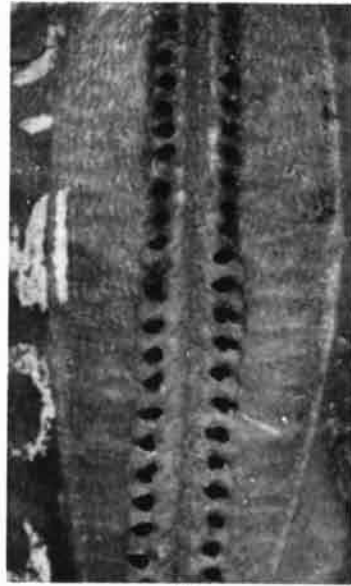
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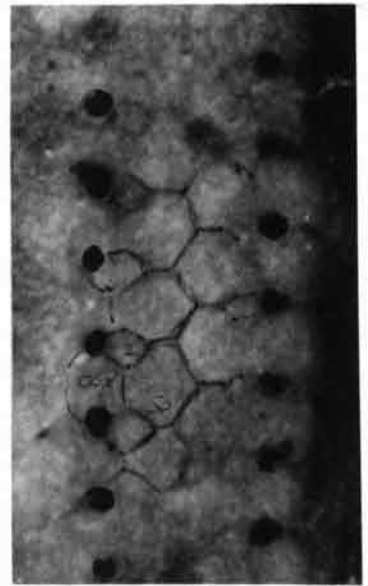
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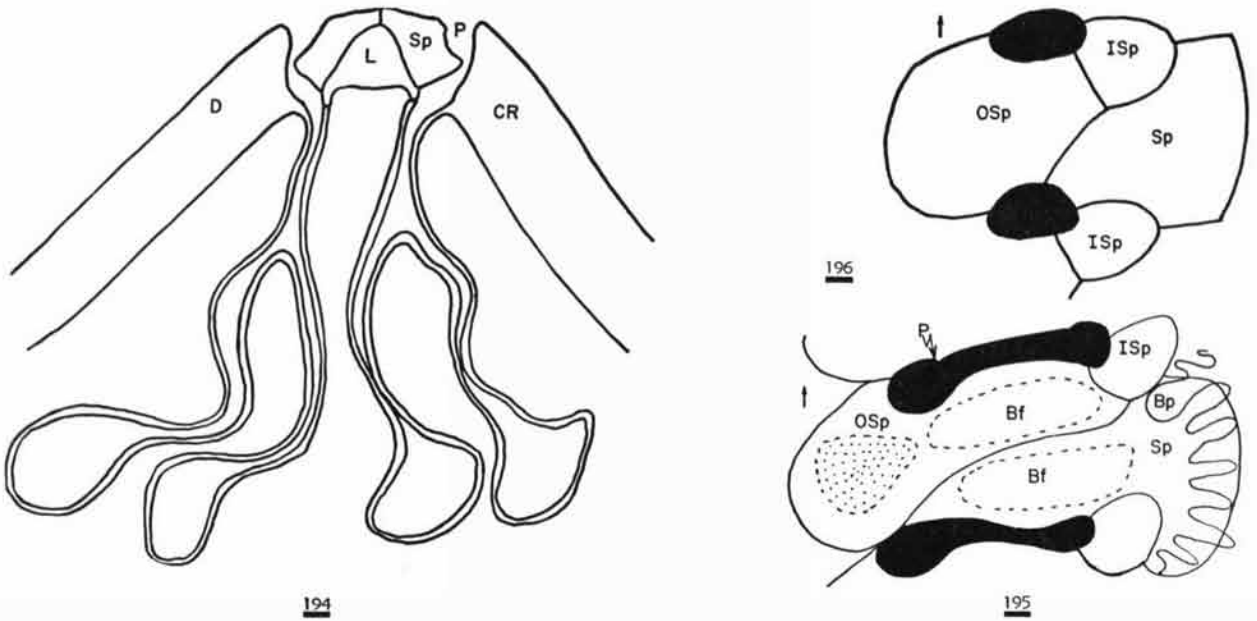
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FIGURES 194-196. *Placoblastus obovatus* (BARRIS), Middle Devonian, Thunder Bay Limestone, near Alpena Michigan (Buffalo Soc. Nat. Sci., nos. E21,113, E21,115).

194. Cross section of "D" ambulacrum, aboral view (no. E21,113),  $\times 15$ .—195. Part of "E" ambulacrum, showing main, inner, and outer side plates (no. E21,115),  $\times 45$ .—196. Part of "C" ambulacrum, drawn from

polished tangential section (no. E21,115),  $\times 45$ . [Explanation.—Bf, brachiolar facet; Bp, brachiolar pit; CR, cryptodeltoid; D, deltoid; ISp, inner side plate; L, lancet; OSp, outer side plate; P, pore; Sp, main side plate.]

five, each short, 8 mm. long by 7 mm. wide, strongly recurved in basal concavity, broadly pentagonal in side view, with short sinus 3 mm. long by 2 mm. wide and wide tapering deltoid margins 4 mm. long between ambulacrum and admedial margins of radial plate. Radiodeltoid suture M-shaped. Deltoids overlap radials.

Deltoids four, broadly lenticular, each 43 mm. long by 13 mm. wide, with trifold sculpture as in *Nucleocrinus*, each ending adorally against an oral plate. On the

anal side at least three anal deltoids are present, a long central quadrangular hypodeltoid 41 mm. long by 6 mm. wide, flanked on each side by two lenticular cryptodeltoids 43 mm. long by 3.5 mm. wide. A large hexagonal plate occurs on the adoral side of the anal opening between the adoral tips of the cryptodeltoids. This plate is here interpreted to be a superdeltoid but it could be an accessory anal oral and the superdeltoid could be below it, not visible externally. The oral opening is covered by

#### EXPLANATION OF PLATE 30

FIGURE PAGE  
1-9. *Nucleocrinus meloniformis* (BARRIS), Middle Devonian, Hungry Hollow Formation (coral zone of Widder beds), near Thedford, Ontario.—1, 2. Plesiotypes, 3,662a, Geol. Survey Canada; 1, oral view showing five large oral plates in place ( $\times 6.4$ ); 2, "B" ambulacrum showing main and outer side plates in place but inner side plates missing, leaving large gaps between side plates ( $\times 13$ ).—3. Plesiotype, E15,939, Charles Southworth coll., Buffalo Soc. Nat. Sci.; tile yard, Thedford, Ontario; polished section of "E" ambulacrum showing inner, outer, and main side plates ( $\times 32$ ).—4. Plesiotypes, E148, Buffalo Soc. Nat. Sci.; oral view of polished section showing hidden super-

deltoid plate between cryptodeltoids and oral plate on anal side ( $\times 9$ ).—5, 6. Plesiotypes, E21,120, Charles Southworth coll., Buffalo Soc. Nat. Sci.; tile yard, Thedford, and Hungry Hill, Arkona, Ontario; 5, anal side of specimen shown in Pl. 29, figs. 1-3, showing large hypodeltoid flanked by ridged cryptodeltoids ( $\times 7.8$ ); 6, aboral view of another specimen ( $\times 14.6$ ).—7-9. Plesiotype, 102,707, Charles Southworth coll., U.S. Natl. Mus.; tile yard, Thedford, Ontario; oral; "B" and "C" combined ambulacral, and aboral views of pathological specimen in which the "B" and "C" ambulacra have almost joined ( $\times 5.1$ )

five large arrow-shaped oral plates, each interambulacral in position, the superdeltoid and adjacent adoral tips of the cryptodeltoids abutting against the large anal oral. The adoral tips of each deltoid are excavated by two semi-elliptical spiracles along ambulacral margins, and each adoral tip of each cryptodeltoid has one marginal slitlike spiracle, separate from the anal opening. Thus, 11 openings surround the oral aperture, consisting of ten spiracles and a separate anal opening. The calyx plates are ornamented as in *Nucleocrinus*. Two elongate hydrospires occur on each side of an ambulacrum, with an elongate hydrospire canal extending to each.

Ambulacra five, linear, recurved below, each 55 mm. long by 2 mm. wide, with 23 side plates in a space of 10 mm. along an ambulacrum, lancet covered by side plates, inner side plate large, and side plates disposed as in *Nucleocrinus*. There is an inward-projecting hornlike process on the inner medial wall of the hypodeltoid. Six cover-plate sockets to each side plate are observed along the main food groove.

*Occurrence*.—Middle Devonian, Thunder Bay Limestone (or Partridge Point Formation), Partridge Point, near Alpena, Michigan.

*Types*.—Topotypes?, E21,113, four specimens; E21,115, two specimens, Buffalo Society of Natural Sciences, Buffalo, New York. The description is taken from the characters mainly seen in specimens E21,115.

#### PLACOBLASTUS ANGULARIS (Lyon)

Plate 32, figure 8; plate 33, figures 1-9; plate 34, figures 1-9; text-figs. 197-199

*Olivanites angularis* LYON, 1857, p. 492, pl. 5, figs. 2, 2a, 2b.

*Nucleocrinus angularis* LYON & CASSEDAY, 1859, p. 295.

*Nucleocrinus powelli* REIMANN, 1935, p. 34, pl. 3, figs. 4-6.

*Description*.—After careful comparison of the types of *P. powelli* with *P. angularis* I have been unable to find significant differences. The description is of a paratype (E9,058) of *P. powelli*.

Calyx calcitic, 19 mm. long by 15.5 mm. wide, with flat summit, slightly concave base, periphery slightly adoral of mid-height, and interambulacral areas concave in oral view. Basal cirlet pentagonal in aboral view, 3 mm. wide, flat to slightly concave, with round stem impression 1.5 mm. wide, with small round central lumen, and three normally disposed basals. Radials five, each 5 mm. long by 5.5 mm. wide, recurved below in basal concavity, with sinus 1.5 mm. long by 1 mm. wide. The radiodeltoid suture is broadly M-shaped. Deltoids overlap radials.

Deltoids four, bluntly lenticular, each 18 mm. long by 8.5 mm. wide, each with a smooth central triangular area with base almost full width of radiodeltoid suture, bordered laterally by two lenticular areas of nodose ornamentation, similar to those of *Nucleocrinus*. Each row of nodes is aligned with a side plate, forming a high angle with the median food groove. The aboral tips of the

nodose side regions extend aborally between each ambulacrum and radial limb, forming a short wedge. On the anal side there are at least three deltoids, the two elongate lenticular cryptodeltoids with the elongate subquadrangular hypodeltoid between, and probably a fourth (superdeltoid) between the adoral tips of the cryptodeltoids. The superdeltoid is covered almost completely by an anal oral plate in approximately the same position, but in some specimens there appear to be two plates fully exposed in this region. Thus, six or seven oral plates cover the summit, depending on interpretation of the plate that is adjacent to the adoral side of the anal opening. There are five large oral plates over the summit, each arrow-shaped and interambulacral in position, with one or two accessory oral plates on the anal side. At present, the interpretation here presented is that two plates occur between the

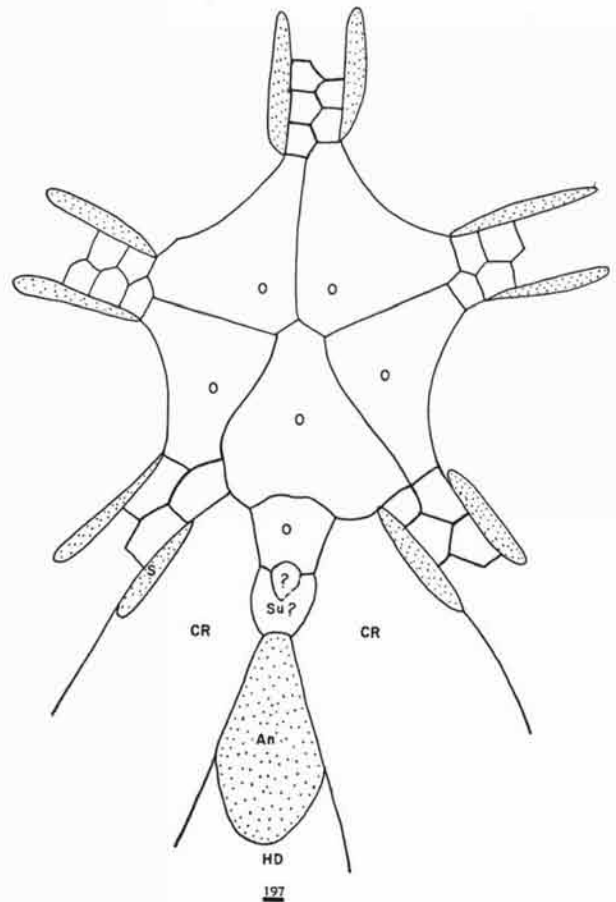


FIGURE 197. *Placoblastus angularis* (LYON), Middle Devonian, Ludlowville Formation, Springbrook, New York (Buffalo Soc. Nat. Sci., no. E9,058); summit and anal areas,  $\times 11.7$ . [Explanation.—An, anal opening; CR, cryptodeltoid; HD, hypodeltoid; O, oral plate; S, spiracle; Su, superdeltoid.]



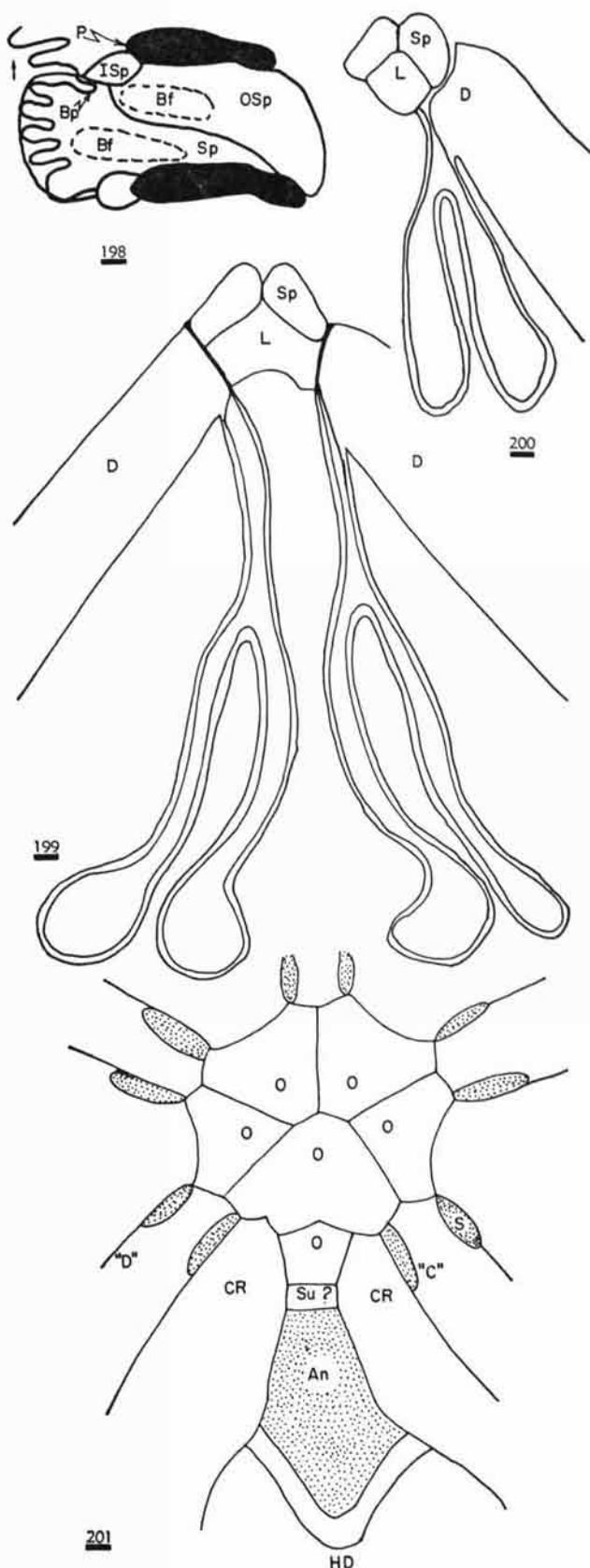
adoral ends of the cryptodeltoids. The adorally disposed plate is termed an accessory anal oral plate and the aborally disposed plate a superdeltoid. The accessory anal oral may override the superdeltoid, thus giving the appearance of one plate in this position. Hydrospire folds two on each side of an ambulacrum, with elongate hydrospire canals.

Ambulacra five, linear, recurved below, each 22 mm. long by 1 mm. wide, with lancet covered by side plates, and 34 side plates in a space of 10 mm. along an ambulacrum. Inner side plate present. Side plates arranged as in *Nucleocrinus*. The ambulacra are covered by a large set of cover plates along the spiracles. The adoral tips of the deltoids are pierced by two slitlike spiracles along the ambulacra, and the cryptodeltoids each have one spiracle in its adoral tip, separate from the anal opening. Thus, 11 openings surround the oral aperture, consisting of ten spiracles and a separate anal opening. Ornamentation of calyx plates similar to that of *Nucleocrinus*.

*Occurrence*.—Middle Devonian, Ludlowville Formation (Tichenor Limestone), Cazenovia Creek, Springbrook, New York (described specimen from here). Hamilton Group, Charlestown, Indiana (13,890). Jeffersonville Limestone, Falls of the Ohio, Louisville, Kentucky (19,052).

*Types*.—Plesiotypes, E9,057, five fragmentary paratypes of *Nucleocrinus powelli*, Reimann collection (1935), Tichenor Limestone; E9,058, two paratypes of *Nucleocrinus powelli* one of which was used for above description, Reimann collection (1935), Tichenor Limestone; E11,629, one paratype of *Nucleocrinus powelli*, Wattles collection (1940), Tichenor Limestone, Buffalo Society of Natural Sciences, Buffalo, New York. Plesiotypes, 13,890, 36 silicified specimens; 19,052, one specimen, Gurley collection, Walker Museum, University of Chicago.

FIGURES 198-201. Species of *Placoblastus* FAY, n. gen., Middle Devonian, New York.—198, 199. *P. angularis* (LYON), Ludlowville Formation, Springbrook, N.Y. (Buffalo Soc. Nat. Sci., nos. E9,057, E11,629); 198, part of "B" ambulacrum, showing main, inner, and outer side plates (no. E11,629),  $\times 15$ ; 199, cross section of "E" ambulacrum, aboral view (no. E9,057),  $\times 15$ .—200, 201. *P. lucina* (HALL), Hamilton Group, Moscow, N. Y. (Univ. Chicago, nos. 13,276, 19,049); 200, partial cross section of "E" ambulacrum, aboral view (no. 13,276),  $\times 15$ ; 201, summit and anal areas (no. 19,049),  $\times 15$ . [Explanation.—An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; CR, cryptodeltoid; "D," amb.; D, deltoid; HD, hypodeltoid; ISp, inner side plate; L, lancet; O, oral plate; OSp, outer side plate; P, pore; S, spiracle; Sp, main side plate; Su, superdeltoid.]



## PLACOBLASTUS ERIENSIS (Reimann)

Plate 32, figures 1-3; text-fig. 202

*Nucleocrinus verneuili eriensis* REIMANN, 1935, p. 33, pl. 4, figs. 4-5.

**Description.**—Calyx ellipsoidal in side view, broadly rounded pentagonal in top view, 26 mm. long by 18 mm. wide, with periphery near mid-height, and flat summit, with flat base. Basal circlet pentagonal in aboral view, 2 mm. wide, with small round stem 0.5 mm. wide in sharp central basal concavity. Each basal plate has a high round ridge extending radially from the center of each plate toward the radial lips, except on the "D" ambulacral side. The ridge on the azygous basal bifurcates into two low rounded ridges that extend to the "A" and "B" radial lips. Radials five, each 6 mm. long by 5 mm. wide, elongate pentagonal in side view, with a broad M-shaped radiodeltoid suture. Radial sinus short, 2 mm. long by 1 mm. wide. Deltoids overlap radials.

Deltoids four, each broadly lenticular, 23 mm. long by 9.5 mm. wide, with smooth central triangular area flanked on either side by lenticular nodose areas, similar to that of *Nucleocrinus*. The adoral tips of each deltoid are notched by two elongate hemielliptical spiracles, one on each side adjacent to the ambulacra. On the anal side there are at least three anal deltoids, the two elongate lenticular cryptodeltoids, with the elongate quadrangular hypodeltoid between. On the adoral side of the anal opening one large plate occurs between the adoral ends of the cryptodeltoids, and possibly there is another plate below it. The upper plate is here interpreted to be an accessory anal oral, but it could be superdeltoid and the plate below could be part of the upper one, with a crack between, instead of a suture. There are five large oral plates covering the summit, each broadly triangular and interambulacral in position and (depending on interpretation) one accessory oral is recognized between the adoral tips of the cryptodeltoids. One hemielliptical spiracle is present in the adoral tip of each cryptodeltoid along the ambulacral margins. Thus, 11 openings surround the oral aperture, consisting of ten spiracles and a separate anal opening. Ornamentation of deltoids and anal deltoids is similar to that of *Nucleocrinus*.

