OKLAHOMA GEOLOGY NOTES

$2.00 per year
.25 per copy

OKLAHOMA
GEOLOGICAL SURVEY
NORMAN, OKLAHOMA

VOLUME 22, NUMBER 2

FEBRUARY 1962

Cover Picture

MOUNT SCOTT

The cover photograph is a vertical view of Mount Scott, near Lawton, Comanche County. The area shown is approximately two miles square, including sec. 11 and parts of secs. 10, 12, 13, 14, and 15, T. 3 N., R. 13 W.

This famous landmark in the Wichita Mountains of southwestern Oklahoma is composed of massive pink granite overlying gabbro. The elevation of the summit, at the center of the road spiral, is 2,464 feet and its height above Elmer Thomas Lake (lower right-hand corner of picture) is 1,081 feet. Two other peaks are shown on the west side of Mt. Scott, Mount Scotts Boy (elevation, 2,020) to the south and Hunting Horse Hill (elevation, 2,040) to the north.

The surface trace of the contact between the granite and the gabbro is clearly delineated on the north and east sides of Mt. Scott by the sharp break between the light-toned, relatively barren granite-outcrop area and the dark-toned, wooded gabbro-outcrop area. The contact dips gently to the south.

Other features of interest are the numerous linears and boulder streams. The linears are traces of joint systems, although a few may be faults. Four of these bracket the mountain. Two others can be seen to intersect near the summit on the west side, forming a V-shaped escarpment. These linears also serve as channels for the boulder streams. One boulder stream crosses the Mt. Scott road approximately 0.3 mile east of the road junction near the bottom of the picture. A second boulder stream can be seen on the west side of Hunting Horse Hill.

Mount Scott was named in 1852 by Capt. R. B. Marcy, who led the expedition in that year to discover the source of the Red River. It was named in honor of General Winfield Scott, then commanding general of the Army.

—A. N.

LPG Storage in Cimarron Salt, Beaver County, Oklahoma

Louise Jordan

An underground storage facility for liquefied petroleum gas (LPG) is being prepared by Warren Petroleum Corporation at their Mocane Plant in sec. 18, T. 5 N., R. 25 ECM, about eight miles northeast of Beaver City, Beaver County, in the Panhandle of Oklahoma. In May, 1961, a hole for disposal of salt water (SWD) during the solution process of forming the cavern was drilled into the carbonate sequence of Wolfcampian age to a total depth of 3,180 feet. Continuous cores were taken from 1,420 to 1,760 feet. In this interval the unit called the Cimarron anhydrite by subsurface geologists and considered by many equivalent to the Stone Corral Formation of the surface, occurs from 1,514 to 1,564 feet. It consists of two beds each of anhydrite near the top and dolomite at the base, each pair of beds being separated by halite and minor amounts of reddish-brown shale (fig. 1). The upper medium-crystalline anhydrite contains crystals of halite, whereas the lower bed is very fine crystalline and banded. The halite strata are colorless and coarse crystalline, except for a two-foot section immediately below the upper anhydrite, which contains clear fibrous halite with a faint pink coloration. Halite just above the medium-gray very fine-crystalline dolomite is clear, colorless, and coarse crystalline. Part of the dolomite is finely oölitic.

A 184-foot section of interbedded and intermingled coarse-crystalline halite and reddish-brown shale, from 1,330 to 1,514 feet, rests upon the Cimarron anhydrite. For the most part the halite contains clay that imparts an overall dull reddish-brown appearance.

The formation is underlain by 280 feet of halite with relatively few interbeds of reddish-brown or greenish-gray shale. Much of the salt is colorless and coarse crystalline, but at places the clay between crystals gives a gray appearance in contrast to the reddish-brown appearance of the salt above the Cimarron anhydrite. Orange-red fibrous halite occurs as veins in shale in both sections.