Ambulacra five, linear, each 29 mm. long by 1 mm. wide, recurved below, with lancet covered by side plates, and 28 side plates in a space of 10 mm. along an ambula-

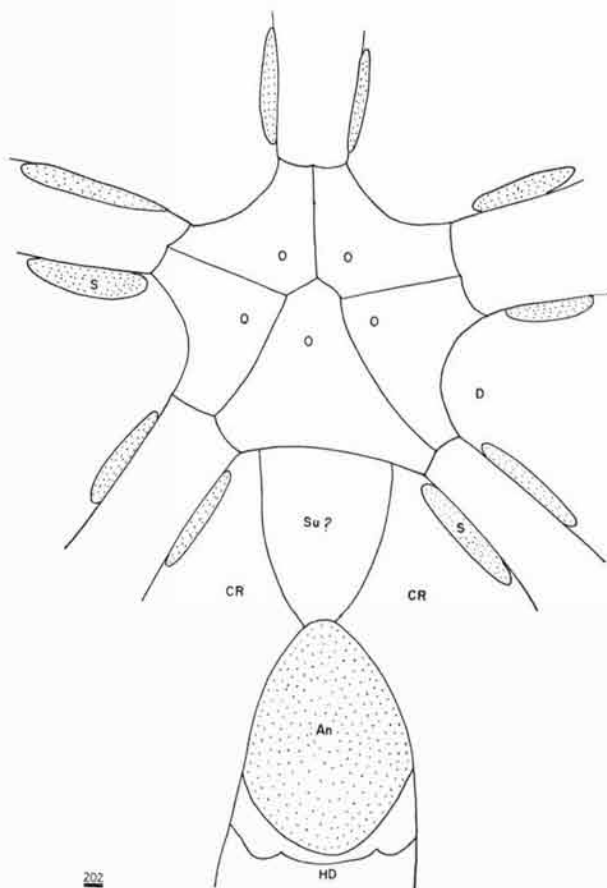


FIGURE 202. *Placoblastus eriensis* (REIMANN), Ludlowville Formation, Springbrook, New York (Buffalo Soc. Nat. Sci., no. E11,811); summit and anal areas,  $\times 10.6$ . [Explanation.—An, anal opening; CR, cryptodeltoid; D, deltoid; HD, hypodeltoid; O, oral plate; S, spiracle; Su, superdeltoid.]

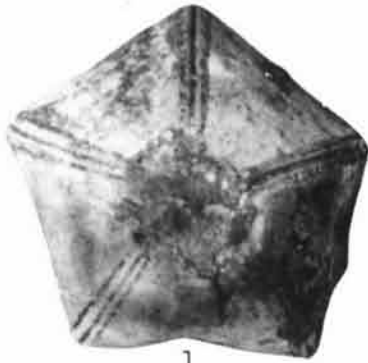
crum. Side plates and pores disposed as in *Nucleocrinus*, with inner side plate present.

**Remarks.**—This and other species of *Placoblastus* may be distinguished by shape, relative proportions of plates, and disposition of orals.

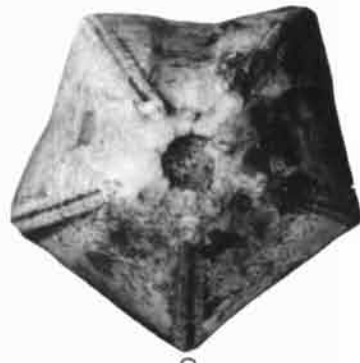
## EXPLANATION OF PLATE 31

FIGURE PAGE  
1-9. *Placoblastus obovatus* (BARRIS), ?topotypes, E21,115 (figs. 1-7, 9), E21,113 (fig. 8), Buffalo Soc. Nat. Sci.; Middle Devonian, Thunder Bay Limestone, Partridge Point, near Alpena, Mich.—1-3. Oral, aboral, and "D" ambulacral views of uncrushed specimen ( $\times 1.5$ ).—4-6. Oral, "EA" interambulacral, and aboral views of slightly crushed specimen with oral plates in place ( $\times 1.8$ ).—Aboral end

of "C" ambulacrum of specimen illustrated in fig. 5, showing main, outer, and inner side plates on polished surface ( $\times 31.5$ ).—8. Cross section (polished) of another specimen showing deep bifurcation of two hydrospire folds on each side of an ambulacrum ( $\times 11.5$ ).—9. Oral view of specimen shown in fig. 4, showing five large oral plates and large additional plate between adoral tips of cryptodeltoids ( $\times 5.4$ )



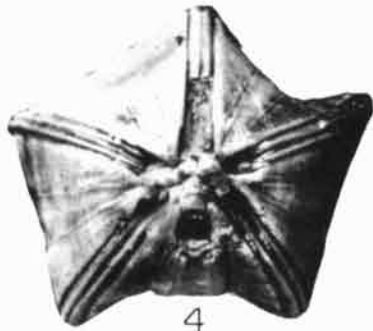
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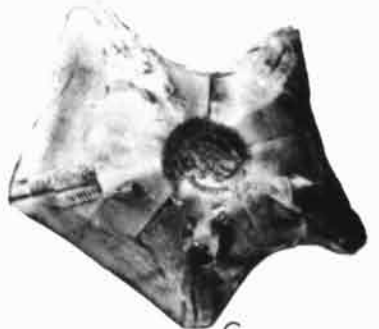
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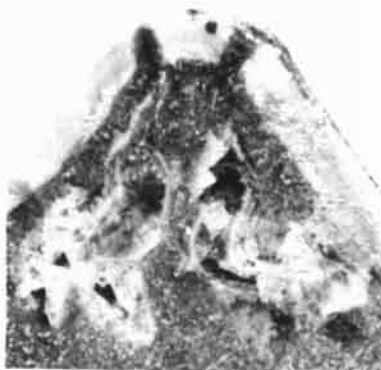
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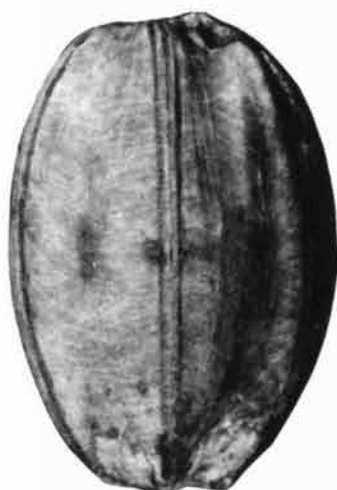
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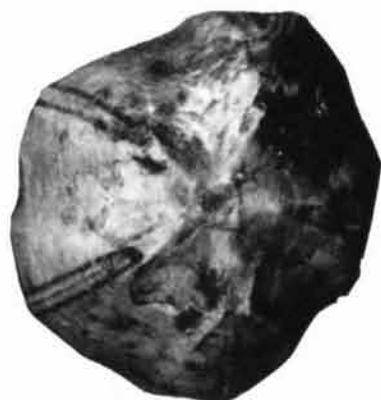
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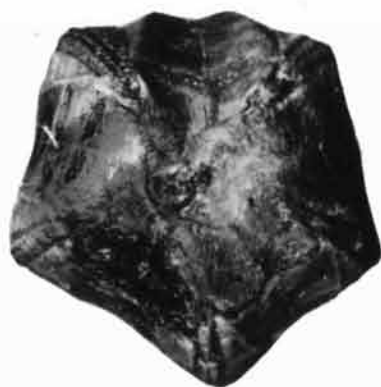
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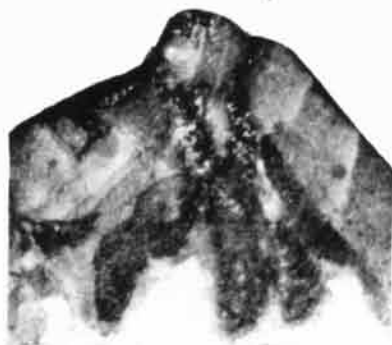
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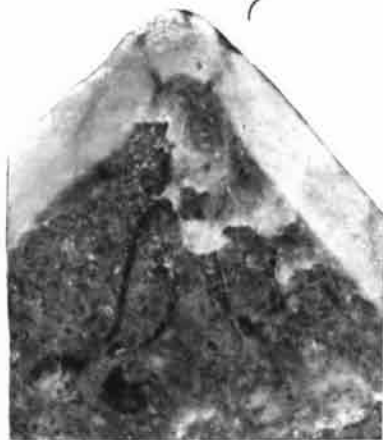
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*Occurrence*.—Middle Devonian, Ludlowville Formation (Tichenor Limestone), Cazenovia Creek, Springbrook, New York.

*Type*.—Holotype, E11,811, one specimen, Fred Wattles collection, Buffalo Society of Natural Sciences, Buffalo, New York.

### PLACOBLASTUS LUCINA (Hall)

Plate 32, figures 4-7, 10; text-figs. 200, 201

*Nucleocrinus lucina* HALL, 1862, p. 148, pl. 1, fig. 16.

*Elaeocrinus lucina* SHUMARD, 1866, p. 369.

*Olivanites lucina* HAMBACH, 1903, p. 50.

*Description*.—Calyx calcitic, flattened spherical in side view, pentagonal in top view with moderately sharp ambulacra and concave interambulacra, 9 mm. long by 9 mm. wide, with slightly concave base. Stem round, 0.25 mm. wide, in flat basal cirlet, crenellar, with small round lumen. Basal cirlet rounded pentagonal in aboral view, 2.5 mm. in diameter, almost flat to slightly concave, with three normally disposed basals. Radials five, short, wide, pentagonal in side view, each 3 mm. long by 4 mm. wide, with short, shallow sinus 1.5 mm. long by 1 mm. wide, recurved below in slightly concave aboral surface. Deltoids overlap radials.

Deltoids four, sublenticular, each 8 mm. long by 5 mm. wide, with two hemielliptical spiracles in the adoral tip along ambulacral margins. In top view the deltoids are slightly concave inward, the aboral end of each abutting against a large arrow-shaped oral plate. On the anal side at least three anal deltoids occur, the two lenticular exposed cryptodeltoids along ambulacral margins, with the elongate subquadrangular hypodeltoid between. On the adoral side of the anal opening there are two polygonal plates between the adoral tips of the cryptodeltoids. The plate adjacent to the anal opening is here interpreted to be a superdeltoid plate, and the adorally disposed plate is interpreted to be an accessory anal oral plate. Calyx plates ornamented as in *Nucleocrinus*. There

are two semielliptical slitlike spiracles on either side of the anal opening, one each in the adoral tip of each cryptodeltoid. Thus, 11 openings surround the oral aperture, consisting of ten spiracles and the separate anal opening. There are two hydrosphere folds on each side of an ambulacrum, with a moderately long hydrosphere canal.

Ambulacra five, linear, recurved below, each 11 mm. long by 1 mm. wide, with lancet covered by side plates, and 40 side plates in a space of 10 mm. along an ambulacrum. Side plates normally disposed, with an inner side plate, as in *Nucleocrinus*.

*Occurrence*.—Middle Devonian, Hamilton beds, Moscow, New York.

*Types*.—The holotype is on deposit at the American Museum of Natural History, Hall collection, 5038/2, and is slightly damaged, but usable for general identification of other specimens. Topotypes, 13,276, Hall collection, one specimen; 19,049, two specimens, one of which is *Nucleocrinus elegans*, Gurley collection, Walker Museum, University of Chicago. The above description is based on specimen 19,049.

### Genus POROBLASTUS Fay, n. gen.

*Type-species*, by original designation (herein).—*Pentremites* (*Granatocrinus*?) *granulosus* MEEK & WORTHEN, 1865.

*Generic diagnosis*.—Spiraculate blastoids with nine spiracles, or eight spiracles and anispiracle, the anispiracle located between an epideltoid and hypodeltoid, radials overlapping deltoids, hydrosphere plate present, one pore between side plates along deltidoid margins but two pores to each side plate along radial margins, one hydrosphere fold on each side of an ambulacrum, lancet covered at aboral end but gradually exposed to one-third of its width near the adoral end, base concave, and shape ellipsoidal. *Mississippian*, Illinois, Iowa, Missouri.

*Remarks*.—The genus *Poroblastus* may have been derived from *Lophoblastus* by infolding of radial mar-

## EXPLANATION OF PLATE 32

FIGURE	PAGE		PAGE
1-3. <i>Placoblastus eriensis</i> (REIMANN), holotype, E11,811, Fred Wattles coll., Buffalo Soc. Nat. Sci.; Middle Devonian, Tichenor Limestone, Cazenovia Creek, Springbrook, N.Y.; oral, "D" ambulacral, aboral views of specimen described as <i>Nucleocrinus verneuili eriensis</i> (all $\times 2.4$ )	97		
4-7, 10. <i>Placoblastus lucina</i> (HALL), ?topotypes, 19,049 (figs. 4-6, 10), Gurley coll., Univ. Chicago, Devonian, Hamilton Group, Moscow, N.Y., and 13,276 (fig. 7), James Hall coll., Univ. Chicago, Middle Devonian, New York; 4-6, one of two specimens labelled <i>Nucleocrinus elegans</i> , oral, "D" ambulacral, aboral views ( $\times 5.1$ ); 10, specimen illustrated in fig. 4, showing large plate between adoral tips of cryptodeltoids ( $\times 3.6$ ); 7. Aboral view of polished	97	cross section showing hydrosphere folds of "E" ambulacrum ( $\times 12.6$ )	97
		8. <i>Placoblastus angularis</i> (LYON), plesiotype, E9,057, Reimann coll., Buffalo Soc. Nat. Sci. (one of five specimens labelled <i>Nucleocrinus powelli</i> ; Middle Devonian, Ludlowville Formation (Tichenor Limestone), Cazenovia Creek, Springbrook, N.Y.; aboral view of polished cross section of "E" ambulacrum showing hydrosphere folds ( $\times 9.3$ )	95
		9. <i>Nucleocrinus meloniiformis</i> (BARRIS), plesiotype, E21,120, Charles Southworth coll., Buffalo Soc. Nat. Sci.; Middle Devonian, Hungry Hollow Formation (coral zone of Widder beds), tile yard, Thedford, Ontario, polished section of "E" ambulacrum showing two folds on right originating at deltidoid ( $\times 19$ )	86

gins along ambulacra to form two pores to each side plate, reduction of hydrospire folds to two on each side of an ambulacrum, and formation of a concave base.

#### **POROBLASTUS GRANULOSUS (Meek & Worthen)**

Plate 40, figures 7-12; plate 41, figures 1-12; plate 42, figure 8; text-figs. 203-205

*Pentremites (Granatocrinus?) granulosis* MEEK & WORTHEN, 1865, p. 165.

*Granatocrinus granulosis* MEEK & WORTHEN, 1873, p. 508, pl. 15, fig. 10.

*Schizoblastus? granulosis* ETHERIDGE & CARPENTER, 1886, p. 223.

*Crioblastus granulosis* HAMBACH, 1903, p. 40.

*Cryptoblastus granulosis* CLINE, 1937, p. 643, pl. 88, figs. 11-16.

*Description.*—The holotype is 7 mm. long by 7 mm. wide, subspherical, complete, and similar to the following described specimen. Calyx calcitic, 7.5 mm. long by 7 mm. wide, flattened elliptical in side view, rounded pentagonal in top view, with concave base, and periphery at mid-height near radiodeltoid suture. Stem impression not seen. Basal circling pentagonal in basal view, in basal depression, 1.5 mm. wide, with three normally disposed basals. Radials five, each pentagonal in side view, 5 mm. long by 4 mm. wide, moderately long, extending to mid-height, recurved below, with a 135 degree angle formed by radial limbs at radiodeltoid suture with center at interradial suture. Radials overlap deltoids.

Deltoids four, elongate, lancet-shaped, each 4.5 mm. long by 3 mm. wide, with two spiracles notched in the adoral end of each, adjacent to the ambulacra. On the anal side there are two deltoids, a short V-shaped epideltoid adjacent to the oral opening, and a long pentagonal hypodeltoid on the aboral side of the anispiracle. The hypodeltoid projects ventrally above the anispiracle a short distance, forming a low hood. Thus there are nine openings surrounding the oral aperture—eight spiracles and the anispiracle. One hydrospire fold occurs on each side of an ambulacrum, ending admedially in a hydrospire plate.

Ambulacra five, linear, recurved below, each 9.5 mm. long by 1 mm. wide, with lancet covered by side plates along the aboral one-half and exposed one-third of its width at the adoral end, with 30 side plates in a space of 10 mm. along an ambulacrum. The side plates are normally disposed, with five or six main cover-plate sockets to each side plate along the main food groove. Approximately two pores to each side plate are present along the radial ambulacral margins and one pore to each side plate along the deltoid margins. The surfaces of the calyx plates are ornamented by fine granules and growth ridges subparallel to plate margins.

*Remarks.*—The presence of one pore to a side plate along the deltoid margins distinguishes this genus from *Ptychoblastus* and *Granatocrinus*, which have two pores

to each side plate along the deltoid margins. Also, *Granatocrinus* is large when mature but *Poroblastus* small. In *Ptychoblastus* the radials and deltoids abut against each other, and in *Granatocrinus* and *Poroblastus* the radials overlap the deltoids.

*Occurrence.*—Lower Mississippian, upper part of Burlington Limestone, locality 21 of WELLER, Springfield, Missouri (described specimen); locality 20 of WELLER, same. Keokuk Group, Warsaw, Illinois (the holotype). Upper part of the Burlington Limestone, Burlington, Iowa (S3,720). Keokuk formation, Jersey County, Illinois (S3,717). Keokuk Group, near Warsaw, Illinois (S3,719). Warsaw Formation, Otterville, Illinois (S3,716). Warsaw Formation, fourth horizon, geode bed, one mile above Warsaw, Illinois (also numbered S3,719).

*Types.*—Holotype, 713, one specimen, old Illinois State Museum no. 1,843, labelled *Schizoblastus granulosis*, Illinois Geological Survey, Urbana. Plesiotypes, 13,893, five specimens, one complete, from locality 20, Weller collection; and 13,894, three specimens, two complete, from locality 21, Weller collection, one specimen of which was used for above description, Walker Museum, University of Chicago. These specimens are also labelled *Schizoblastus granulosis*. Topotypes?, S3,719, one specimen, Springer collection, from the Keokuk near Warsaw, Illinois; also S3,719, 35 specimens, from the ?Warsaw (labelled Keokuk), 4th horizon, geode bed, one mile above Warsaw, Illinois, Springer collection, labelled *Cryptoblastus granulosis*; S3,716, 15 specimens, Springer collection; S3,717, one specimen, Springer collection; S3,720, 20 specimens, Springer collection, all of which are labelled *Cryptoblastus granulosis*; U. S. National Museum, Washington.

#### **POROBLASTUS CHOUTEAUENSIS (Peck)**

Plate 42, figures 1-3; text-fig. 206

*Orbitremites chouteauensis* PECK, 1938, p. 69, pl. 26, fig. 18.

*Description.*—Calcitic, fragmentary, 9.5 mm. long by 9 mm. wide, subspherical, with periphery at mid-height, base sharply concave, with basal circling 1 mm. in diameter in basal concavity. Radials five, each approximately 5 mm. long by 4.5 mm. wide, strongly recurved below, with sinus 5 mm. long by 1 mm. wide, and angle of 150 degrees formed by radial limbs along radiodeltoid suture with interradial suture as center. Radials overlap deltoids.

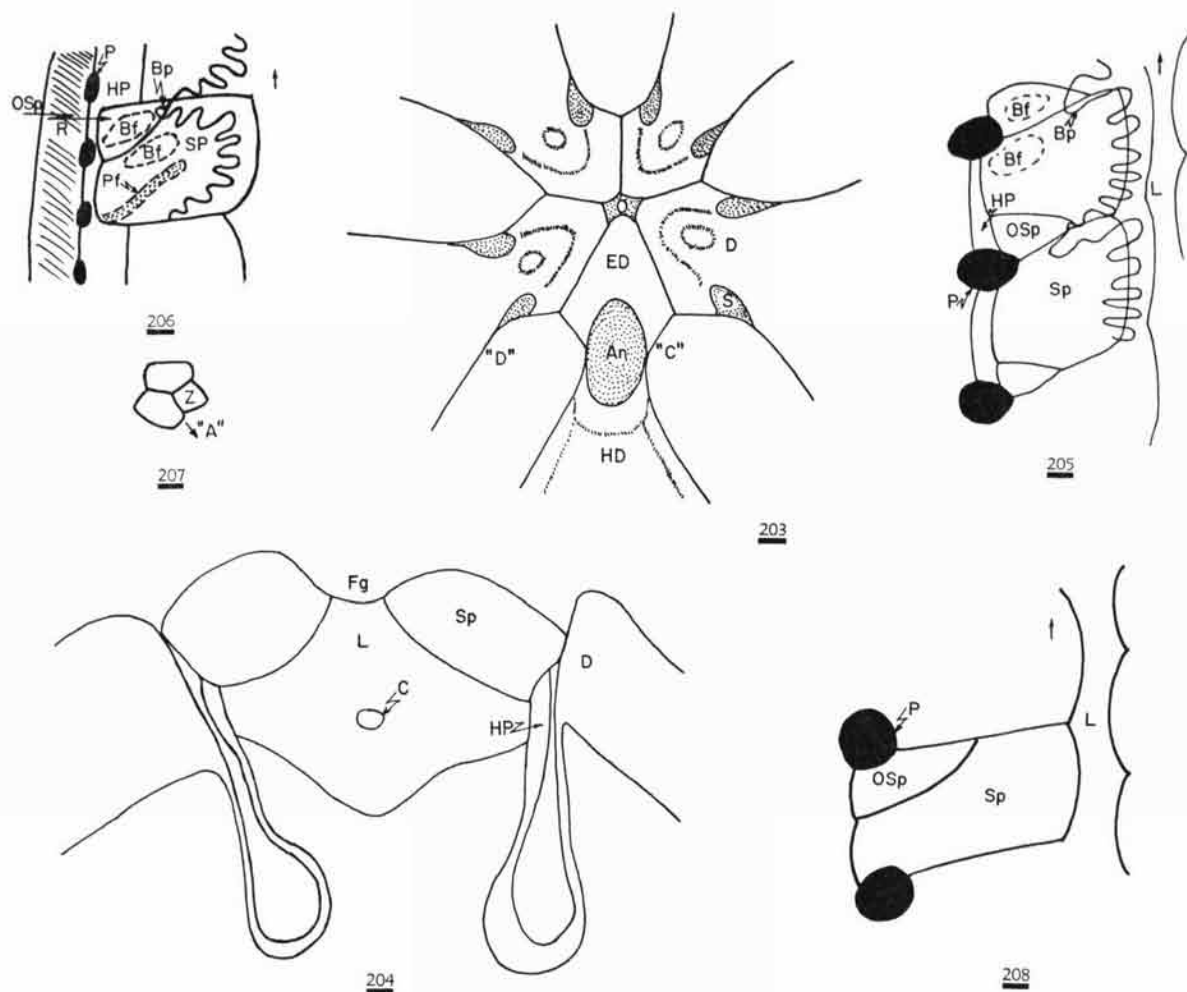
Deltoids four, each 6 mm. long by 4 mm. wide, long, extending below periphery, with adoral tips of each notched by two small spiracles on the ambulacral margins. On the anal side the anispiracle is apparently placed between an epideltoid and hypodeltoid plate. Thus, apparently nine openings surround the oral aperture, consisting of eight spiracles and the anispiracle. The number of hydrospire folds is unknown.

Ambulacra narrow, linear, each 11 mm. long by 1 mm. wide, recurved below, with lancet covered by side plates in aboral one-half of each ambulacrum but gradually exposed to one-third of its width at the adoral end, with 30 side plates in a space of 10 mm. along an ambulacrum. Approximately two pores to each side plate are found along the radial ambulacral margins, and one pore

to each side plate along the deltoid margins, with a hydrospire plate present along deltoid and radial margins.

The surfaces of the calyx plates are ornamented by finely granular growth ridges subparallel to plate margins, and the side plates are normally disposed.

*Occurrence.*—Lower Mississippian, Chouteau Limestone, near Providence, Boone County, Missouri.



FIGURES 203-208. Species of *Poroblastus* FAY, n. gen., and *Schizoblastus* ETHERIDGE & CARPENTER.

203-205. *P. granulatus* (MEEK & WORTHEN), Lower Mississippian, Burlington Limestone, Springfield, Mo. (Univ. Chicago, nos. 13,893, 13,894); 203, summit and anal areas (no. 13,894),  $\times 15$ ; 204, cross section of "C" ambulacrum, oral view (no. 13,893),  $\times 45$ ; 205, part of "A" ambulacrum, showing side plates (no. 13,894),  $\times 45$ .—206. *P. chouteauensis* (РЕСК), Lower Mississippian, Chouteau Limestone, near Providence, Mo. (Univ. Missouri, no. 1,290); part of "A" ambulacrum, showing side plates,  $\times 45$ .—207, 208. *S. sayi* (SHUMARD), Lower Mississippian, Burlington Limestone, Boone and Marion Counties,

Missouri (U. S. Natl. Mus., no. S3,735); 207, basal cirlet, arrow directed toward "A" ambulacrum,  $\times 2.5$ ; 208, part of "A" ambulacrum, showing side plates,  $\times 20$ . [Explanation.—"A," amb.; An, anal opening; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); "D," amb.; D, deltoid; ED, epideltoid; Fg, main food groove; HD, hypodeltoid; HP, hydrospire plate; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; S, spiracle; Sp, main side plate; Z, azygous basal.]

*Type*.—Holotype, 1,290, one specimen, C. C. Branson collection, University of Missouri, Columbia.

### Genus PTYCHOBLASTUS Fay, 1960

*Type-species*, by original designation.—*Ptychoblastus pustulosus* FAY, 1960.

*Generic diagnosis*.—Spiraculate blastoids with nine spiracles, or eight spiracles and anispiracle located between an epideltoid and hypodeltoid, radials abutting against deltoids, hydrospire plate present, two pores to each side plate and along deltoid and radial margins, one hydrospire fold on each side of an ambulacrum, lancet covered at aboral end but gradually exposed to one-third of its width near the adoral end; shape of calyx ellipsoidal. *Mississippian*, Missouri.

*Remarks*.—The genus *Ptychoblastus* was probably derived from *Poroblastus* by infolding of the poral canals along the deltoid margins to form two pores to each side plate, and downward migration of the deltoid plates so that they abut against the radials.

### PTYCHOBLASTUS PUSTULOSUS Fay

Plate 42, figures 4-7, 9-10

*Ptychoblastus pustulosus* FAY, 1960, pp. 1198-1201, text-fig. 1.

*Description*.—A detailed description is given in the above article and is not here repeated. Of importance is the presence of two pores to each side plate along the deltoid margins and radials abutting against the deltoids.

*Occurrence*.—Upper Mississippian, Warsaw Limestone, 12 feet below the top, SW $\frac{1}{4}$  NW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 9, T. 44 N., R. 5 E., just below level of St. Louis & San Francisco RR tracks, Keyes Summit, St. Louis County, Missouri.

*Types*.—Holotype, 3,643; paratypes, 3,644 (a thin-section), and 3,645 (six specimens and one thin-section with fragment), Geology Department, University of Oklahoma, Norman.

### Genus SCHIZOBLASTUS Etheridge & Carpenter, 1882

*Type-species*, by subsequent designation (ETHERIDGE & CARPENTER, 1886).—*Pentremites sayi* SHUMARD, 1855.

*Generic diagnosis*.—Spiraculate blastoids with 11 openings around the mouth, consisting of ten spiracles and separate anus, which is located between an epideltoid and hypodeltoid, lancet exposed along main food groove, one pore between side plates along deltoid and radial margins, deltoids moderately long, deltoids overlapping radials, two hydrospire folds on each side of an ambulacrum; form of calyx ellipsoidal. *Mississippian*, Iowa, Missouri.

*Remarks*.—The genus *Schizoblastus* was probably derived from a genus approaching *Schizotremites*, in which the deltoid septa moved out to form ten spiracles with anus separate, cryptodeltoids fused with superdeltoid to form an epideltoid, and lancet moved out and down while the hydrospires atrophied to two folds on each side of an ambulacrum.

### SCHIZOBLASTUS SAYI (Shumard)

Plate 46, figures 1-2; text-figs. 207-208

*Pentremites sayi* SHUMARD, 1855, p. 185, pl. B, figs. 1a-d.

*Crioblastus sayi* HAMBACH, 1903, p. 42, pl. 5, fig. 14.

*Schizoblastus sayi* var. *sayi* CLINE, 1936, p. 269, pl. 44, figs. 17-22.

*Description*.—The holotype is fragmentary. Calyx calcitic, 12 mm. long by 16 mm. wide, crushed on one side, in limestone matrix. Base slightly concave. Shape of calyx widely elliptical in side view. Deltoids overlap radials and extend below the periphery for about three-fourths the length of the specimen. Spiracles apparently ten, separate from anus, with anus between an epideltoid and hypodeltoid plate. Ambulacra five, linear, each 19-20 mm. long by 1.5 mm. wide, recurved below, with lancet exposed along the middle one-fifth of its width along the main food groove, and 32 side plates in a space of 10 mm. along an ambulacrum. The anal opening is covered on the aboral side by a low adoral projection of the hypodeltoid plate. Each deltoid plate has three longitudinal ridges extending toward the adoral tip, one in the mid-line of the plate and two marginal ones. The surfaces of the calyx plates are ornamented by fine growth lines subparallel to plate margins, with a tendency toward granulation.

## EXPLANATION OF PLATE 33

FIGURE	PAGE	
1-9. <i>Placoblastus angularis</i> (LYON), plesiotypes, 13,890 (figs. 1-6), Gurley coll., Univ. Chicago, Middle Devonian, Hamilton Group, Charlestown, Ind., 19,052 (figs. 7-9), Falls of the Ohio, near Jeffersonville, Ind.; 1-3, oral, "D" ambulacral, and aboral views of average specimen, ( $\times 2.9$ );		4-6, oral, "D" ambulacral, and aboral views of a gerontic specimen ( $\times 2.2$ ); 7-9, oral, "D" ambulacral, aboral views of four-sided specimen in which the "A" ambulacrum failed to develop, thus with only four radials and four deltoids ( $\times 7$ ) .....
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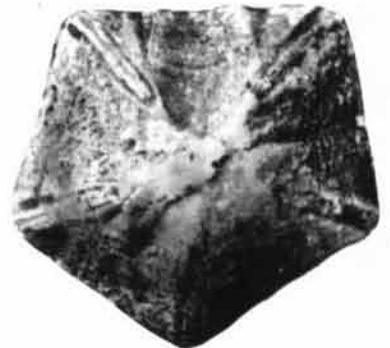




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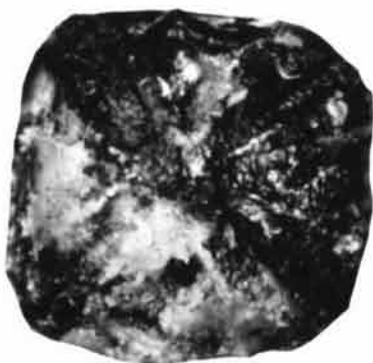
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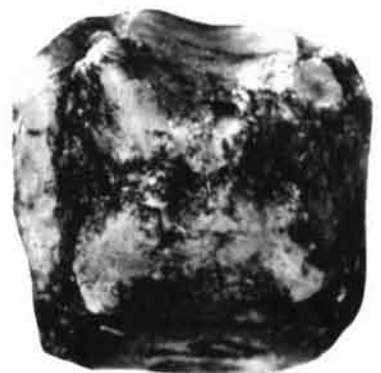
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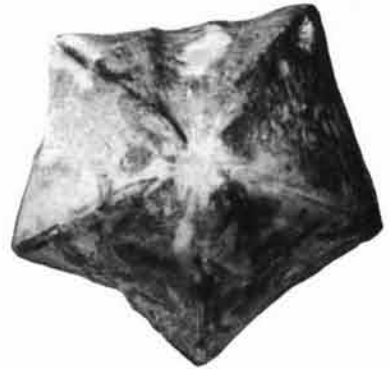
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*Occurrence*.—Lower Mississippian, lower part of Encrinital (Burlington) Limestone, Boone and Marion Counties, Missouri.

*Types*.—Holotype, S3,735, with a green label in a glass vial with two fragments with orange labels, Shumard collection, of the Hambach collection, sold to SPRINGER, now in U. S. National Museum, Washington. HAMBACH evidently had some of SHUMARD's types in his personal collection when he sold his collection to SPRINGER. The type probably came from Marion County, Missouri, judging from the label.

### SCHIZOBLASTUS WINSLOWI (Miller & Gurley)

Plate 46, figures 3-5

*Granatocrinus winslowi* MILLER & GURLEY, 1894, p. 66, pl. 6, figs. 34-35.

*Orbitremites winslowi* BATHER, 1899, p. 32.

*Description*.—The calyx of the holotype is silicified, imperfectly preserved, 11.5 mm. long by 12 mm. wide, with vault 11.5 mm. long, pelvis flat, with periphery above radiodeltoid suture. Stem round, 0.5 mm. wide. Basal cirlet pentagonal in aboral view, 2 mm. wide. Radials five, each 8 mm. long by 6.5 mm. wide, pentagonal in side view, extending to mid-height, with a 120 degree angle formed by radial limbs at radiodeltoid suture, with center at interradsial suture. The radial sinuses are each 6 mm. long by 2 mm. wide. Deltoids overlap radials.

Deltoids four, each 8 mm. long by 6 mm. wide, with two spiracles notched in the adoral tip of each. It is presumed that an anal opening was present between an epideltoid and a hypodeltoid plate, and that two hydrospire folds are present on each side of an ambulacrum.

Ambulacra linear, long, recurved below, each 15 mm. long by 2 mm. wide, with lancet exposed along main food groove, but covered by side plates at the aboral end, and 30 side plates in a space of 10 mm. along an ambulacrum. Side plates and pores normally disposed. The surfaces of the deltoids and radials are covered by large aligned nodes, with about eight nodes in three longitudinal rows on each deltoid, and nine nodes in three aligned rows on each radial, the rows being subparallel to the plate margins.

*Occurrence*.—Lower Mississippian, ?Burlington Lime-

stone (drift), at Danville, Illinois (?transported from Burlington Limestone outcrops to the north).

*Type*.—Holotype, 6,621, one specimen, Walker Museum, University of Chicago.

### Genus TANAOBLASTUS Fay, n. gen.

*Type-species*, by original designation (herein).—*Pentremites roemeri* SHUMARD, 1855.

*Generic diagnosis*.—Spiraculate blastoids with nine openings around mouth, consisting of eight spiracles and an anispiracle, with anispiracle between a superdeltoid, and hypodeltoid, with two hidden cryptodeltoids, deltoids moderately short, pores absent along deltoid margins, with hydrospire plate and two pores to each side plate along radial margins, two hydrospire folds on each side of an ambulacrum, lancet exposed along main food groove, interradsial sutures even, base flat to convex outward, radials overlapping deltoids; form of calyx subelliptical. *Mississippian*, Missouri, Montana, ?Arizona, Alberta.

*Remarks*.—The genus *Tanaoblastus* may have been derived from some primitive type of *Lophoblastus* in which the pores atrophied along the deltoids, and the ambulacral margins of the radials infolded to form two pores to each side plate, with reduction of the number of hydrospire folds to two.

### TANAOBLASTUS ROEMERI (Shumard)

Plate 36, figures 7-12; text-figs. 209-213

*Pentremites roemeri* SHUMARD (*partim*), 1855, p. 186, pl. B, fig. 2a; HAMBACH, 1884, pl. D, figs. 3, 3a.

*Schizoblastus? roemeri* KEYES, 1894, p. 137.

*Cryptoblastus roemeri* PECK, 1938, p. 60, pl. 26, figs. 19-21, 23-24.

*Pentremites sampsoni* HAMBACH, 1884, p. 551, pl. D, figs. 2, 2a.

*Schizoblastus sampsoni* ETHERIDGE & CARPENTER, 1886, p. 223.

*Description*.—Calyx calcitic, 6.5 mm. long by 5.5 mm. wide, vault 6 mm. long, pelvis 0.5 mm. long, and pelvic angle 150 degrees. The calyx is elliptical in side view, with truncated summit, convex base, and periphery at radiodeltoid suture about one-third of the distance down from the summit. Stem round, 0.25 mm. wide, crenellar.

## EXPLANATION OF PLATE 34

FIGURE	PAGE	
1-9.		<i>Placoblastus angularis</i> (LYON), plesiotypes, E11,629 (figs. 1-3, 7), E9,057 (fig. 8), E9,058 (figs. 4-6, 9), Reimann coll., Buffalo Soc. Nat. Sci.; Middle Devonian, Ludlowville Formation (Tichenor Limestone), Cazenovia Creek, Springbrook, N.Y.; 1-3, oral, "D" ambulacral, and aboral views of gerontic paratype of <i>Nucleocrinus powelli</i> REI-
		MANN ( $\times 1.2$ ); 4-6, oral, "D" ambulacral, and aboral views of holotype of <i>N. powelli</i> ( $\times 3$ ); 7, detail view of "B" ambulacrum of specimen shown in fig. 1 ( $\times 13$ ); 8, aboral view of another paratype of <i>N. powelli</i> ( $\times 8$ ); 9, oral view of specimen shown in fig. 4, showing what appears to be several large plates between adoral tips of cryptodeltoids, anal opening in black ( $\times 2.6$ ) ..... 95

Basal cirlet convex outward, pentagonal in aboral view, 1.5 mm. wide, with raised margins and depressed interbasal sutures, and raised pentagonal aboral portion adjacent to stem, with three normally disposed basals. Radials five, each 5 mm. long by 3 mm. wide, with sinus 4 mm. long by 0.75 mm. wide, and 115-degree angle formed by radial limbs at radiodeltoid suture with center at interradian suture. Radials overlap deltoids.

Deltoids four, short, each 2.5 mm. long by 1.5 mm. wide, notched in the adoral tip by two spiracles, adjacent to the ambulacra. On the anal side the anal opening is confluent with adjacent spiracles, thus forming an anispiracle. The anispiracle is located between a small U-shaped superdeltoid and a pentagonal hypodeltoid, with two small hidden cryptodeltoids beneath the hypodeltoid on either side of the anal opening, separating the anal opening from the adjacent spiracles. Thus there are nine openings around the mouth, consisting of eight spiracles and the anispiracle. Two hydrospire folds occur on each side of an ambulacrum, ending admedially in a hydrospire plate. Pores are absent along the deltoid margins.

Ambulacra five, linear, narrow, each 7 mm. long by 1 mm. wide, with lancet exposed along immediate food groove and 35 side plates in a space of 10 mm. along an ambulacrum. Side plates normally disposed, the primary side plate being subquadrangular and the outer side plate subtriangular, resting upon the adoral-abmedial bevelled corner of the primary side plate. Approximately two pores to each side plate are seen along the radial margins, and five cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented by coarse growth ridges subparallel to plate margins. The above description is mainly based on hypotype 1,143.

*Occurrence.*—Lower Mississippian, Chouteau Limestone, near Sedalia and Hallsville, Missouri.

*Types.*—Hypotype, 1,143, one specimen, Blair collection, from Sedalia; 1,063, one ground specimen, Peck collection, 3.5 miles west of Hallsville, Missouri, University of Missouri, Columbia; these specimens are labelled *Cryptoblastus roemeri*; plesiotypes, 19,106, from Sedalia, Gurley collection, 11 specimens identified as *Cryptoblastus roemeri* by PECK but labelled *Orbitremites roemeri*, Walker Museum, University of Chicago.

#### TANAOLASTUS BELLATULUS (Peck)

Plate 37, figures 4-6

*Cryptoblastus bellatulus* PECK, 1938, p. 68, pl. 26, figs. 1-3.

*Description.*—Calyx globular, 3.5 mm. long by 2.5 mm. wide, with periphery above center, convex base, linear ambulacra each 4 mm. long by 0.75 mm. wide, with 35 side plates in a space of 10 mm. along an ambulacrum. Lancet covered by side plates in aboral one-half of each ambulacrum and exposed almost one-third of its width near the adoral end. This and other species may

be distinguished by shape of the calyx and relative proportions of pelvis, vault, length, and width.

*Occurrence.*—Lower Mississippian, Chouteau Limestone, 9 miles northeast of Osceola, Missouri.

*Type.*—Holotype, 3,293, Peck collection, University of Missouri.

#### TANAOLASTUS CONCINNULUS (Rowley & Hare)

Plate 38, figures 1-3, 5; text-figs. 214-217

*Granatocrinus concinnulus* ROWLEY & HARE, 1891, p. 117, pl. 3, figs. 13-14.