Stratigraphic data for the SWD hole (Elevation: 2,668 feet) obtained by study of rock samples adjusted to log surveys are as follows:

0-372	Alluvium and Tertiary and Cretaceous rocks.
372	Top Permian.
788?	Base Dog Creek Shale-top Blaine Formation.
839	Base Blaine Formation-top Flowerpot Shale.
839-1035	Flowerpot Shale, grayish-red.
1035-1070	Halite and shale, interbedded.
1070-1330	Shale, moderate reddish-brown with some halite, gypsum, and light-gray siltstone.
1330-1504	Upper Cimarron salt. Halite interbedded with moderate reddish-brown shale containing coarse crystals of halite.
1504-1514	Halite with two thin (less than one inch) seams of anhydrite.
1514-1564	Cimarron anhydrite or Stone Corral Formation.
1564-1746	Lower Cimarron salt. Halite with moderate reddish-brown and green-gray shale.

1746-1990	Shale as above. Samples poor.
1990	Possible top of Wellington Formation. Increase in gray shale and recurrence of thin (2-4 feet) beds of anhydrite. Change in character of gray shale from hackly to platy fracture with varve-like laminae.
2233-2496	Hutchinson Salt Member of the Wellington. Halite interbedded with shale and anhydrite.
2496-2874	Basal part of Wellington Formation. Anhydrite with gray and dark moderate reddish-brown shale.

The Texaco LPG-storage facility in sec. 31, T. 1 N., R. 20 ECM, is in salt in the Flowerpot Shale immediately below the Blaine Formation (Jordan, 1961). Data from various types of tests in the vicinity of the Mocane Plant indicated that a similar amount of Flowerpot salt might be found. A lithologic log of the Champlin No. 1 Maple (SE¼ SE¼ NW¼ sec. 20), about one mile southeast of the storage site, shows some 200 feet of salt section just below the Blaine Formation. The interval from the base of the Blaine to the base of the Cimarron is 938 feet. Rock sections at this position in other holes in the southern part of the township have similar thicknesses. However, at the Mocane Plant SWD hole, the thickness is 725 feet, or more than 200 feet thinner than that in the Maple test in section 20. A minor amount of salt in a 35-foot section occurs 200 feet below the base of the Blaine whereas in the Maple hole the 200-foot section immediately below the Blaine is primarily salt.

Because the data on the Maple test are based solely on a lithologic log from well cuttings, one might say that the information is erroneous, but a similar condition may be demonstrated by the electrical log of the Pure No. 1 Albert (SE¼ SE¼ SW¼ sec. 16) and a laterolog of the Ammco Tools, Inc. No. 1 Davis (NE¼ NE¼ NE¼ sec. 17), wells about one mile apart in T. 5 N., R. 26 ECM, approximately six miles to the east.

	ALBERT TEST DEPTH (ALTITUDE)	DAVIS TEST DEPTH (ALTITUDE)
Base Blaine	560 (+2035)	780 (+1780)
Base Cimarron	1496 (+1100)	1482 (+1081)
Thickness	935	702

The 233-foot increase in thickness in the Albert test is due to the presence of salt in the section from 560 to 1,000 feet whereas no salt is evident from 780 to 1,000 feet in the Davis test.

D. F. Moore (1954) reported similar conditions in unspecified areas of southwestern Kansas and the Panhandle of Oklahoma. He stated

> The Blaine formation illustrated an anomalous condition when a salt area was entered, whereas the Cimarron, only a few hundred feet lower in the section, expressed only regional dip. Divergence of the Blaine-Cimarron interval occurred abruptly in every instance within a lateral distance of two to four miles with as much as 100 to 350 feet of thickening apparent.

He ascribed the convergence of the marker beds in areas of salt absence to solution of salt and to collapse of the section after deposition of the Blaine Formation. Moore believed that solution and collapse occurred since Late Permian time.