*Orbitremites concinnulus* BATHER, 1899, p. 25.

*Cryptoblastus concinnulus* ROWLEY, 1900, pp. 246, 251.

*Description.*—Calyx flattened elliptical in side view, 8 mm. long by 7 mm. wide, with rounded summit and flat base, periphery above mid-height. Stem round, crenellar, 0.75 mm. in diameter, with about 25 crenellae extending radially inward about half-way from the circumference. Basal cirlet flat, pentagonal in basal view, 2 mm. in diameter, with depressed basiradial sutures and azygous basal in (DE) interradian position. Radials five, each 7 mm. long by 4 mm. wide, recurved below, with prominent radial lip and narrow, shallow sinus 7 mm. long by 1-1.5 mm. wide; radials overlapping deltoids.

Deltoids four, short, lancet-shaped, each with two spiracles notched in the adoral tip along ambulacral margins. On the anal side the anispiracle is between a pentagonal superdeltoid and a pentagonal hypodeltoid, probably with two hidden cryptodeltoids. Thus there are nine openings around the mouth, consisting of eight spiracles and the anispiracle. Two hydrospire folds occur on each side of an ambulacrum, ending admedially in a hydrospire plate. Pores absent along deltoid margins.

Ambulacra five, long, linear, recurved below, with lancet exposed along food groove adorally, and 30 side plates in a space of 10 mm. along an ambulacrum. The side plates are normally disposed, with two pores to each side plate along the radial margins, and five main cover-plate sockets to each side plate along the main food groove. The surfaces of the calyx plates are ornamented by fine ridges or granular lines subparallel to plate margins.

*Occurrence.*—Lower Mississippian, lower part of Burlington Limestone, Louisiana, Missouri.

*Types.*—Holotype, one complete specimen; paratypes, one cut section and a specimen in rock, Rowley collection, Department of Geology, University of Illinois.

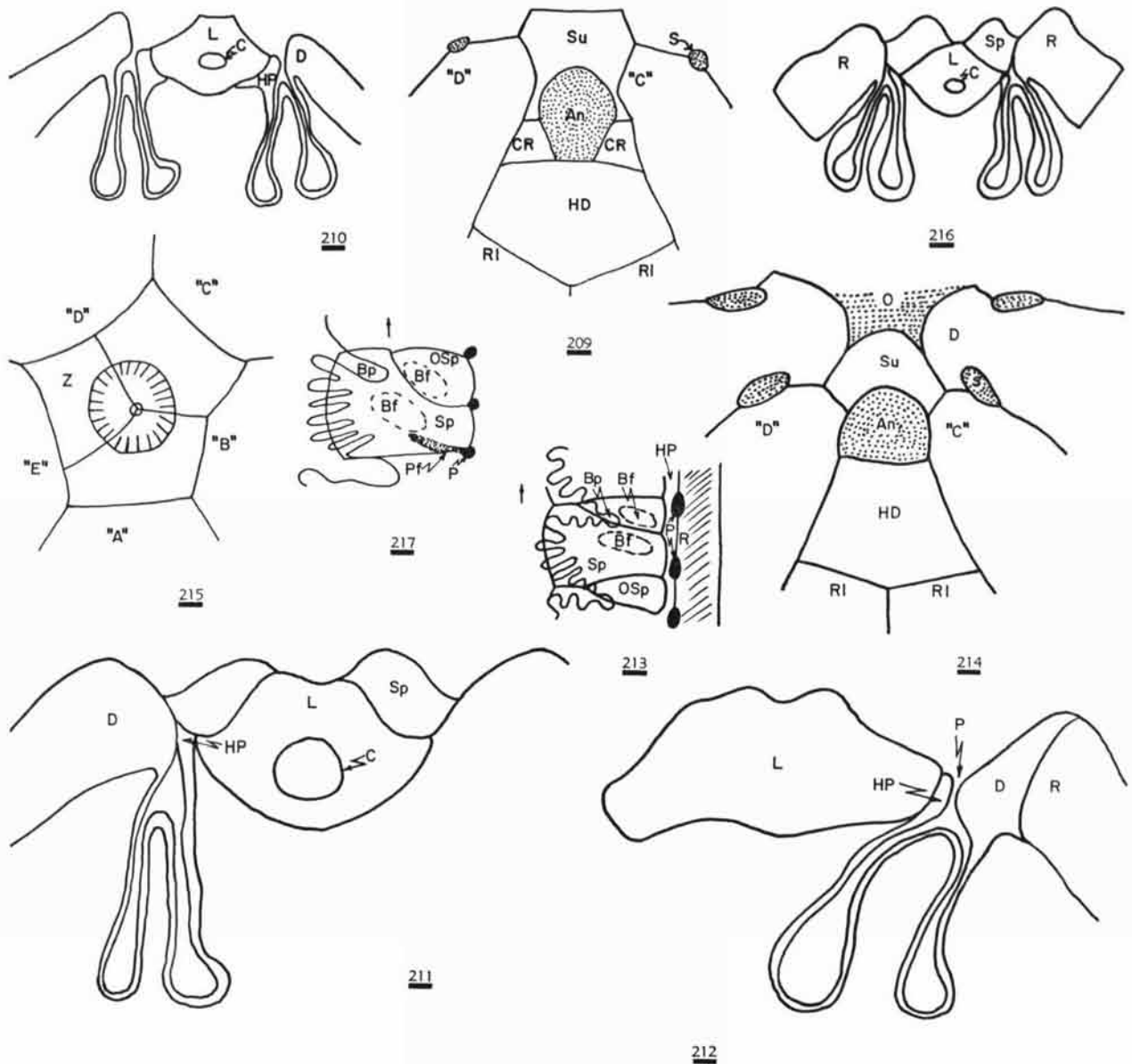
#### TANAOLASTUS HAYNESI (Clark)

Plate 37, figures 7-9

*Shizoblastus haynesi* T. H. CLARK, 1917, p. 371, pl. 1, figs. 15-20.

*Mesoblastus haynesi* FRITZ & CLINE, 1937, pp. 307-312, pl. 17, figs. 1-13.

*Description.*—The holotype is 7 mm. long by 6 mm.



FIGURES 209-217. Species of *Tanaoblastus* FAY, n. gen., Mississippian North America.

209-213. *T. roemerii* (SHUMARD), Chouteau Limestone, near Sedalia and Hallsville, Mo. (Univ. Missouri, nos. 1,063, 1,143; Univ. Chicago, no. 19,106); 209, anal area, drawn from polished tangential section (no. 19,106),  $\times 15$ ; 210, cross section of "B" ambulacrum, oral view (no. 19,106),  $\times 15$ ; 211, partial cross section of "D" ambulacrum, aboral view (no. 1,063),  $\times 45$ ; 212, partial cross section of "B" ambulacrum, aboral view (no. 1,063),  $\times 45$ ; 213, part of "D" ambulacrum, showing side plates (no. 1,143),  $\times 45$ .—214-217. *T. concinnulus* (ROWLEY & HARE), Burlington Limestone,

Louisiana, Mo. (Univ. Illinois, nos. RX206, RX206a); 214, anal area of holotype,  $\times 15$ ; 215, basal circllet of holotype,  $\times 15$ ; 216, cross section of ambulacrum,  $\times 15$ ; 217, part of "B" ambulacrum, showing side plates,  $\times 45$ . [Explanation.—"A," amb.; An, anal opening; "B," amb.; Bf, brachiolar facet; Bp, brachiolar pit; "C," amb.; C, canal (radial); CR, cryptodeltoid; "D," amb.; D, deltoid; "E," amb.; HD, hypodeltoid; HP, hydrospire plate; L, lancet; O, oral opening; OSp, outer side plate; P, pore; Pf, pore furrow; R, radial; RI, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoid; Z, azygous basal.]

wide, calcitic, and not well preserved. The radials overlap the deltoids and apparently two hydrospire folds are present on each side of an ambulacrum. An excellent description is given by FRITZ & CLINE (1937), who apparently described similar specimens.

*Occurrence.*—Lower Mississippian, Madison Limestone, Squaw Creek, Montana.

*Type.*—Holotype, 347, one specimen, Harvard Museum of Comparative Zoology, Cambridge, Mass.

### TANAOLASTUS MISSOURIENSIS (Shumard)

Plate 36, figures 1-3

*Granatocrinus missouriensis* SHUMARD, 1866, p. 375.

*Schizoblastus missouriensis* ETHERIDGE & CARPENTER, 1882, p. 247.

*Cryptoblastus missouriensis* PECK, 1938, p. 65, pl. 26, figs. 9-15.

*Pentremites roemeri* SHUMARD (*partim*), 1855, p. 186, pl. B, figs. 2b-d; HAMBACH, 1903, pl. 5, fig. 10.

*Cribroblastus roemeri* HAMBACH, 1903, pl. 5, fig. 10.

*Granatocrinus mutabilis* ROWLEY (*partim*), 1893, p. 306, pl. 14, figs. 4-5.

*Description.*—Calyx 7.5 mm. long by 6.5 mm. wide, base flat, periphery below center, with linear ambulacra 8 mm. long by 1.5 mm. wide, recurved below, with 28 side plates in a space of 10 mm. along an ambulacrum. Comparison of photographs indicates difference from other species in calyx shape.

*Occurrence.*—Lower Mississippian, Chouteau Limestone, Sweeney Quarry, Missouri.

*Type.*—Hypotype, 3,576, C. C. Branson collection, University of Missouri.

### TANAOLASTUS TENUIS (Hambach)

Plate 36, figures 4-6

*Cribroblastus tenuis* HAMBACH, 1903, p. 63, pl. 5, figs. 17, 17a.

*Cryptoblastus tenuis* PECK, 1938, p. 62, pl. 26, figs. 16-17, 22.

*Description.*—Calyx barrel-shaped, with truncated summit and convex base, 7.5 mm. long by 6.5 mm. wide, with linear ambulacra 8 mm. long by 1.25 mm. wide, and periphery central. There are 30 side plates in a space of 10 mm. along an ambulacrum. Comparison of photographs serves to show differences in shape that distinguish various species.

*Occurrence.*—Lower Mississippian, Chouteau Limestone, near Providence, Missouri.

*Type.*—Hypotype, 3,572, one specimen, C. C. Branson collection, University of Missouri.

### Genus TRICOELOCRINUS Meek & Worthen, 1868

*Type-species*, by original designation.—*Pentremites (Troostocrinus?) woodmani* MEEK & WORTHEN, 1868.

*Generic diagnosis.*—Spiraculate blastoids with five paired spiracles, or four paired spiracles and a paired anispiracle, with superdeltoid, two cryptodeltoids, and a hypodeltoid plate on the anal side; lancet covered by side plates, one pore between adjacent side plates along deltoid and radial margins, radials overlapping deltoids, three short hydrospire folds on each side of an ambulacrum extending only one-half way down each ambulacrum and ending within the substance of the thick radial plates beneath the ambulacra; pelvis long, widely inflated outward; deltoids not visible in side view but large hypodeltoid visible in side view; calyx form subpyramidal, subrounded below, with aborally directed ambulacra. *Mississippian*, Indiana, Tennessee, Kentucky, Missouri, Illinois.

*Remarks.*—The genus *Tricoelocrinus* was probably derived from *Metablastus* by reduction in the number of hydrospires to three within the radial plates, and outward inflation of the pelvis.

### TRICOELOCRINUS WOODMANI (Meek & Worthen)

Plate 52, figures 1-2

*Pentremites (Troostocrinus?) woodmani* MEEK & WORTHEN, 1868, p. 356; 1873, p. 506, pl. 16, fig. 4.

*Tricoelocrinus woodmani* ETHERIDGE & CARPENTER, 1886, p. 206, pl. 19, figs. 13-16.

*Description.*—A detailed description of the holotype is reserved for another paper, to appear in the Oklahoma Geology Notes. This species may be distinguished from all others by the widely inflated pelvis.

*Occurrence.*—Lower Mississippian, Keokuk? Limestone, Salem, Indiana.

## EXPLANATION OF PLATE 35

### FIGURE

### PAGE

1-8. *Petaloblastus ovalis* (GOLDFUSS), "Devonian" [=Lower Carboniferous], Uebergangskalke, (Etroungtian), Cromford bei Rättingen, Germany.—1-3. Topotype, 151, deKoninck coll., Harvard Mus. Comp. Zoology; oral, "D" ambulacral, aboral views of described specimen (all  $\times 15.2$ ).—4, 6, 7. Topotypes, 316, Bronn coll., Harvard Mus. Comp. Zoology; 4, cross section of specimen showing

four hydrospire folds on each side of an ambulacrum ( $\times 12$ ); 6, 7, two specimens showing details of an ambulacrum and "D" ambulacral view ( $\times 12$ ,  $\times 12.8$ ).—5, 8. Topotype, 151, deKoninck coll., Harvard Mus. Comp. Zoology; two side views of "AB" interambulacrum showing details of deltoid plate at pointed adoral tips of radial limbs ( $\times 9.7$ ,  $\times 11$ )



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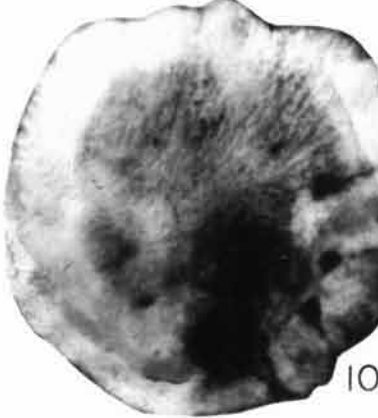
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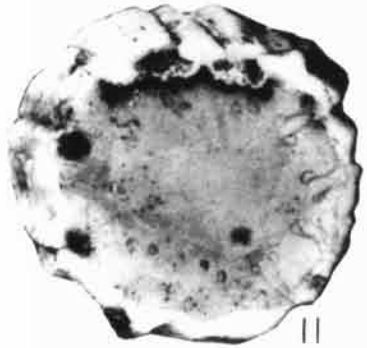
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*Type*.—Holotype, 7,225/1, Woodman collection, American Museum of Natural History, New York.

### Genus TROOSTICRINUS Shumard, 1866

*Type-species*, by subsequent designation (ETHERIDGE & CARPENTER, 1882).—*Pentremites reinwardti* TROOST, 1835.

*Generic diagnosis*.—Spiraculate blastoids with five paired spiracles, consisting of four paired spiracles and a paired anispiracle, with a superdeltoid, two cryptodeltoids, and a hypodeltoid, edges of the cryptodeltoids slightly exposed; lancet covered by side plates, one pore between adjacent side plates along ambulacral margins, radials overlapping deltoids; ambulacra short, directed outward and downward, with three to five hydrospire folds on each side of an ambulacrum; pelvis long, deltoids not visible in side view but hypodeltoid visible in side view, and steeply obconical in side view. *Silurian*, Missouri, Oklahoma, Tennessee, Kentucky, Indiana, Illinois, Ohio.

*Remarks*.—The genus *Troosticrinus* may have been derived from a form similar to *Polydeltoideus* in which the sinuses closed, or both of these genera may have come from an unknown group of echinoderms with diverse structures that early differentiated the Fissiculata from the Spiraculata. An Ordovician group of echinoderms that may have given rise to the blastoids is the newly distinguished class Edrioblastoidea, proposed in an article to appear in the "Journal of Paleontology." The only genus known in this group is *Astrocystites*, which has many regular thecal plates and deep infolds crossing the sutures, with five regular straight petaloid or widely linear ambulacra.

### TROOSTICRINUS REINWARDTI (Troost)

Plate 19, figures 1-5; text-figs. 218-221

*Pentremites reinwardti* TROOST, 1835, p. 224, pl. 10, figs. 10-11.

*Pentrematites reinwardtii* ROEMER, 1851, p. 373, pl. 6, figs. 13a-c; 1860, p. 60, pl. 3, figs. 2a-c; 1876, pl. 11, fig. 10.

*Troosticrinus reinwardti* SHUMARD, 1866, p. 385, footnote.

*Troosticrinus reinwardti* ETHERIDGE & CARPENTER, 1886, p. 193, text-fig. 7, p. 194, pl. 12, figs. 11-12, pl. 17, fig. 17; BATHER, 1900, p. 87, fig. 8; WOOD, 1909, pp. 13, 17, pl. 3, figs. 2-4; SPRINGER, 1913, p. 170, fig. 264; JAEKEL, 1918, p. 107, fig. 101;

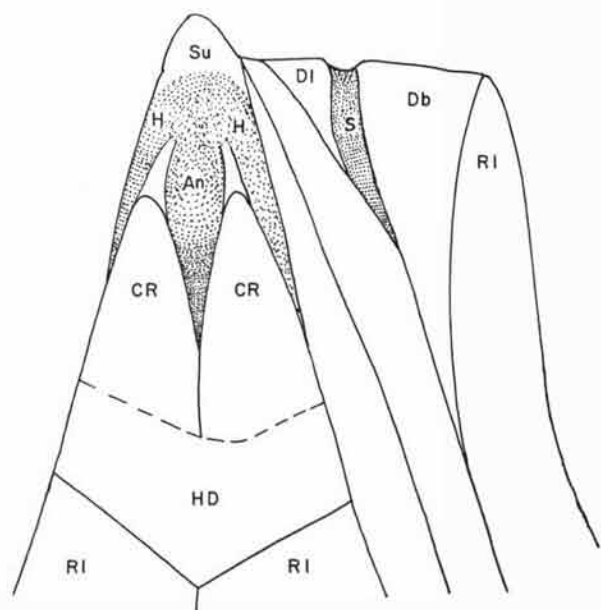
SPRINGER, 1926, p. 141, pl. 33, figs. 1-8; WANNER, 1933, p. 495, fig. 32; AMSDEN, 1949 (as *Troosticrinus*), pp. 82-83, pl. 12, figs. 5-7, text-fig. 29.

*Description*.—The holotype is obconical in side view, 23 mm. long by 8 mm. wide, vault 5 mm. long, pelvis 18 mm. long, pelvic angle 30 degrees; periphery at radial lips above mid-height, and rounded pentagonal in top view. Basal circlet conical in side view, 9 mm. long, with three normally disposed basals. Radials five, each approximately 14 mm. long by 5 mm. wide, with short radial limbs and linear sinuses. The radial limbs on the anal side are shorter than those on the other sides. Radials overlap deltoids.

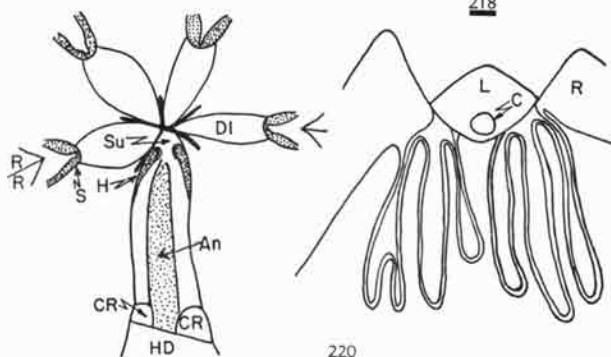
Deltoids four, short, externally appearing as an inverted V, each with a paired spiracle elongate in its medial portion. Deltoids not visible in side view except along sinus areas. On the anal side are four anal deltoids. The small superdeltoid is adjacent to the oral opening, and the two elongate cryptodeltoids rest on the aboral face of the superdeltoid, separating the anal opening from the adjacent hydrospire canals internally and partly externally. The pentagonal hypodeltoid almost covers the cryptodeltoids but the suture between these plates is visible along sinus margins in well-preserved specimens. The elongate hypodeltoid is visible in side view and abuts against the short radial limbs on the anal side. The cryptodeltoids reach the exterior slightly and therefore a paired anispiracle is present, in which the anal opening and adjacent hydrospire canals are incompletely fused. Thus, five paired openings surround the mouth, consisting of four paired spiracles and a paired anispiracle. There are three to five hydrospire folds on each side of an ambulacrum, distinguishing this genus from *Metablastus*, which has four or five hydrospire folds, and *Tricoelocrinus*, which has three small folds in the substance of the radial plates.

## EXPLANATION OF PLATE 36

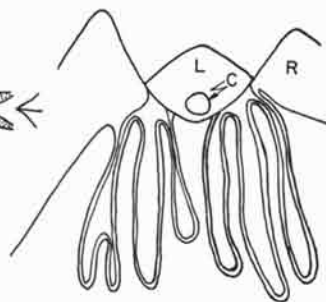
FIGURE	PAGE	
1-3. <i>Tanaoblastus missouriensis</i> (SHUMARD), hypotype, 3,576, Carl C. Branson coll., Univ. Missouri; Lower Mississippian, Chouteau Limestone, quarry near Sweeney, Mo.; oral, "D" ambulacral, aboral views of specimen figured by Peck (1938, pl. 26, fig. 39) (all $\times 6.9$ )	104	
4-6. <i>Tanaoblastus tenuis</i> (HAMBACH), hypotype, 3,572, Carl C. Branson coll., Univ. Missouri; Lower Mississippian, Chouteau Limestone, near Providence, Mo.; oral, "D" ambulacral, aboral views of specimen figured by Peck (1938, pl. 26, figs. 16, 22) (all $\times 7.2$ )	105	
7-12. <i>Tanaoblastus roemerii</i> (SHUMARD), 7-9. Hypotype, 1,143, Blair coll., Univ. Missouri; Lower Mississippian, Chouteau Limestone, near Sedalia, Mo.; oral, "D" ambulacral, aboral views of specimen figured by Peck (1938, pl. 26, figs. 24, 28, 32) (all $\times 8.5$ ).—10-12. Plesiotypes, 19,106, Gurley coll., Univ. Chicago; Lower Mississippian, Chouteau Limestone, Sedalia, Mo.; 10, polished cross section of summit showing cryptodeltoids adjacent to anal opening ( $\times 9.6$ ); 11, oral view of polished cross section with "A" ambulacrum upward, showing two hydrospire folds on each side of ambulacrum ( $\times 6.6$ ); 12, oral view of another specimen showing lack of pores along margins of deltoid plates ( $\times 7.5$ )	102	



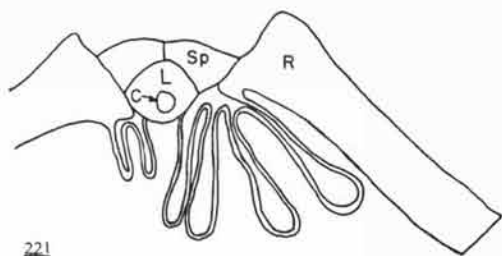
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FIGURES 218-221. *Troosticrinus reinwardti* (TROOST), Silurian, Decatur County, Tennessee (U. S. Natl. Mus., no. 33,071).—218. Anal area of metatype,  $\times 22.5$ .—219. Summit and oblique anal tangential section (polished) of metatype,  $\times 20$ .—220. Cross section of "E" ambulacrum, oral view, of paratype,  $\times 17.5$ .—221. Cross section of an ambulacrum, oral view, of paratype,  $\times 17.5$ . [Explanation.—An, anal opening; C, canal (radial); CR, cryptodeltoideum; Db, deltoideum body; DI, deltoideum lip; H, hydrospire; HD, hypodeltoideum; L, lancet; R, radial; RI, radial limb; S, spiracle; Sp, main side plate; Su, superdeltoideum.]

Ambulacra five, short, slightly rounded at aboral end, with lancet covered by side plates, and 28 side plates in a space of 10 mm. along an ambulacrum. One pore occurs between side plates along the ambulacral margins, and side plates are normally disposed. Surfaces of calyx plates ornamented by fine growth lines subparallel to plate margins.

*Occurrence.*—Silurian, Niagara Group, Decatur County, Tennessee.

*Types.*—Holotype, 139,105, one specimen with green label, with three other specimens; paratypes, 139,106, two sections and two specimens, Troost collection, old number 33,071 and another 1,468 which included 16 specimens in all, U. S. National Museum, Washington.

### PHYLOGENETIC TRENDS OF FISSICULATA

Primitive fissiculate blastoids are *Polydeltoideus* and *Deltoschisma*, which have a steeply conical form, four to six anal deltoids, hydrospire slits exposed in ten sinus areas, and linear ambulacra with lancet covered by side plates. Blastoids of this group may form a natural family from which all others could have been derived.

One trend is in the direction of reducing hydrospire fields on the anal side and closure of the sinus areas to form eight spiracular slits, as seen in *Pentremitidea*. Thus, all forms with eight spiracular slits may form a natural family (*Astrocrinidae* AUSTIN & AUSTIN, 1843). Within this assemblage one may find forms in which (1) the lancet has migrated outward (*Cryptoschisma*) or (2) has remained the same except that one ambulacrum is shortened and the hypodeltoideum has become small or atrophied (*Astrocrinus*, *Pentephyllum*), or (3) the pelvis is elongated, the ambulacra becoming small, with superdeltoideum and subdeltoideum fusing to form an epideltoideum, and hypodeltoideum becoming atrophied or small (*Ceratoblastus*), or (4) the ambulacra shortened, with an epideltoideum and hypodeltoideum remaining or (5) the hypodeltoideum atrophied, with concurrent formation of radial wings (*Nannoblastus*). *Pentremitidea* probably gave rise to this group of blastoids, and this genus very likely came from *Deltoschisma*, which shows a reduction of the hydrospire slits on the anal side. Thus, *Deltoschisma* probably gave rise to *Pentremitidea* by fusion of the cryptodeltoids to form a subdeltoideum, complete reduction of the hydrospires on the anal side, and closure of the sinus walls to form eight spiracular slits.

Certain trends seem to have taken place within the primitive family of blastoids characterized by the possession of ten exposed hydrospire fields (Phaeno-

schismatidae ETHERIDGE & CARPENTER, 1886). The most primitive form is *Polydeltoideus*, with ten exposed fields, six anal deltoids, steeply conical form, and lancet covered by side plates. One trend is toward reduction of the number of hydrospire folds on the anal side (*Deltoschisma*), from which group presumably came blastoids that developed an adoral epideltoid plate or in which the lancet plate migrated outward (*Phaenoblastus*). Another trend is one in which the cryptodeltoids fuse to form a subdeltoid plate (*Decaschisma*), and the ambulacra move out laterally. A plausibly distinguished trend seems to be one in which the ten fields close and pores and spiracles (five) are formed (*Hyperoblastus*), but the aboral ends of the exposed slits remain. A fourth trend may be one in which the ambulacra move downward, then laterally outward, concurrent with outward migration of the hydrospire fields (*Pleuroschisma*), with reduction or fusion of the superdeltoid and cryptodeltoids to form an epideltoid (*Conoschisma*). This last mentioned genus probably gave rise to *Nymphaeoblastus*, in which the ambulacra continued to move downward, to *Neoschisma* and *Notoblastus*, in which the ambulacra moved outward from the oral area and atrophied on the summit, to *Dipteroblastus*, in which three ambulacra completely atrophied on the summit, and to *Thaumatooblastus*, in which the ambulacra extended outward into long wings. Thus, the above-mentioned genera seem to form a natural family.

Another natural family (Orophocrinidae JAEKEL, 1918) is considered to be one characterized by the presence of ten spiracular slits. The most primitive known blastoid of this group is *Orophocrinus*, which may have been derived from *Pleuroschisma* by fusion of the cryptodeltoids and superdeltoid into an epideltoid and closure of the sinuses to form ten spiracular slits. *Orophocrinus* probably gave rise to *Anthoblastus* by outward migration of the lancet plate, to *Sphaeroschisma* by downward migration of the ambulacra and atrophy or reduction in size of the hypodeltoid, and to *Pentablastus* by fusion of the epideltoid and hypodeltoid to form an anal deltoid, retaining the elongate spiracular slits in all genera. A trend in this group is reduction in length of the spiracular slits to form small round slits on the summit and shape of the calyx becoming spherical (*Sundablastus*), or in addition the ambulacra migrate away from the oral opening (*Indoblastus*) and the ambulacra become short, with winglike interradian projections (*Timoroblastus*), or the ambulacra migrate away from the oral opening, become short, and the hypodeltoid becomes

small or atrophied (*Microblastus*). These trends seem to be logical and therefore the mentioned genera may belong to a natural family.

A fourth family of fissiculate blastoids (here designated as Brachyschismatidae, FAY, n. fam.) is conceived to be one in which the hydrospire fields have been reduced to nine. This assemblage includes the single genus *Brachyschisma*, which was probably derived from *Decaschisma* by reduction of the hydrospire field on the left (D side) of the anal opening, so that only nine fields remained.

The fifth and remaining family (Codasteridae ETHERIDGE & CARPENTER, 1886) is one with eight exposed hydrospire fields. The primitive forms of this group is *Trionoblastus*, which has eight hydrospire fields exposed and three anal deltoids. *Trionoblastus* was probably derived directly from *Decaschisma* by reduction of the hydrospire fields in the anal region, thus leaving eight exposed hydrospire fields. It is also possible that the hypodeltoid became small or atrophied, since it is generally absent in this family. *Trionoblastus* probably gave rise to *Codaster* as result of fusion of the subdeltoid and superdeltoid to form an epideltoid plate. *Codaster* probably gave rise to *Paracodaster* by reduction or atrophy of the slits on the radial plates, to *Angioblastus* and *Sagittoblastus* by restriction of the hydrospire fields to deep slits, and to *Pterotoblastus* by formation of radial wings.

Thus, the order Fissiculata may include five natural families differentiated on the basis of having (1) ten exposed hydrospire fields, (2) nine exposed hydrospire fields, (3) eight exposed hydrospire fields, (4) ten spiracular slits, and (5) eight spiracular slits. These respectively are appropriately named Phaenoschismatidae ETHERIDGE & CARPENTER, 1886 (*nom. correct. pro Phaenoschismidae*); Brachyschismatidae FAY, n. fam.; Codasteridae ETHERIDGE & CARPENTER, 1886; Orophocrinidae JAEKEL, 1918; and Astrocrinidae AUSTIN & AUSTIN, 1843.

#### PHYLOGENETIC TRENDS OF SPIRACULATA

Two diverse origins of the five families here recognized in the order Spiraculata may be considered. One family of blastoids (Pentremitidae) with five oval spiracles seems to have been derived from *Hyperoblastus*, a Devonian genus. The other four families severally characterized by having five paired spiracles; nine spiracles; ten spiracles with anus separate; and ten spiracles, anus separate, and two cryptodeltoids

exposed, probably were derived from *Troosticrinus*, a Silurian genus. These families are here recognized as Pentremitidae D'ORBIGNY, 1852; Troosticrinidae BASSLER, 1938; Granatocrinidae FAY, n. fam.; Schizoblastidae FAY, n. fam.; and Nucleocrinidae BATHER, 1899, respectively.

The family Pentremitidae, D'ORBIGNY, 1852, includes ten genera, of which all have five spiracles and probably were derived from *Hyperoblastus* by complete closure of the sinus. The genus *Cordyloblastus*, with four anal deltoids, simple gaps between side plates, and lancet covered by side plates, was probably derived from *Hyperoblastus*. *Petaloblastus* probably was derived from *Cordyloblastus* by outward migration of the lancet plate and downward migration of the deltoids, visible in side view, with concurrent fusion of the cryptodeltoids and superdeltoid into an epideltoid plate. Another trend from *Hyperoblastus* is one toward *Devonoblastus*, in which the deltoids migrate downward, become visible in side view, and the sinuses are completely closed. This trend leads to *Pentremites* in which the lancet moves outward and one anal deltoid is formed, culminating in *Ambolostoma* where five large orals are formed from many small ones, and to *Rhopaloblastus*, in which the anal opening moves aborally. A distinct side trend from *Hyperoblastus* is one toward *Eleutheroocrinus*, in which the (D) ambulacrum is shortened and the deltoids move slightly downward, visible in side view. Another trend is toward *Globoblastus*, which probably was derived from a *Devonoblastus* that developed a hydrospire plate and two pores to each side plate as result of infolds of the ambulacral margins, with reduction of the hydrospire folds on each side of an ambulacrum to two. *Globoblastus* probably gave rise

to *Ellipticoblastus* by reduction of the hydrospire folds to a single one on each side of an ambulacrum, and *Ellipticoblastus* probably gave rise to *Orbitremites* by downward migration of the deltoids over the radials. From this it can be seen that the hydrospire plate is probably of little importance in classification and may develop independently in diverse families. Also, fore-shortening of an ambulacrum has little value in higher classification of blastoids.

The family Troosticrinidae BASSLER, 1938 includes five genera, four of which are closely related. *Troosticrinus* is here considered to be a primitive genus that probably gave rise to other members of this family by downward migration of the deltoids (*Schizotremites*), or to forms oval in shape (*Pentremitella*), or conical, with long pelvis and four or five hydrospire folds (*Metablastus*), reduced to three, with flaring pelvis (*Tricoelocrinus*), or from which came globular forms with hydrospires reduced to two folds on each side of an ambulacrum (*Diploblastus*).

The family Nucleocrinidae BATHER, 1899, was probably an aberrant off-shoot from *Troosticrinus* in which the cryptodeltoids moved outward and downward. *Elaeocrinus*, with many oral plates, is inferred to be a primitive genus from which came *Nucleocrinus* with five simple orals, and *Placoblastus* with six or seven orals. It is possible that *Placoblastus* may be an intermediate genus with the superdeltoid plate exposed, and *Nucleocrinus* an advanced genus with the superdeltoid suppressed. These genera probably did not give rise to other known genera.

The Schizoblastidae FAY, n. fam. (herein distinguished) include forms probably derived from a form similar to *Schizotremites*, in which the five paired spiracles form ten spiracles, with anus separate

#### EXPLANATION OF PLATE 37

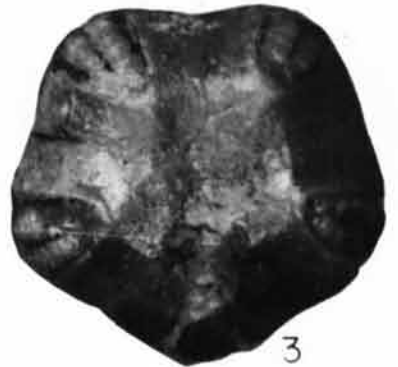
FIGURE	PAGE
1-3, 10. <i>Monadoblastus granulatus</i> FAY, n.gen., n.sp., holotype (figs. 1-3), paratype (fig. 10), E14,750, Reimann coll., Buffalo Soc. Nat. Sci.; Lower Mississippian, Lake Valley Formation (?Nunn member), Lake Valley, N.Mex.; 1-3, oral, "D" ambulacral, aboral views (all $\times 11$ ); 10, aboral view of polished cross section with "B" ambulacrum downward ( $\times 9.6$ )	83
4-6. <i>Tanaoblastus bellatulus</i> (PECK), "hypotype" on label (but presumed to be holotype), 3,293, Peck coll., Univ. Missouri; Lower Mississippian, Chouteau Limestone, 9 miles northeast of Osceola, Mo.; oral, "D" ambulacral, aboral views of specimen figured by Peck (1938, pl. 26, figs. 1-3) (all $\times 13.1$ )	102
7-9. <i>Tanaoblastus haynesi</i> (T. H. CLARK), holotype, 347, Harvard Mus. Comp. Zoology, Mississippian, Madison Limestone, Squaw Creek, Mont.; oral; "D" ambulacral, aboral views showing two hydrospire folds on each side of an ambulacrum and nine spiracular openings around oral opening (all $\times 6.7$ )	104
11, 12. <i>Carpenteroblastus magnibasis</i> (ROWLEY), metatype, RX-22, Robert R. Rowley coll., Univ. Illinois; Lower Mississippian, Upper Burlington Limestone, Louisiana, Mo.; 11, aboral view of internal mold of specimen figured by ROWLEY (1901, pl. 28, figs. 22-23) ( $\times 3.9$ ); 12, oral view of same showing remnant of circumesophageal ring and pores in deltoids ( $\times 8$ )	52



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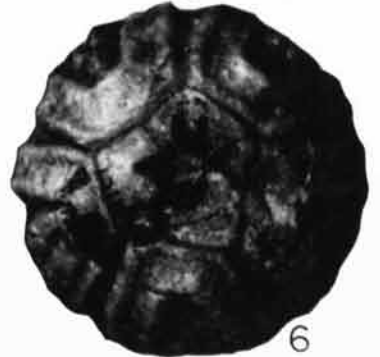
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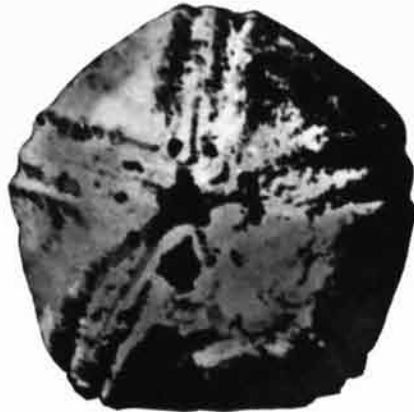
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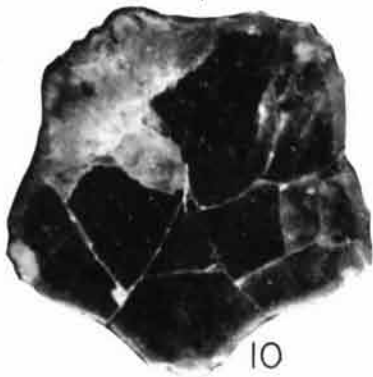
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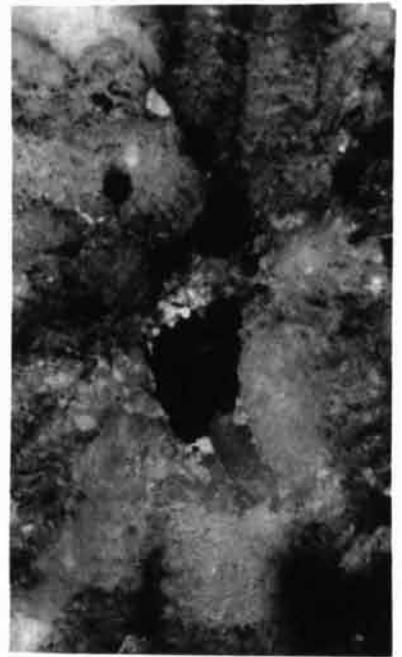
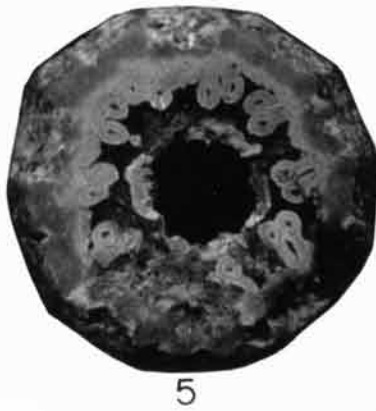
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11



12



as result of outward migration of the deltoid septa and fusion of the superdeltoid and cryptodeltoids into an epideltoid. Thus, *Schizoblastus* may have been derived. *Acentrotremites* could have been formed from *Schizoblastus* by atrophy of pores along the deltoids, with consequent downward migration of the ten spiracles and infolding of the radial margins to form a hydrospire plate and numerous pores, with fusion of the three basals into one. *Deltoblastus* probably came from *Schizoblastus* by outward migration of the lancet plate and retrogressive overlap of the deltoids by the radials.

The Granatocrinidae FAY, n. fam., which contains blastoids having nine spiracles, exhibits diverse trends. The various genera probably came from a form related to *Schizotremites*, by reduction of the number of hydrospire folds to three, with retention of simple pores along deltoid and radial margins (*Lophoblastus*), or with loss of pores along deltoids and development of five pores to each side plate along radial margins (*Mesoblastus*). The remaining genera (except *Calycoblastus*) can be derived from *Lophoblastus*. One trend is toward *Carpenteroblastus*, in which the number of hydrospire folds is reduced to two. The trend toward *Tanaoblastus* involves reduction of hydrospires to two, loss of pores along deltoid margins, formation of a hydrospire plate, and occurrence of two pores to each side plate as a result of infolding of the ambulacral margins of the radials. The trend toward *Poroblastus* from *Lophoblastus* is marked by reduction of the hydrospire folds from three to one, retention of simple pores along the deltoid margins, but formation of a hydrospire plate and formation of multiple pores to each side plate along the radial margins. The trends from *Carpenteroblastus* are toward reduction in number of folds to a single hydrospire fold on each side of an ambulacrum, with downward movement of deltoids over the radials

(*Monoschizoblastus*), or toward formation of deltoid coronal processes and a concave base (*Cribroblastus*), from which *Heteroblastus* could have been derived by downward movement of deltoids over the radials. *Calycoblastus* may have been produced from *Schizotremites* by atrophy or suppression of the hypodeltoid. *Tanaoblastus* probably gave rise to *Cryptoblastus* as consequence of wedge-shaped overlap of radials on the deltoids, and to *Monadoblastus* by atrophy of the hydrospire folds to one on each side of an ambulacrum, accompanied by development of a concave base. The trends from *Poroblastus* are toward formation of multiple pores along deltoid margins, with increase in size (*Granatocrinus*), or with retention of small size and abutment of radials against deltoids (*Ptychoblastus*).