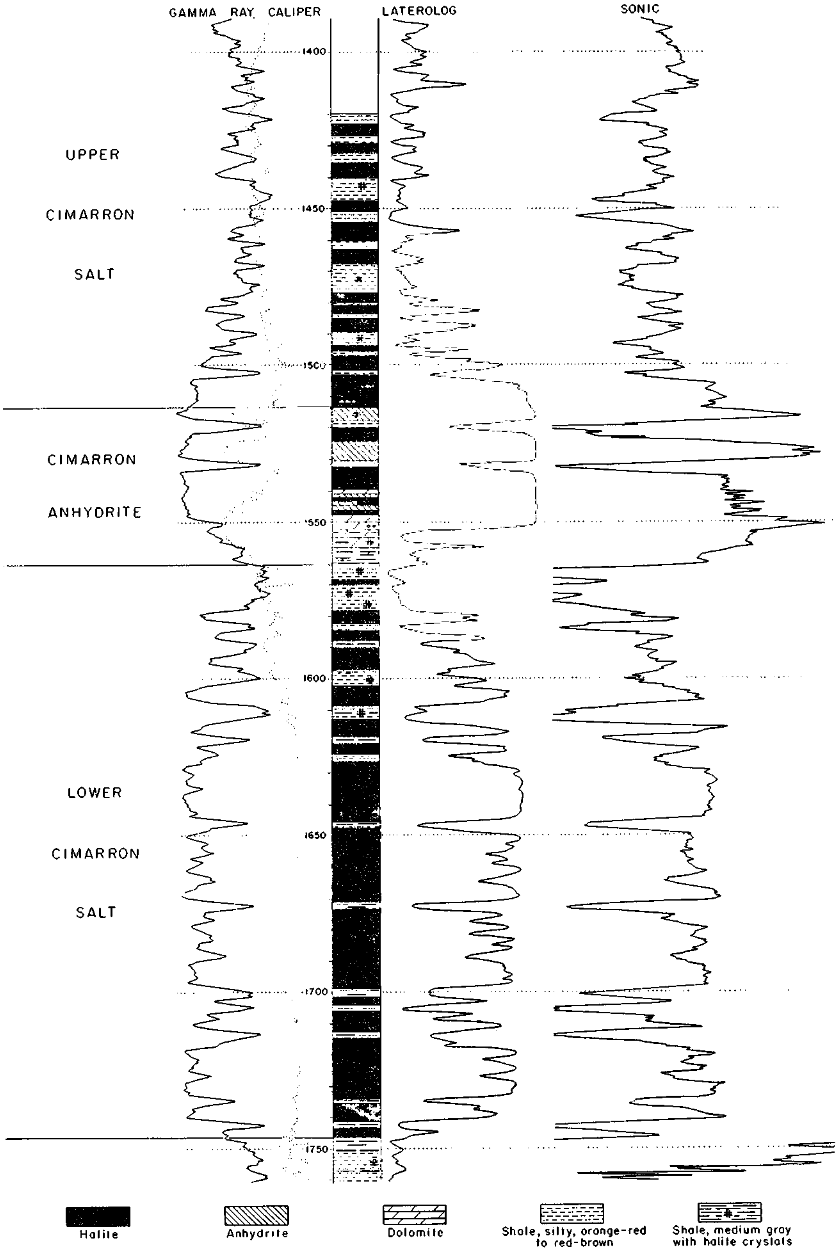


Figure 1. Lithologic, gamma-ray, caliper, laterolog, and sonic logs of Gulf-Warren's SWD1 Mocane Plant, SE¼ SW¼ SE¼ NW¼ sec. 18, T. 5 N., R. 25 ECM, Beaver County, Oklahoma, showing salt section above and below the Cimarron anhydrite.

Warren's underground LPG storage facility, about 800 feet east of the SWD hole, will be formed in the lower Cimarron salt, that is, below the Cimarron. Elevation datums in the LPG hole differ little from the illustrated SWD hole (fig. 1). The shoe on the 9⅝-inch casing was set at 1,579 feet. Seven-inch casing was hung to a depth of 1,679 feet for outflow of the salt-saturated water and 4½-inch tubing to a depth of 1,730 feet for inflowing water. A pear-shaped cavity with an estimated capacity of two million gallons (nearly 50,000 barrels) will be formed below 1,600 feet when the washing-out process is completed in July, 1962.

References Cited

Jordan, Louise, 1961, LPG storage in Flowerpot Shale, Beaver County, Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 21, p. 34-35.

Moore, D. F., 1954, Permian salt problem—western Kansas: Geophy. Soc. Tulsa, Proc., vol. 2, p. 34-37.