Extensive restudy of many old-named blastoid species is needed. These are not considered in this paper because types or other specimens are unavailable for study, or time did not permit. For instance, the form known as *Orbitremites malaianus* from Permian beds of the Basleo region in Timor in all probability is a species of a new genus if demonstrated to have a simple epideltoid on the anal side instead of a superdeltoid and two cryptodeltoids; *Tricoelocrinus? belfordi*, of the Permian *Fenestella* shale of New South Wales, and *T.? carpenteri*, of the Permian Gympie beds of Queensland, probably also belong to a new genus if shown to possess an epideltoid instead of a superdeltoid and two cryptodeltoids on the anal side; *Tricoelocrinus? leai*, of the Devonian Tor Bay Limestone of Devonshire, England, is probably misplaced, actually belonging to some other genus; various species referred to *Codaster* are judged likely to belong to other genera (e.g., *C. blairi*, *C. curtus*, *C. gracillimus*, *C. grandis*, *C. gratiosus*, *C. hindei*, *C. lorae*, and *C. superbus*); *Mesoblastus australis*, of the Permian Gympie beds of Queensland, probably belongs to some

## EXPLANATION OF PLATE 38

FIGURE	PAGE		
1-3, 5. <i>Tanaoblastus concinnulus</i> (ROWLEY & HARE), holotype, one of three specimens (figs. 1-3), paratype, polished section (fig. 5), Robert R. Rowley coll., Univ. Illinois; Lower Mississippian, base of Lower Burlington Limestone, Louisiana, Mo.; 1-3, oral, "D" ambulacral, aboral views of holotype ( $\times 7$ ); 5, oral view of polished section showing hydrospires ( $\times 8$ )	103	crushed specimen showing form of brachioles attached to calyx ( $\times 2.8$ )	61
4. <i>Cryptoblastus shumardi</i> (MEEK & WORTHEN), topotype, S3.765, Springer coll., U.S. Natl. Mus.; Lower Mississippian, Lower Burlington Limestone, Burlington, Iowa;		6-9. <i>Cryptoblastus melo</i> (OWEN & SHUMARD)—6. Unlabelled specimen, Philadelphia Acad. Sci. Mus.; ?Mississippian, ?locality; view showing cryptodeltoid (dark calcite) adjacent to lancet plate on right with hypodeltoid partly removed, anal opening black ( $\times 14.6$ ).—7-9. Neotype (new holotype), S4,959, Springer coll., U.S. Natl. Mus.; Lower Mississippian, Lower Burlington Limestone, Burlington, Iowa; oral, "D" ambulacral, aboral views (all $\times 4.4$ )	61

new genus; so-called *Metablastus hispanicus* of the Devonian of Spain, probably does not belong to this genus; forms identified as *Orbitremites aplatus*, *O. calycinus*, *O. excavatus*, *O. fimbriatus*, *O. grandis*, *O. magnificus*, *O. ornatus*, *O. parvus*, *O. spathatus*, *O. spinuliferus*, and *O. wachsmuthi* probably belong to diverse genera, some perhaps to new genera, but seemingly not to *Orbitremites*; *Phaenoschisma? kentuckyense* probably does not belong to *Phaenoschisma*. It is hoped that others will restudy blastoids in collections of various museums in order to fill in gaps in knowledge such as are here suggested.

It is significant that very few blastoids have been described from Pennsylvanian deposits and that records of blastoids in South America, Africa, Antarctica, Asia, and the North Polar regions are meager or lacking. Evidently the study of blastoids is not yet far advanced. It is premature to say that the center of dispersal of blastoids is the mid-Continent region of the United States, merely because the oldest and most primitive blastoids occur in Silurian deposits of this region. The basis for this sort of statement is that Silurian blastoids have not been described from other continents, but it would not be surprising if they are discovered in various regions outside of North America.

There is little in common between blastoid genera of Europe and North America, or between those of Timor and Europe, or between Timor and North America, and yet when lineages are traced, a tie between these regions seems to exist. "Missing links," both stratigraphic and geographic, are postulated to account for the differences; when missing links are found, the literature on blastoids will probably be double its present size. To date, approximately 800 articles have been published on blastoids; they treat some 33 genera of the Fissiculata and 35 genera of the Spiraculata, together including about 350 species.

#### KEY TO FAMILIES AND GENERA OF BLASTOIDEA

The following key is offered as an aid to those who may wish to identify genera of blastoids, as now known and understood. The key is arranged by families belonging to the two orders Fissiculata and Spiraculata. In using the key, one should proceed by noting the characters recorded under successive letters and numbers until the desired end is reached.

Hydrospire fields exposed or spiracular slits present ..... FISSICULATA

Hydrospire fields concealed, pores and spiracles present ..... SPIRACULATA

#### FISSICULATA [Families, see nos. 1-5]

1. Exposed hydrospire fields ten (Phaenoschismatidae) .....A
2. Exposed hydrospire fields nine (Brachyschismatidae) .....B
3. Exposed hydrospire fields eight (Coadasteridae) .....C
4. Spiracular slits ten (Orophocrinidae) .....D
5. Spiracular slits eight (Astrocrinidae) .....E

#### SPIRACULATA [Families, see nos. 6-10]

6. Spiracles five, simple (Pentremitidae) .....F
7. Spiracles five, paired (Troosticrinidae) .....G
8. Spiracles nine (Granatocrinidae) .....H
9. Spiracles ten, anus separate, cryptodeltoids exposed (Nucleocrinidae) .....I
10. Spiracles ten, anus separate, cryptodeltoids absent (Schizoblastidae) .....J

#### A. PHAENOSCHISMATIDAE (Silurian-Permian)

[Genera, see nos. 11-31]

11. Anal deltoids four to six .....14, 15
12. Anal deltoids three ..... *Decaschisma*
13. Anal deltoids two or one .....16, 17
14. Hydrospire slits reduced in number on anal side ..... *Deltoschisma*
15. Hydrospire slits not reduced in number on anal side .....18, 19
16. Ambulacra with lancets widely exposed ..... *Phaenoblastus*
17. Ambulacra with lancets covered by side plates .....22, 23
18. Ambulacra directed laterally outward, six anal deltoids ..... *Polydeltoideus*
19. Ambulacra directed downward, four anal deltoids .....20, 21
20. Hydrospire slits completely exposed .. *Pleuroschisma*
21. Hydrospire slits almost hidden, with formation of pores ..... *Hyperoblastus*
22. Ambulacra five .....24, 25
23. Ambulacra two ..... *Dipteroblastus*
24. Ambulacra extremely long .....26, 27
25. Ambulacra moderately long to extremely short 28, 29
26. Ambulacra flaring outward into elongate wings ..... *Thaumatoblastus*
27. Ambulacra projecting downward aborally, calyx globular ..... *Nymphaeoblastus*
28. Ambulacra moderately long ..... 30a, 30b, 31
29. Ambulacra extremely short ..... *Neoschisma*
- 30a. Calyx conical, ambulacra narrow ..... *Conoschisma*
- 30b. Calyx conical, ambulacra broad ..... *Phaenoschisma*
31. Calyx flattened ..... *Notoblastus*



## B. BRACHYSCHISMATIDAE (Devonian)

[Genus, see no. 32]

32. Hydrosfire field on left "D" side of anal opening atrophied ..... *Brachyschisma*

## C. CODASTERIDAE (Devonian-Permian)

[Genera, see nos. 33-42]

33. Anal deltoids three or at least two invariably present along with subdeltoid *Trionoblastus*
34. Anal deltoids two or at least one invariably present, subdeltoid absent ..... 35, 36
35. Hydrosfire slits extending onto radials ..... 37, 38
36. Hydrosfire slits restricted to deltoids .. *Paracodaster*
37. Radials with winglike projections ..... *Pterotoblastus*
38. Radials lacking winglike projections ..... 39, 40
39. Hydrosfire fields wide ..... *Codaster*
40. Hydrosfire fields restricted ..... 41, 42
41. Deltoids long, lancet-shaped, with small hypodeltoid ..... *Angioblastus*
42. Deltoids wide, arrow-shaped, seemingly without hypodeltoid ..... *Sagittoblastus*

## D. OROPHOCRINIDAE (Mississippian-Permian)

[Genera, see nos. 43-56]

43. Spiracular slits long ..... 45, 46
44. Spiracular slits short ..... 47, 48
45. Lancet widely exposed ..... *Anthoblastus*
46. Lancet mostly covered by side plates ..... 49, 50
47. Lancet close to oral opening ..... *Sundablastus*
48. Lancet moderately distant from oral opening .. 51, 52
49. Hypodeltoid large ..... *Orophocrinus*
50. Hypodeltoid small or lacking ..... 53, 54
51. Winglike interradial projections on calyx ..... *Timoroblastus*
52. Winglike interradial projections lacking ..... 55, 56
53. Anal opening restricted to single deltoid ..... *Pentablastus*
54. Anal opening adjacent to radial limbs, possibly with an atrophied hypodeltoid  
*Sphaeroschisma*
55. Ambulacra moderately short, hypodeltoid possibly atrophied ..... *Microblastus*
56. Ambulacra moderately long, large hypodeltoid present ..... *Indoblastus*

## E. ASTROCRINIDAE (Devonian-Permian)

[Genera, see nos. 57-66]

57. Slits elongate along lancet ..... 59, 60
58. Slits extremely small, confined to summit ..... 61, 62
59. Ambulacra five, normal ..... 63, 64
60. Ambulacrum "D" extremely short, other four long ..... 65, 66
61. Calyx shape steeply conical, extremely narrow ..... *Ceratoblastus*

62. Calyx shape bluntly conical, hypodeltoid large, ambulacra extremely short .. *Nannoblastus*
63. Lancet covered by side plates ..... *Pentremiteida*
64. Lancet completely exposed ..... *Cryptoschisma*
65. Radials bluntly winglike, three basals present ..... *Pentephyllum*
66. Radials concave inward, single basal present ..... *Astrocrinus*

## F. PENTREMITIDAE (Devonian-Permian)

[Genera, see nos. 67-84]

67. Deltoids four, not visible in side view *Cordyloblastus*
68. Deltoids visible in side view ..... 69, 70
69. Ambulacra five, normally developed ..... 71, 72
70. Ambulacra five, ambulacrum "D" shorter than others ..... *Eleutherocrinus*
71. Hydrosfire plate present, two pores to each side plate ..... 73, 74
72. Hydrosfire plate absent, pores simple ..... 75, 76
73. Calyx globular, two hydrosfire folds on each side of an ambulacrum ..... *Globoblastus*
74. Calyx globular, single hydrosfire fold on each side of an ambulacrum ..... 77, 78
75. Calyx club-shaped, base pyriform, orals small ..... 79, 80
76. Calyx elongate-elliptical, with five large orals ..... *Ambolostoma*
77. Radials overlapping deltoids ..... *Ellipticoblastus*
78. Deltoids overlapping radials ..... *Orbitremites*
79. Anal deltoids two or more ..... 81, 82
80. Anal deltoid single ..... 83, 84
81. Lancet completely exposed, two anal deltoids ..... *Petaloblastus*
82. Lancet covered by side plates, four anal deltoids ..... *Devonoblastus*
83. Anispiracle adjacent to oral opening ... *Pentremites*
84. Anispiracle adjacent to radial limbs .. *Rhopaloblastus*

## G. TROOSTICRINIDAE (Silurian-Mississippian)

[Genera, see nos. 85-92]

85. Calyx conical in side view ..... 87, 88
86. Calyx globular ..... *Diploblastus*
87. Deltoids not visible in side view ..... 89, 90
88. Deltoids plainly visible in side view .. *Schizotremites*
89. Ambulacra directed outward, pelvis long ..... *Troosticrinus*
90. Ambulacra directed downward, pelvis long or short ..... 91, 92
91. Pelvis steeply conical, hydrosfire folds four or five on each side of an ambulacrum ..... *Metablastus*
92. Pelvis bluntly flaring, with three short hydrosfire folds in radials on each side of an ambulacrum ..... *Tricoelocrinus*

- H. GRANATOCRINIDAE (Mississippian-Permian)  
[Genera, see nos. 93-116]
93. Hydrosfire folds three or more on each side of an ambulacrum .....95, 96
94. Hydrosfire folds two or one on each side of an ambulacrum .....97, 98
95. Hydrosfire plate present, five pores to each side plate, pores absent along deltooids ..... *Mesoblastus*
96. Hydrosfire plate absent, simple pores present along deltooids .....99, 100
97. Hydrosfire folds two on each side of an ambulacrum .....101, 102
98. Single hydrosfire fold on each side of an ambulacrum .....103, 104
99. Hydrosfire folds five on each side of an ambulacrum ..... *Calycoblastus*
100. Hydrosfire folds three on each side of an ambulacrum ..... *Lophoblastus*
101. Hydrosfire plate present, two pores to each side plate along radial margins .....105, 106
102. Hydrosfire plate absent, pores simple .....107, 108
103. Pores present along deltooid margins .....109, 110
104. Pores absent along deltooid margins .....*Monadoblastus*
105. Radials overlapping deltooids, inter-radial sutures even, calyx base convex .. *Tanaoblastus*
106. Radials overlapping deltooids except at adoral tip where overlap is reversed, inter-radial sutures indented, calyx base flat to concave ..... *Cryptoblastus*
107. Deltooids without coronal process .. *Carpenteroblastus*
108. Deltooids with coronal process .....111, 112
109. One pore to each side plate along deltooid margins .....113, 114
110. Two pores to each side plate along deltooid margins .....115, 116
111. Deltooids short, overlapped by radials .. *Cribroblastus*
112. Deltooids long, overlapping radials ..... *Heteroblastus*
113. Deltooids short, overlapped by radials ..... *Poroblastus*
114. Deltooids long, overlapping radials *Monoschizoblastus*
115. Calyx large, radials overlapping deltooids ..... *Granatocrinus*
116. Calyx small, radials abutting against deltooids ..... *Ptychoblastus*
- I. NUCLEOCRINIDAE (Devonian)  
[Genera, see nos. 117-120]
117. Oral plates five, generally wide, with cryptodeltooids closely adjacent to each other externally on adoral side of anal opening ..... *Nucleocrinus*
118. Oral plates more than five, calyx generally elongate or oval, with externally visible plate between adoral tips of cryptodeltooids ..... 119, 120
119. Calyx oval, with 18 to 21 oral plates ..... *Elaeocrinus*
120. Calyx elongate oval, with six or seven oral plates ..... *Placoblastus*
- J. SCHIZOBLASTIDAE (Mississippian-Permian)  
[Genera, see nos. 121-124]
121. Spiracles near oral opening .....123, 124
122. Spiracles well separated from oral opening at aboral corners of deltooids *Acentrotremites*
123. Lancet covered by side plates, deltooids overlapping radials ..... *Schizoblastus*
124. Lancet exposed to full width, radials overlapping deltooids ..... *Deltoblastus*

## EXPLANATION OF PLATE 39

## FIGURE

## PAGE

- 1, 2. *Heteroblastus cumberlandi* ETHERIDGE & CARPENTER, topotype, S3,776, Springer coll., U.S. Natl. Mus.; Lower Carboniferous, Yoredale (Viséan), near Hexham, Northumberland, England; interambulacral and ambulacral views of fragmentary specimen showing long deltooids overlapping radial plates ( $\times 7.5$ ,  $\times 7.8$ ) ..... 76
- 3-9. *Granatocrinus granulatus* (ROEMER), Lower Mississippian, New Providence Formation, Kentucky, Tennessee.—3-5, 7. Plesiotypes, S3,751, Springer coll., U.S. Natl. Mus.; headwaters of Medlock's Creek, 10 miles south of Lebanon, Marion County, Ky.; 3, oral view of summit showing eight spiracles and anispiracle around oral opening ( $\times 8$ ); 4, ambulacral view showing side plates completely covering lancet ( $\times 10.7$ ); 5, "C" ambulacral view of another specimen showing pores in hydrosfire plate mar-

ginal to side plates and lancet ( $\times 4$ ); 7, view of radiodeltooid suture showing radials overlapping deltooids, (same specimen as shown in fig. 3) ( $\times 8$ ).—6. Topotype, 33,080, Troost coll., U.S. Natl. Mus.; Bedford County, Tennessee; labelled *Granatocrinus cidariformis* (after HAMBACH, 1903, pl. 3, fig. 2, designated *Cidaroblastus granulatus*) ( $\times 1$ ).—8. Plesiotype, 127,323, James Conkin coll., U.S. Natl. Mus.; New Providence Formation (upper part of Coral Ridge member), east quarry of Coral Ridge Brick Company yards, Coral Ridge, southwestern Jefferson County, Kentucky; labelled *Orbitremites oppelti*; polished cross section showing one hydrosfire fold on each side of ambulacrum ( $\times 10$ ).—9. Plesiotype, S5,746, Springer coll., Univ. Michigan; Mason County, Kentucky; area of radiodeltooid suture showing large rounded spines of a specimen labelled *Schizoblastus granulatus* ( $\times 8$ ) ..... 74



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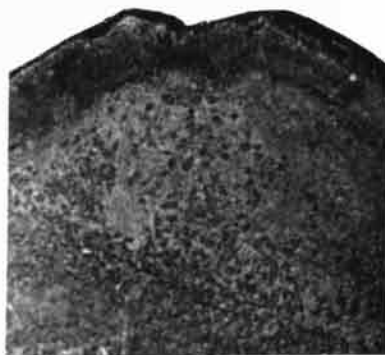
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## EXPLANATION OF PLATE 40

## FIGURE

1-6. *Granatocrinus kentuckyensis* (CONKIN), paratypes, CONKIN's specimen 1 (figs. 1-3), and specimen 2 (figs. 4-6), previously unfigured, labelled *Orbitremites kentuckyensis*, U.S. Natl. Mus.; Lower Mississippian, lower part of New Providence Formation (upper part of Coral Ridge member), east quarry of Coral Ridge Brick & Tile Company, Coral Ridge, Jefferson County, Kentucky; 1-3, oral, "D" ambulacral, aboral views ( $\times 2.6$ ); 4-6, oral, "B" ambula-

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cral, aboral views ( $\times 5.3$ ) ..... 75  
 7-12. *Poroblastus granulatus* (MEEK & WORTHEN), plesiotypes, S3,720 (figs. 7-9); S3,719 (figs. 10-12), Springer coll., U.S. Natl. Mus.; Lower Mississippian, Upper Burlington Limestone, Burlington, Iowa (figs. 7-9), and Warsaw Formation (fourth horizon, geode bed), one mile above Warsaw, Ill. (figs. 10-12); 7-9, oral, "D" ambulacral, aboral views ( $\times 6.2$ ); 10-12, oral, "D" ambulacral, aboral views ( $\times 6.3$ ) ..... 98

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## EXPLANATION OF PLATE 41

FIGURE	PAGE
1-12. <i>Poroblastus granulatus</i> (MEEK & WORTHEN), Mississippian.—1-3. Plesiotype, S3,716, Springer coll., U.S. Natl. Mus.; Warsaw Formation, Otterville, Ill.; oral, "D" ambulacral, aboral views (all $\times 8.3$ ).—4-6. Plesiotype, S3,717, Springer coll., U.S. Natl. Mus.; Keokuk Formation, Jersey County, Illinois; oral, "B" ambulacral, aboral (with "C" ambulacrum downward) views (all $\times 4.8$ ).—	
7-9. Holotype, 713, Illinois Geol. Survey, labelled <i>Schizoblastus granulatus</i> (old number 1843 of Illinois State Mus., Springfield, transferred to Urbana); Keokuk Group, Warsaw, Ill.; oral, "D" ambulacral, aboral views (all $\times 6.7$ ).—10-12. Plesiotype, 13,894, Weller coll., Univ. Chicago; Upper Burlington Limestone, Springfield, Mo., locality 21; oral; "D" ambulacral, aboral views of described specimen (all $\times 7.1$ )	98