Use of Hoyer's Solution as a Palynological Mounting Medium*

L. R. Wilson

Hoyer's solution appears to have been first reported as a palynological mounting medium by McGregor (1961). Previously it had been widely used for the mounting of mites, and more recently it has been used in bryological studies (Anderson, 1954). Experiments with Hoyer's solution in the Oklahoma Geological Survey palynological laboratory have shown that it is a good mounting medium for microscopic objects that do not require staining. It also has a tendency to aid in the clearing of near-opaque objects such as some fungus spores and chitinozoans. All efforts to mount stained spores and pollen in it have been unsatisfactory because stain "bleeds" out of the specimens.

Hoyer's solution is a water-miscible mounting medium that has nearly the same optical properties as glycerine jelly and Clearcol (Wilson, 1959). When spread on a microslide, it evaporates rapidly, leaving a hard, transparent residue. It may be heated to 40°C without cracking. A comparison of specimens mounted in glycerine jelly, Clearcol, and Hoyer's solution shows that under magnification of 250 diameters or more, Hoyer's does not give as sharp definition as do the others. The best magnification for specimens mounted in Hoyer's solution is less than 150 diameters; consequently it is not particularly suitable for the smaller palynomorphs.

The preparation of Hoyer's solution published by Anderson (1954) is as follows:

Distilled water	50 cc
Gum arabic (U.S.P. Flake)	30 g
Chloral hydrate	200 g
Glycerine	20 cc

*Report of one study conducted under National Science Foundation Grant G 6589.

It is of prime importance that the gum arabic be in flake form so that it will go readily into solution. The ingredients should be mixed in the order listed above and should not be heated at higher than room temperature. A magnetic mixer is a definite aid in speeding the combination of the ingredients. After the solution has been prepared, it should be stored in a bottle with an airtight stopper. For transparent and translucent fossils, a malachite green stain may be added to Hoyer's solution. The stained mounting medium generally gives better definition than does the clear, but for most opaque specimens the unstained is best.

The slide preparation procedure found most satisfactory with Hoyer's solution is as follows: Place a clean cover slip on a level surface and, in its center, put enough Hoyer's solution to spread thinly to within one-eighth of an inch of the cover-slip edges. Slightly spread the solution with a needle and add a small drop of water containing the fossil preparation. Mix the two solutions thoroughly, being careful not to cause bubble formation. Spread the materials nearly to the edges of the glass. Place the cover slip, preparation up, on a labeled microscope slide and allow the solution to dry to a hard film. The drying may be speeded by placing the slide in an oven at a temperature of approximately 40°C. Generally 15 to 20 minutes are required for drying. Remove the cover slip from the microscope slide and place a drop of Canada balsam, or other permanent mounting medium, on the slide. Invert the cover slip and place it, preparation down, on the Canada balsam. When the Canada balsam has spread to the edges of the cover slip, the slide can be studied. To make the slide permanent, place it on a warming table until the balsam has set.

References Cited

Anderson, L. E., 1954, Hoyer's solution as a rapid permanent mounting medium for bryophytes: Bryologist, vol. 57, p. 242-244.

McGregor, D. C., 1961, Spores with proximal radial pattern from the Devonian of Canada: Canada, Geol. Survey, Dept. of Mines Technical Surveys, Bull. 76, 13 p.

Wilson, L. R., 1959, A water-miscible mountant for palynology: Okla. Geol. Survey, Okla. Geology Notes, vol. 19, p. 110-111.

Pennsylvanian Cephalopods

In January the Oklahoma Geological Survey issued Bulletin 96, *Pennsylvanian Cephalopods of Oklahoma*, by A. G. Unklesbay, professor of geology, University of Missouri. The report describes the known cephalopod fauna of the Pensylvanian rocks of Oklahoma, including three new nautiloid species and three new ammonoid species. The new species are *Michelinoceras directum, Liroceras patulum, Coelogasteroceras planum, Wewokites newelli, Eoasianites subdiscus,* and an unnamed species of *Proshumardites.*

The book contains 150 pages, 16 text-figures, and 19 plates. Price: $3.00 cloth bound, $2.00 paper bound.