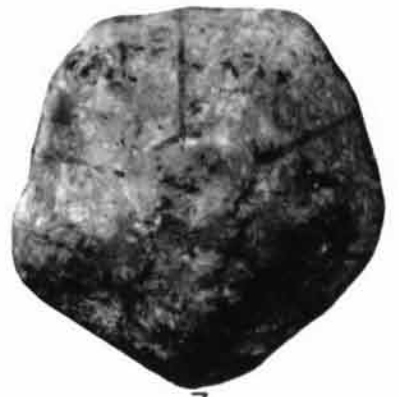




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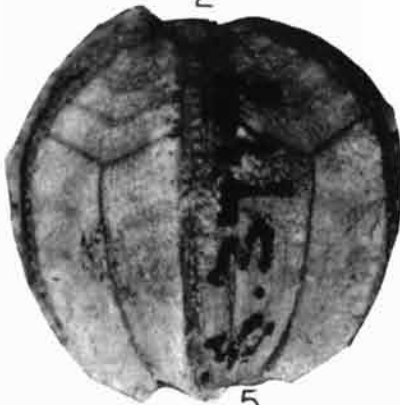
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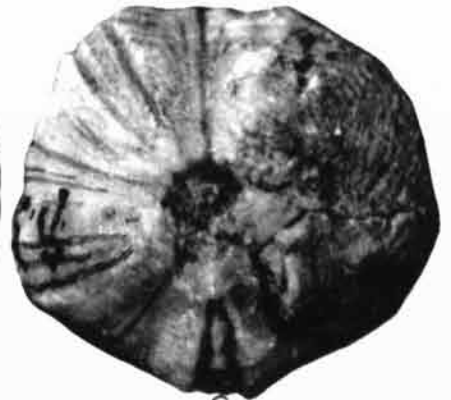
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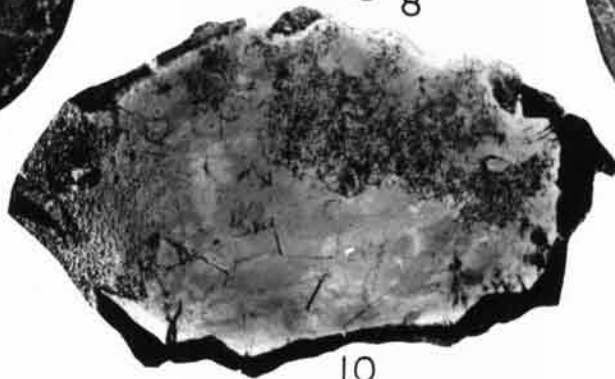
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EXPLANATION OF PLATE 42

FIGURE	PAGE	
1-3. <i>Poroblastus chouteauensis</i> (PECK), holotype, 1,290, Carl C. Branson coll., Univ. Missouri; Lower Mississippian, Chouteau Limestone, near Providence, Boone County, Mo.; oral, "D" ambulacral, aboral views of specimen figured by PECK (1938, pl. 28, fig. 18, labelled <i>Orbitremites chouteauensis</i> ) (all $\times 5.2$ )	100	
4-7, 9, 10. <i>Ptychoblastus pustulosus</i> FAY, holotype, 3,643 (figs. 4-6), paratypes, 3,644 (fig. 10), 3,645 (figs. 7, 9), Fay coll., Univ. Oklahoma; Mississippian, Warsaw Limestone, 12-15 feet below top, SW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 9, T. 44 N., R. 5 E., Keyes Summit, St. Louis County, Missouri; 4-7, oral, "D" ambulacral, aboral views ( $\times 6.3$ ); 7, 9, "EA" interambulacral and reverse side of same ( $\times 6.3$ ); 10, thin section showing one hydrosphere fold on each side of an ambulacrum ( $\times 9$ )	100	
8. <i>Poroblastus granulatus</i> (MEEK & WORTHEN), topotype, S3,719, Springer coll., U.S. Natl. Mus.; Lower Mississippian, Keokuk Group, near Warsaw, Ill.; polished cross section showing one hydrosphere fold on each side of an ambulacrum ( $\times 6.6$ )	98	

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## EXPLANATION OF PLATE 43

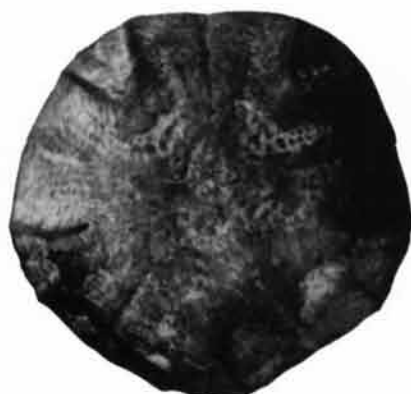
FIGURE	PAGE		
1-3, 10-11. <i>Orbitremites ellipticus</i> (SOWERBY).—1-3. Plesio-type, 245, deKoninck coll., Harvard Mus. Comp. Zoology; Lower Carboniferous limestone, Yorkshire, England; oral, "D" ambulacral, aboral views (all $\times 7.2$ ).—10-11. Plesio-type, fragmentary, unnumbered, Joysey coll. given to Harold Beaver, Humble Oil & Refining Company, Houston, Texas; Lower Carboniferous, upper part of Clitheroe Limestone (Ca) of Salt Hill Knoll, Clitheroe, Lancashire, England; 10, oral view showing wide triangular spiracles ( $\times 10$ ); 11, "AB" interambulacral view showing deltoid overlapping radial limbs ( $\times 4.3$ )	89	stone, ?Devonshire, England; 4, 6, "C" ambulacral, aboral views ( $\times 6.6$ ); 5, oral view of "D" ambulacrum showing one hydrospire fold (short, wide) on each side of the ambulacrum (inked on one side to show outline of hydrospire plate) ( $\times 13$ )	89
4-6. <i>Orbitremites campanulatus</i> (M'COY), plesio-type, 1,633, James coll., Univ. Chicago; Lower Carboniferous lime-	89	stone, 13,877, Gurley coll., Univ. Chicago; Lower Carboniferous limestone, Lancashire, England; oral, "D" ambulacral, aboral views, showing radial plates overlapping deltoids (all $\times 6.1$ ).—12. Plesio-type, 241, deKoninck coll., Harvard Mus. Comp. Zoology; Lower Carboniferous limestone, Settle, England; oral view of summit showing wide triangular spiracles ( $\times 10$ )	73



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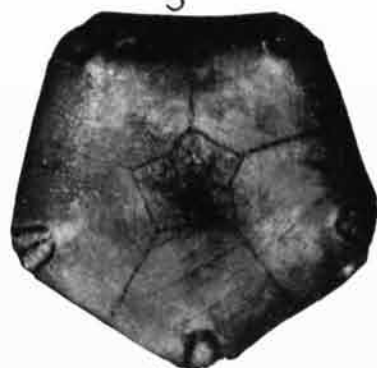
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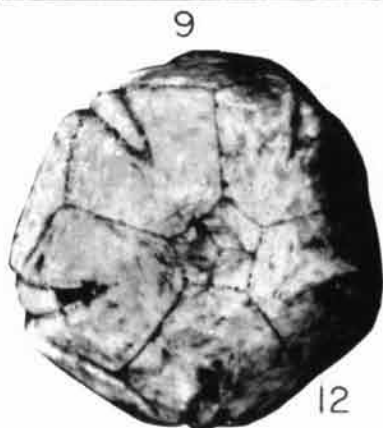
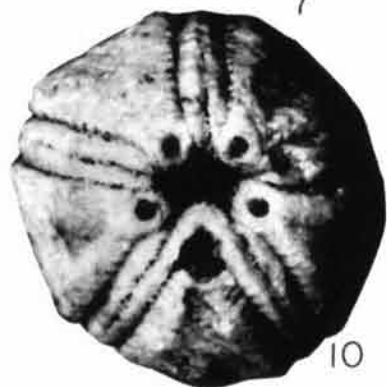
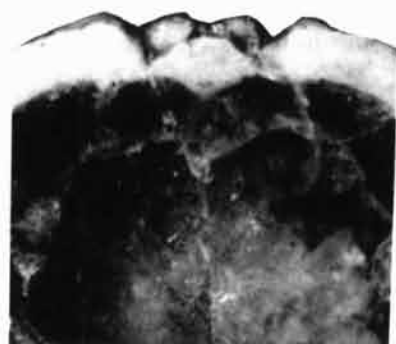
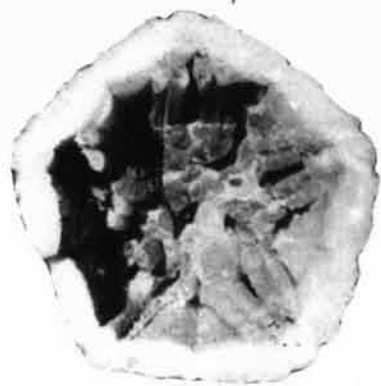
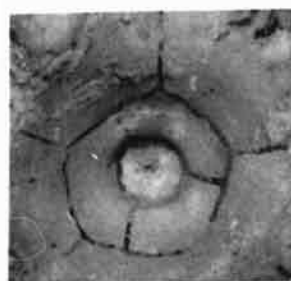
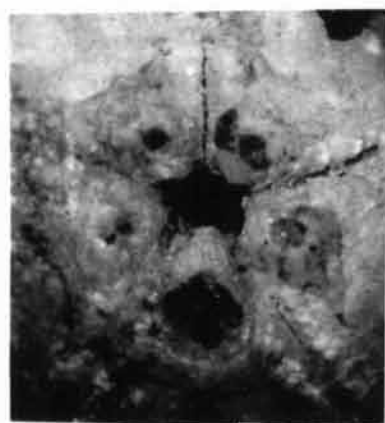
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## EXPLANATION OF PLATE 44

FIGURE	PAGE		
1-7. <i>Globoblastus norwoodi</i> (OWEN & SHUMARD), neotypes, S4,956 (new holotype, figs. 1-6), S4,955 (new paratype, fig. 7), Springer coll. (old number S3,759), U.S. Natl. Mus.; Lower Mississippian, Upper Burlington Limestone, Burlington, Iowa; 1-3, oral, "D" ambulacral, aboral views ( $\times 3.5$ ); 4, oral view of summit of same ( $\times 7.4$ ); 5, aboral view of basal circler ( $\times 8$ ); 6, "C" ambulacrum showing nature of pores and lancet covered by side plates ( $\times 6.7$ ); 7, aboral view of polished section (empty) showing two hydrosphere folds on each side of an ambulacrum, "E" ambulacrum upward ( $\times 5.2$ )	74	8-12. <i>Orbitremites derbiensis</i> (SOWERBY), plesiotypes, 328 (figs. 10-12), 4 (fig. 9), unnumbered etched specimen (fig. 8), Joysey coll. given to Harold Beaver, Humble Oil & Refining Company, Houston, Texas; Lower Carboniferous, Cockleshell beds of Middle Limestone of Yarnbury, near Grassington, Yorkshire, England; 8, detailed oral view showing cryptodeltoids (CD), hypodeltoid (HD), hydrosphere plate (HP), lancet plate (L), and superdeltoid plate (Su) ( $\times 15.3$ ); 9, oral view of polished cross section of "E" ambulacrum showing one hydrosphere fold on each side of an ambulacrum, each fold long and curved ( $\times 9$ ); 10-12, oral, "D" ambulacral, aboral views ( $\times 6.3$ )	88

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### EXPLANATION OF PLATE 45

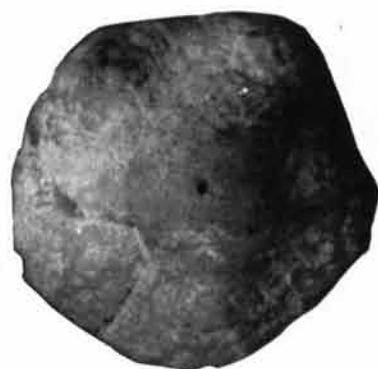
FIGURE	PAGE	
1-9. <i>Lophoblastus inopinatus</i> (ROWLEY & HARE), lectotypes, RX-134 (figs. 1-3, new holotype), (figs. 4, 6, 8, ?same as Rowley, 1901, pl. 28, fig. 8, a syntype), (fig. 5, new paratype), (fig. 7, probably original paratype of ROWLEY & HARE, 1891, pl. 3, fig. 17, and ROWLEY, 1901, pl. 28, fig. 5), (fig. 9, a new paratype), Rowley coll., Univ. Illinois; Lower Mississippian, Lower Burlington Limestone (chert), Louisiana, Mo.; 1-3, oral, "D" ambulacral, aboral views (×7.2); 4, 6, 8, anal interambulacral, aboral, "D" ambulacral views (×8.3); 5, aboral view of polished section showing three hydrosphere folds on each side of an ambulacrum (×10); 7, oral view (×6.2); 9, aboral view of another specimen (×8.7) .....	76	
10-12. <i>Carpenteroblastus magnibasis</i> (ROWLEY), holotype, RX-194, Rowley coll., Univ. Illinois; Lower Mississippian, Upper Burlington Limestone, Louisiana, Mo.; oral, "D" ambulacral, aboral views (all ×4.2) .....	52	



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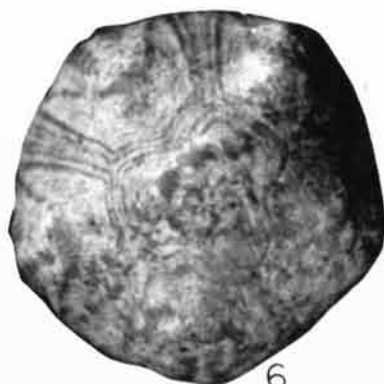
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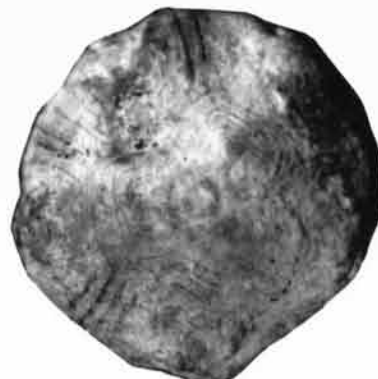
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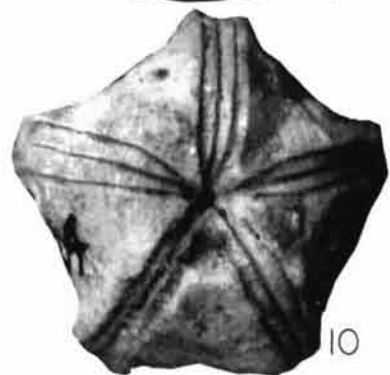
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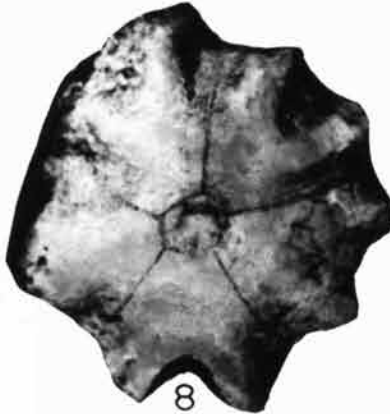
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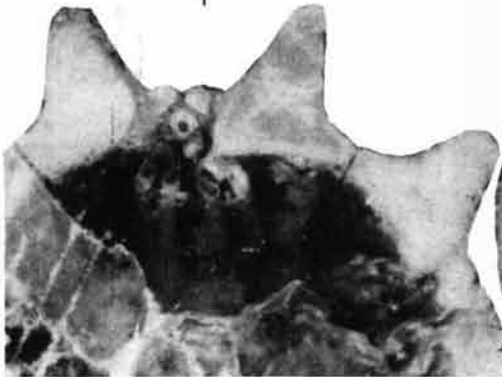
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## EXPLANATION OF PLATE 46

FIGURE	PAGE		
1, 2.		<i>Schizoblastus sayi</i> (SHUMARD), holotype, S3,735, Shumard coll. of Hambach coll. of Springer coll. (transferred in that order), U.S. Natl. Mus.; Lower Mississippian, Burlington Limestone, Marion County, Mo.; oral, "A" ambulacral views of slightly crushed specimen in matrix ( $\times 3$ )	101
3-5.		<i>Schizoblastus winslowi</i> (MILLER & GURLEY), holotype, 6,621, Univ. Chicago; Lower Mississippian, ?Burlington Limestone, from drift at Danville, Ill.; 3, oblique oral view of "B" ambulacrum showing some spiracles in white ( $\times 8$ ); 4, 5, "B" ambulacral, aboral views ( $\times 4.3$ )	101
6-11.		<i>Crioblastus cornutus</i> (MEEK & WORTHEN), holotype, X-361, Univ. Illinois (figs. 10, 11); plesiotypes, S3,771, Springer coll., U.S. Natl. Mus. (figs. 6-9); Mississippian, St. Louis Group, Brown County, Illinois (holotype), and Warsaw Formation, Fenton, Mo. (plesiotypes); 6, polished section of summit showing spiracles and anispiracle in white ( $\times 8.5$ ); 7, 8, "B" ambulacral and aboral views of another specimen ( $\times 5.3$ ); 9, aboral view of "B" ambulacrum (same specimen as shown in fig. 6) ( $\times 7.6$ ); 10, side view of specimen in rock (background clipped from photograph), showing imperfect nature of holotype ( $\times 3.8$ ); 11, ambulacrum of same showing one large pore between side plates ( $\times 27.2$ )	60

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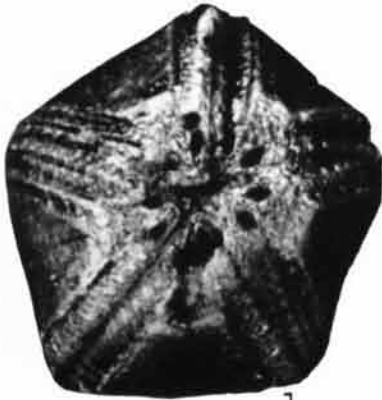
## EXPLANATION OF PLATE 47

## FIGURE

1-13. *Mesoblastus crenulatus* (ROEMER). Lower Carboniferous limestone, Tournai, Belgium.—1-3. Topotype?, 5,196, Krantz coll., Univ. Chicago; oral, "D" ambulacral, aboral views ( $\times 6.7$ ).—4-6. Topotype?, 536, deKoninck coll., Harvard Mus. Comp. Zoölogy; oral, "D" ambulacral, aboral views of an elongate specimen ( $\times 5.5$ ).—7-9. Topotype?, S3,775, Krantz coll. of Springer coll., U.S. Natl. Mus.; oral, "D" ambulacral, aboral views ( $\times 4.1$ ).