Endelocrinus bransoni, A NEW SPECIES FROM THE LENAPAH LIMESTONE

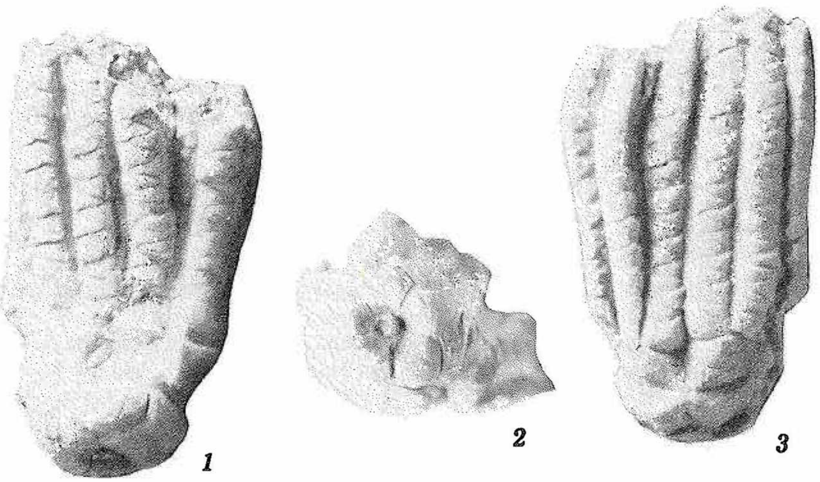
HARRELL L. STRIMPLE

A note on the restricted biofacies of the Perry Farm Shale has been given by Branson (1960). The collecting locality is in the waste heaps of the Peerless Stone Company quarry in sec. 31, T. 28 N., R. 16 E., Nowata County, 1½ miles north of Lenapah and east of U. S. Highway 169. The predominant fossil is *Desmoinesia muricatina* (Dunbar and Condra). The crinoid crown, listed by Branson as *Erisocrinus* sp., and collected by Branson in 1951, is an excellent crown that has been in my hands for description for quite some time. I have collected from the exposure several times, over a period of years, without finding any crinoid remains other than occasional stem or plate ossicles. The crinoid is an erisocrinid and is described below as *Endelocrinus bransoni* Strimple, new species.

ERISOCRINIDAE S. A. Miller
Endelocrinus Moore and Plummer

Endelocrinus bransoni Strimple, new species
Figures 1-3

The dorsal cup is low, bowl-shaped, with a well-defined deep basal concavity. Five infrabasals are confined to the bottom of the concavity and are mainly covered by the medium-sized proximal columnals. Five basals are relatively large elements, forming the walls of the basal con-



Figures 1-3. Endelocrinus bransoni, new species. Posterior (1), basal (2), and anterior (3) views of the holotype, OU 3960.

cavity and curving strongly to form the basal plane of the cup and thence to participate in the lateral walls of the cup. The posterior basal is truncated to receive the single anal plate. Five radials are wide, tumid plates, particularly in the arm-articulating area where the cup actually becomes mildly constricted. Although the cup plates are tumid, the pits at the corners of the plates are not especially pronounced. The column is round.

Ten stout, biserial arms branch with the first primibrach in all five rays. The axillary primibrachs are of unequal lengths and four of them are preserved in a manner which permits measurements of the lengths which are listed under the measurements of the specimen. The brachials become interlocking with about the fourth secundibrach. Brachials are low and extend for an unusual distance across the face of the arms. The outer surface of the arms is convex. Pinnules are poorly preserved but each brachial is seen to bear a pinnule.

Measurements in millimeters:	
Length of crown	32.0
Width of cup	11.2
Height of cup	4.5
Width of basal concavity	4.2
Width of proximal columnals	1.5
Length of basal	6.4*
Width of basal	4.8*
Length of radial	4.1*
Width of radial	7.2*
Length of first primibrachs	
left posterior	4.3
left anterior	3.7
anterior	4.6
right posterior	5.1

*Measurement taken along surface curvature.

Remarks.—The most comparable described species appears to be *Endelocrinus grafordensis* Moore and Plummer (1940); however, in that species the cup plates are not quite so tumid, the primibrachs have a more pointed apex and the upper brachials do not extend quite so far across the face of the arms as they do in *E. bransoni.*

Occurrence.—Perry Farm Shale, Lenapah Limestone, Marmaton Group, Desmoinesian, Pennsylvanian; sec. 31, T. 28 N., R. 16 E., 1½ miles north of Lenapah, Nowata County, Oklahoma.

Holotype.—The University of Oklahoma, paleontological collections, OU 3960.

Reference Cited

Moore, R. C., and **Plummer, F. B.**, 1940, Crinoids from the Upper Carboniferous and Permian strata in Texas: Texas, Univ., Publ. 3945, p. 9-468, pls. 1-21.

Some Brachiolar and Ambulacral Structures of Blastoids

Robert O. Fay and Irving G. Reimann*

INTRODUCTION

The brachioles of blastoids are rarely preserved, and it is difficult to find accurate illustrations or descriptions of brachiolar and ambulacral structures. A few well-preserved Devonian and Mississippian specimens were collected by Reimann and others, forming a basis for this paper. Miss Eileen Krall of the Oklahoma Geological Survey lettered and numbered the illustrations.

TERMINOLOGY

The terms used in this paper are relatively new and therefore are briefly reviewed. The *calyx* of a blastoid includes two parts: the body or *theca,* and the *brachioles* or filamentous appendages attached to the ambulacra. The direction toward the point of attachment of the stem or column to the theca is termed *proximal* or *dorsal,* and the direction away from this point is *distal* or *ventral. Adoral* is toward the mouth, on the upper side of the theca, and *aboral* is any direction away from the mouth. The ambulacra are lettered "A", "B", "C", "D", and "E", where "A" stands for anterior ambulacrum (opposite anus), and the others are read in clockwise order when the specimen is oriented with the mouth up and the anus toward the observer. The terms width and length of a primary side plate and associated structures are used to mean parallel to and at right angles to the line of the main food groove, respectively. The brachiolars of blastoids are described accordingly so that the long dimension is referred to as the length, an end dimension as width, and a dimension normal to the side plates as height.

ABBREVIATIONS

Detailed terminology, shown by abbreviations on the figures and plates, is explained in the following list.

"A"—anterior ambulacrum
An—anal opening
AO—accessory oral plate
APl—anal plates
As—ambulacral spines
Asc—anal sac
B—basal plate
"B"—right anterior ambulacrum
Bf—brachiolar facet
Bl—brachiolar plate
Bp—brachiolar pit
Br—brachiole
BrFg—brachiolar food groove
"C"—right posterior ambulacrum
CD—cryptodeltoid plate
Col—column or stem
Cp—cover plates
CpLo—cover plate lobes
D—deltoid plate
"D"—left posterior ambulacrum
"E"—left anterior ambulacrum
ED—epideltoid plate
FHp—fused hydrospire plate
GSt—granulostriations
HD—hypodeltoid plate
Hs—hydrospire slits
ICp—inner cover plates
L—lancet plate
MFg—main food groove
Mr—median ridge
O—oral plate or oral opening
OCp—outer cover plates
Os—oral spines
P—pore
Pf—pore furrow
PSp—primary side plate
R—radial plate
Rl—radial lip
S—spiracle
SD—superdeltoid plate
SFg—side food groove
Sp—side plates
Ss—spiracular slit
SSp—secondary side plate

*Director, The Exhibit Museum, University of Michigan.

The gross external morphology of blastoids belonging to the orders SPIRACULATA (hydrospires hidden, spiracles and pores present) and FISSICULATA (hydrospire slits exposed, pores absent) is illustrated and described from observations of some selected Devonian and Mississippian specimens. Although most blastoids are basically similar (3 basals, 5 radials, 5 deltoids with 1-6 on anal side, 5 lancets, 5 ambulacra, a stem), there is wide variation in the pattern of the oral and anal plates, shape of thecal plates, number and position of hydrospires, position of lancet plates, type of radial-deltoid overlap, type and number of pores, position and number of spiracles, and ornamentation. These variations have been used as basis for separation of genera and species. The variety of brachiolar plates has been overlooked generally, making it necessary to investigate these and other related structures.