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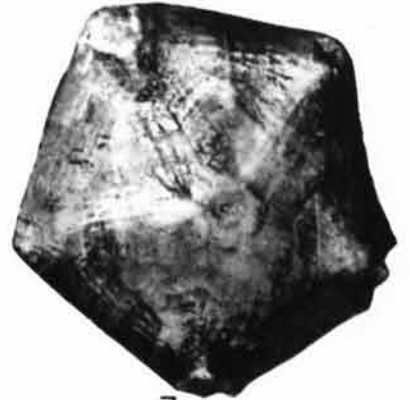
—10. Oral view of specimen S3,775, showing cryptodeltoids in place where hypodeltoid is removed ( $\times 2.2$ ).—11. Topotype?, 19,083, Gurley coll., Univ. Chicago; aboral view of polished cross section showing three hydrospire folds on each side of an ambulacrum ( $\times 9.3$ ).—12, 13. Tangential and ambulacral views of "C" ambulacrum of specimen 5,196 illustrated in fig. 1, showing side plates covering lancet and detailed pores of hydrospire plate ( $\times 10$ )



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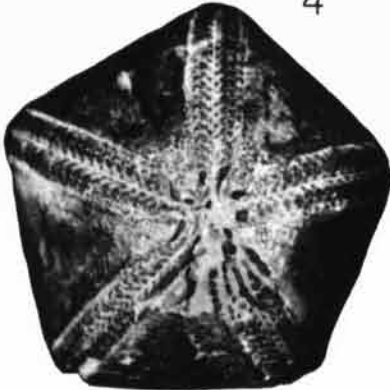
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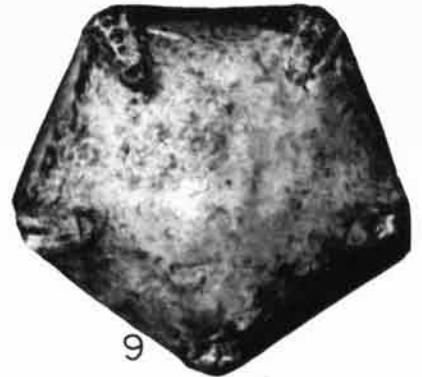
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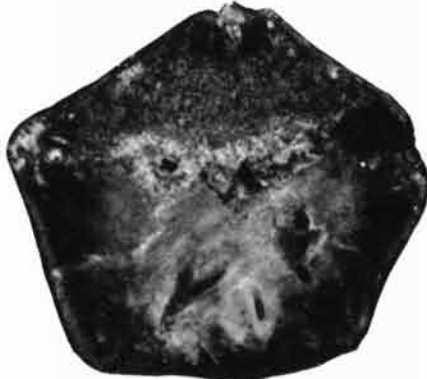
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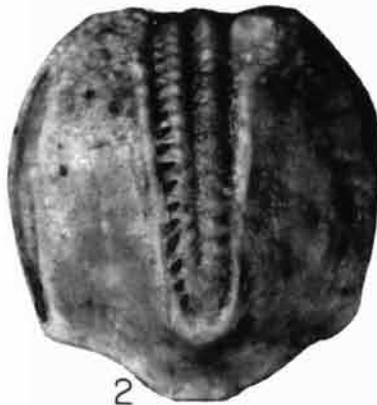
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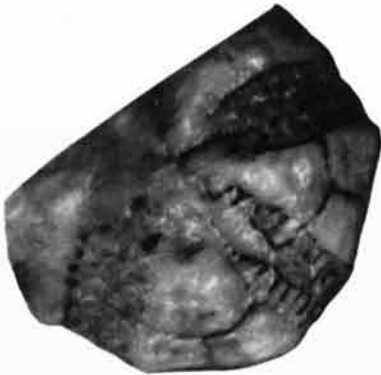
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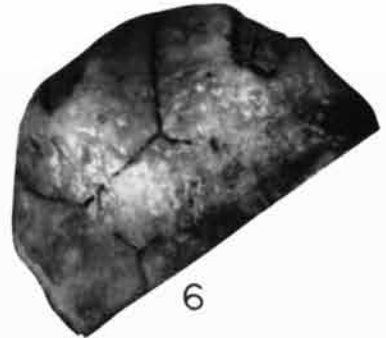
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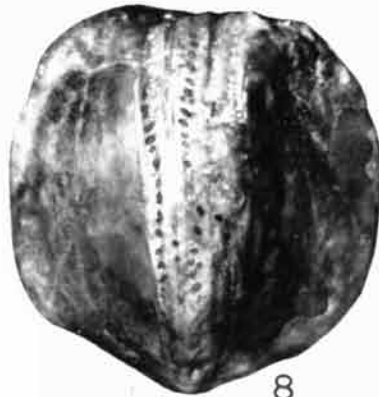
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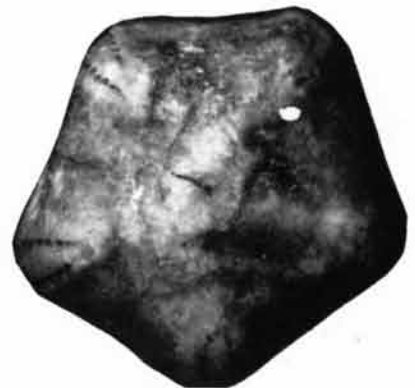
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## EXPLANATION OF PLATE 48

## FIGURE

1-12. *Diploblastus glaber* (MEEK & WORTHEN), Mississippian, Meramecian Series.—1-3. Plesiotypes, 1,303, Univ. Kentucky. St. Genevieve Limestone, Crittenden County, Ky.; oral, "D" ambulacral, aboral views, with azygous basal in "DE" interambulacrum (all  $\times 13$ ).—4-6. Plesiotype, E1,498, Worthen coll., Univ. Illinois, labelled *Mesoblastus kirwoodense*; St. Louis Group, Brown County, Ill.; oral, "C" ambulacral, aboral views of specimen that may not belong to this species (notice large side plates

## PAGE

and rounded outline in top and side views) (all  $\times 14.3$ ).—7-12. Syntypes, X-363, A. H. Worthen coll., Univ. Illinois; St. Louis Group, Hardin County, Ill.; 7-9, oral, "DE" composite ambulacral, aboral views of abnormal specimen in which "D" and "E" ambulacra are coalesced ( $\times 7.3$ ); 10-12, oral, "D" ambulacral, aboral views of complete specimen showing quadrangular outline in side view and pentagonal outline in top view, with flat basal circle (compare with above specimens that probably should be classed as distinct species) ( $\times 8.8$ )

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## EXPLANATION OF PLATE 49

## FIGURE

1-9. *Diploblastus glaber* (MEEK & WORTHEN), Mississippian, Meramecian Series.—1-5, 8, 9. Plesiotypes, 1,303, Univ. Kentucky. Ste. Genevieve Limestone, Crittenden County, Kentucky; 1-3, oral, "D" ambulacral, aboral views of wide, short specimen with azygous basal in "DE" interambulacrum ( $\times 12.3$ ); 4, oral view of polished summit showing cryptodeltoid on right, adjacent to superdeltoid ( $\times 13$ ); 5, aboral view of thin section with "B" ambulacrum upward ( $\times 13.8$ ); 8, "E" ambulacral view of another speci-

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men ( $\times 11.3$ ); 9, same ( $\times 39.6$ ).—6. Plesiotype, S3,782, Springer coll., U.S. Natl. Mus.; Warsaw Formation, Florence, Ala.; oral view of silicified internal mold showing circumesophageal ring of specimen labelled *Mesoblastus glaber* var. *sphaeroidalis* ( $\times 7.5$ ).—7. Plesiotype, 71,650, U.S. Natl. Mus.; Ste. Genevieve Limestone or Gasper Formation, Huntsville, Ala.; side view of specimen with brachioles attached, (figured by BUTTS, 1926, pl. 59, fig. 3) ( $\times 4.8$ )

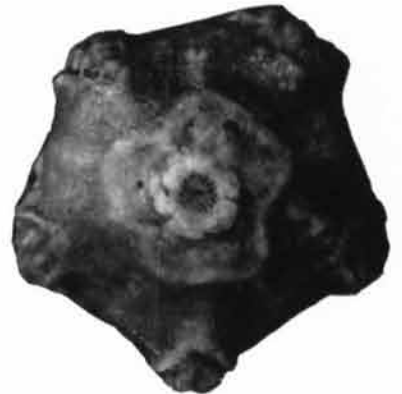




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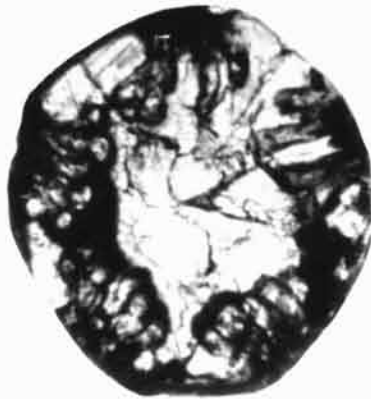
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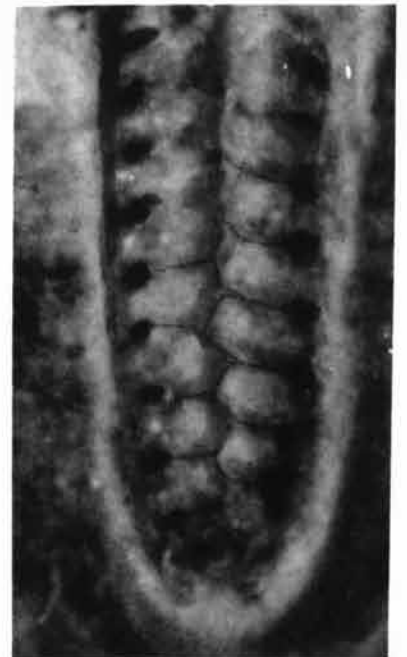
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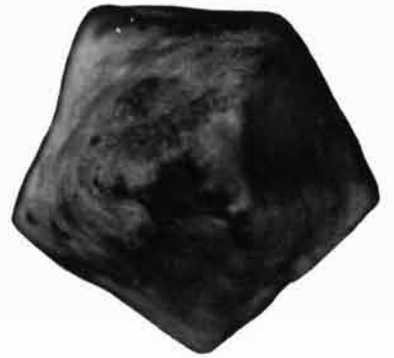
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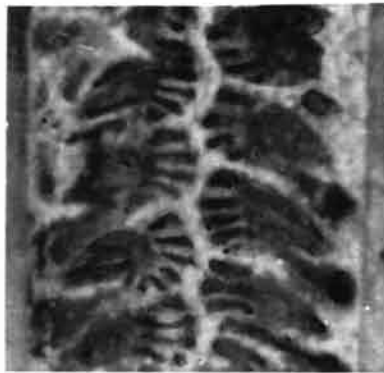
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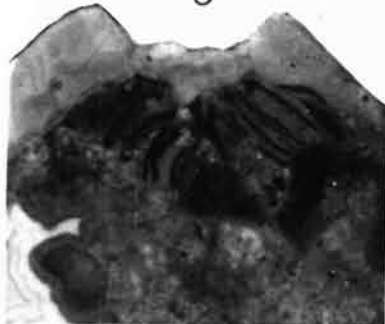
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## EXPLANATION OF PLATE 50

FIGURE	PAGE	
1-3. <i>Metablastus varsoviensis</i> (WORTHEN), syntype, 1, 885, Illinois Geol. Survey, Worthen coll.; Mississippian, Warsaw beds, Monroe County, Illinois; 1, anal view (×6.2); 2, oral view (×6.3); 3, "C" ambulacral view (×5.3) ....	82	specimens (figs. 4-6, 9), and another unnumbered specimen (fig. 7, 8), Buffalo Soc. Nat. Sci.; Mississippian, Warsaw Group, Boonville, Mo.; 4-6, oral, "D" ambulacral, aboral views (×6.3); 9, anal area (×22.2); 7, "B" ambulacrum (×43); 8, polished cross section of "C" ambulacrum showing four or five hydrosphere folds on each side of an ambulacrum, (×15) .....
4-9. <i>Metablastus wortheni</i> (HALL), plesiotype, one of four		

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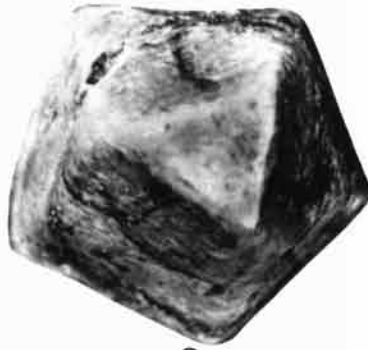
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## EXPLANATION OF PLATE 51

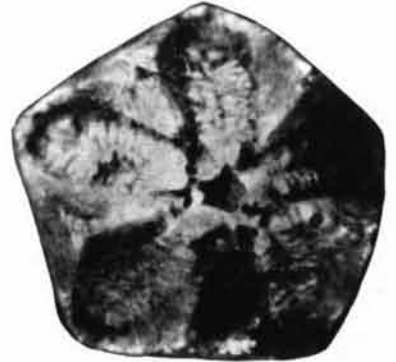
FIGURE	PAGE	
1-2, 5. <i>Metablastus wachsmuthi</i> (GURLEY), holotype, 6,323, Gurley coll., Univ. Chicago; Mississippian, Salem Limestone, Ellettsville, Ind.; oral, aboral, "D" ambulacral views (all $\times 2.9$ )	82	
3-4, 7. <i>Metablastus nitidulus</i> (MILLER & GURLEY), syntype, 6,284, Gurley coll., Univ. Chicago; Mississippian, Salem Limestone, Lanesville, Ind.; oral, aboral, "D" ambulacral views (all $\times 11.7$ )	80	
6. <i>Metablastus bipyramidalis</i> (HALL), holotype, 7,226/1, Am. Mus. Nat. History; Lower Mississippian, Keokuk Limestone, Boonville, Mo.; "C" ambulacral view of specimen figured by HALL (1858, pl. 15, fig. 2) ( $\times 4.7$ )	80	



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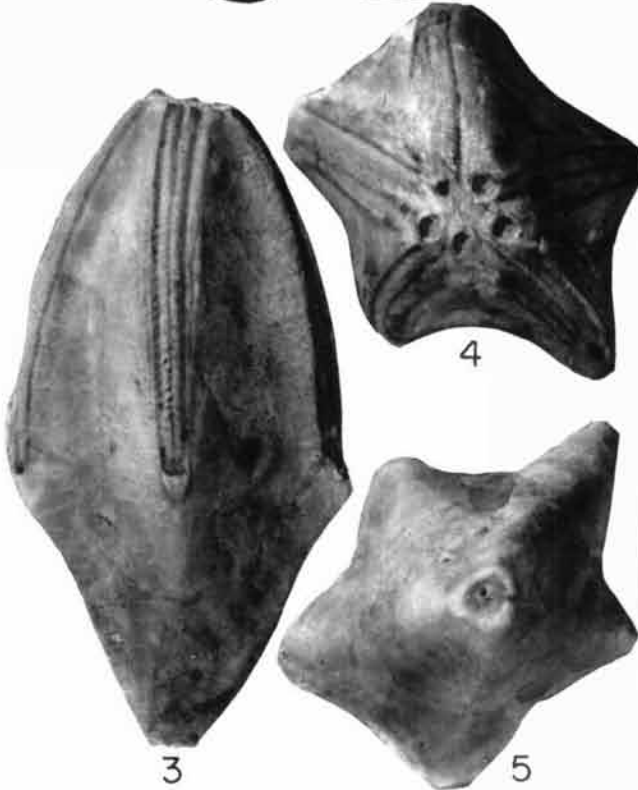
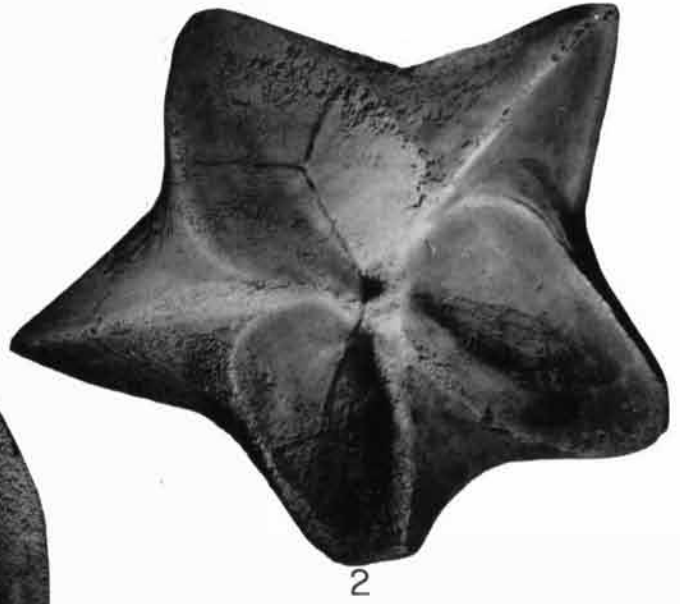
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## EXPLANATION OF PLATE 52

FIGURE	PAGE		
1, 2. <i>Tricoelocrinus woodmani</i> (MEEK & WORTHEN), holotype, 7,225/1, Am. Mus. Nat. History, by purchase of Woodman coll.; Mississippian, ?Keokuk Limestone, Salem, Ind.; "A" ambulacral, aboral views of specimen figured by MEEK & WORTHEN (1873, pl. 16, figs. 4a-d). (×1.9) .....	105		
3-5. <i>Hyperoblastus bassleri</i> (REIMANN), paratype, E15,337,		Buffalo Soc. Nat. Sci.; Middle Devonian, Partridge Point Formation, Partridge Point, Michigan; "D" ambulacral, oral, aboral views (all ×3.2) .....	31
		6. <i>Metablastus varsouviensis</i> (WORTHEN), syntype, 1885, Illinois Geol. Survey; Mississippian, Warsaw beds, Monroe County, Illinois; anal view showing large cryptodeltoids in place, hypodeltoid missing (×24.3) .....	82

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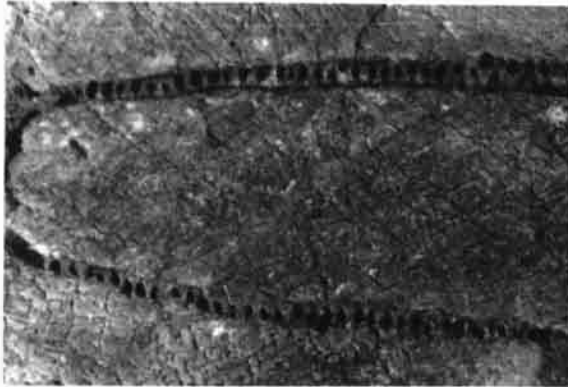
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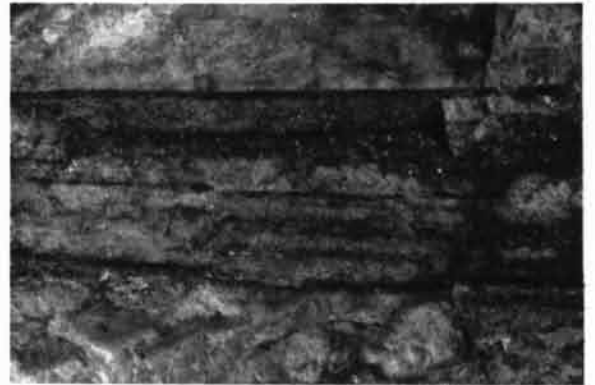
## EXPLANATION OF PLATE 53

- | FIGURE  | PAGE |  |
|---|------|--|
| 1-6, <i>Ambolostoma baileyi</i> Peck, Mississippian.—1. Plesiotype, 8,914 (holotype of <i>Pentremites grandis</i> Warren, Geol. Survey Canada; Rundle Limestone, Cascade Mountain, Alberta; short ambulacrum showing inner or lower ends of side plates between lancet and adjacent radial plates ( $\times 5.3$ ).—2, 3. Plesiotype, 8,915 (holotype of <i>Pentremites perelongatus</i> Warren), Geol. Survey Canada; Rundle Limestone, Cascade Mountain, Alberta; 2, fragmentary specimen in dark crystalline limestone showing ambulacrum with lancet plate removed to reveal hydrospire slits ( $\times 5.6$ ); 3, side view from food groove of impression of abmedial ends of side plates showing long pores between plates ( $\times 5$ ).—4-6. Syntypes, 11,762, U.S. Natl. Mus.; Mississippian, Upper Brazer Limestone, 6 miles west of Mendon, Utah; 4, ambulacral view showing side plates on left and lancet on right ( $\times 17.6$ ); 5, a smaller specimen, oral plate on anal side showing large anispiracle adjacent to deltoid body (outlined in white) ( $\times 15$ ); 6, aboral view of "A" ambulacrum of specimen shown in fig. 5, deeply etched with acid, indicating possible outline of three hydrospire folds on one side of ambulacrum ( $\times 24.8$ ) ..... 50 |      |  |

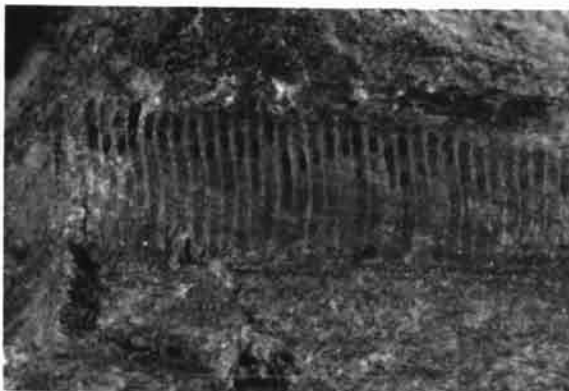




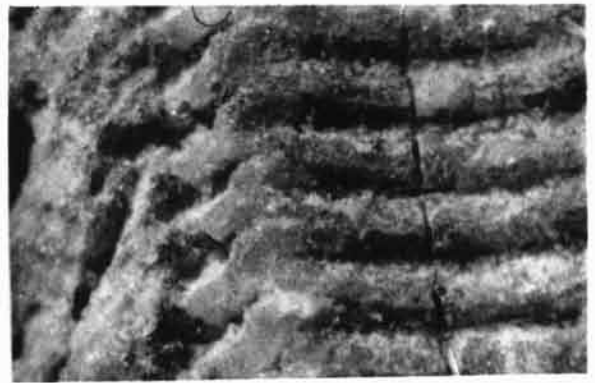
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## EXPLANATION OF PLATE 54

FIGURE	PAGE
1-3. <i>Pentremites pyriformis</i> SAY, plesiotypes, unnumbered, U.S. Natl. Mus.; Upper Mississippian, Chesteran Series, Huntsville, Ala.; side views of three specimens showing attached brachioles ( $\times 5.1$ , $\times 6.1$ , $\times 5.1$ ) .....	91
4, 5. <i>Pentremites burlingtonensis</i> MEEK & WORTHEN, plesio-	90

types, S3,634, Springer coll., U.S. Natl. Mus.; tray containing four specimens labelled *Metablastus lineatus*; Lower Mississippian, Lower Burlington Limestone, Burlington, Iowa; 4, side view of crushed specimen ( $\times 4.5$ ); 5, side view of another crushed specimen showing attached brachioles ( $\times 3$ ) .....

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