SYSTEMATIC DESCRIPTIONS

Order SPIRACULATA Jaekel, 1918

Genus *Placoblastus* Fay, 1961

Placoblastus ehlersi, new species

Plate I, figures 1-7

Theca calcitic, ellipsoidal, 31 mm long by 21 mm wide, with truncated summit and base, pentagonal in top view. Basalia pentagonal, small, in basal concavity, 2.5 mm in diameter, hidden by large round stem 2.5 mm in diameter. Each columnal of the stem has a rimmed border, tapering adaxially, and extending about 0.75 mm outward from the stem proper. Radials 5, short, each 5 mm long by 7 mm wide, subpentagonal, infolded below, with maximum width along radiodeltoid suture, tapering aborally to a border 2 mm wide. The radial sinus is broad and short, confined almost exclusively to the radial lip, 1.5 mm long by 1.5 mm wide. Deltoids overlap radials.

Deltoids 4, elongate, sublenticular, each 28 mm long by 12 mm wide, with central smooth triangular portion basally in contact with the radiodeltoid suture, bordered on either side by lenticular striated portions. The striae are small curved ridges and hollows, parallel to the outer margins of the side plates, extending longitudinally in parallel rows. The central triangular portion is ornamented with fine growth lines, parallel to the bracket-shaped radiodeltoid suture, and the radial plates are also ornamented with growth lines parallel to the plate margins. In top view, the marginal outline of each deltoid plate is even and straight, giving a pentagonal appearance to the theca. The adoral tips of each deltoid are pierced with two hemielliptical spiracles, adjacent to the ambulacral margins, separated by a wide medium septum. Each deltoid lip abuts against a large oral plate (interambulacral in position). On the anal side, there are four anal deltoid plates: a central triangular hypodeltoid aboral to the anal opening, bordered on either side by two cryptodeltoids, corresponding to the three main parts of the other four deltoids. The adoral tips of the cryptodeltoids border the anal opening laterally and are separated medially by two plates, the one adjacent to the anal opening being termed a superdeltoid, and the one adjacent to the anal oral plate being termed an accessory oral plate. Each adoral tip of each cryptodeltoid is notched by one hemielliptical spiracle, separate from the anal opening, adjacent to the "C" and "D" ambulacra respectively. Thus there are 10 spiracles, separate from the anal opening, around the mouth. There are five large oral plates, each interambulacral in position, against which the deltoids and cryptodeltoids abut. Each is arrow-shaped, and on the anal side an additional subquadrangular plate (accessory oral) is present between the anal oral plate and the superdeltoid plate. The anal opening appears to be almost covered with many small polygonal plates, termed anal plates, which probably were flexible along the sutures and covered the anal opening in the living animal.

Ambulacra five, narrow, linear, recurved below, each 36 mm long by 2 mm wide, with lancet covered by side plates, and 24 side plates in 10 mm length of an ambulacrum. The outer or secondary side plate rests upon the adoral-abmedial edge of the subquadrangular primary side plate, and a small subtriangular inner side plate is adjacent to the main food groove, between adjacent primary side plates. There are four cover-plate lobes per side plate along the main food groove and four side-cover-plate lobes along each side food groove. Each primary side plate is approximately 0.25 mm wide by 1 mm long, with one large pore between adjacent side plates. The brachioles are attached to the side plates, with a football-shaped brachiolar facet, one half of which is on the outer side plate and the other half on the handle of the primary side plate. The longitudinal axis of the facet is at an 80 degree angle with the main food groove, thus giving an initial rotation to the attached brachioles. The side plates are alternately arranged on each side, and the brachioles appear to have an alternately imbricate arrangement, with one on the right overlapped by one on the left, and vice versa for the next adoral pair. Along the ambulacral margins are small striated spines, about 1 mm long by 0.1 mm wide, here termed *ambulacral spines*

Explanation of Plate I

Figures 1-7. Placoblastus ehlersi, new species. **Dock Street Shale, Thunder Bay quarry, Alpena, Michigan.**

1, 2, 4, 5, **holotype, University of Michigan, 26,427;** 1, 2, 5, **oral, "D" ambulacral, and aboral views, x1.7.** 4, **enlarged summit view, x4.6.**

3, 7, **paratype, Buffalo Society of Natural Sciences, E 15,339; 3, top view of "C" ambulacrum, x9.5; 7, side view of "C" ambulacrum, x8.4.**

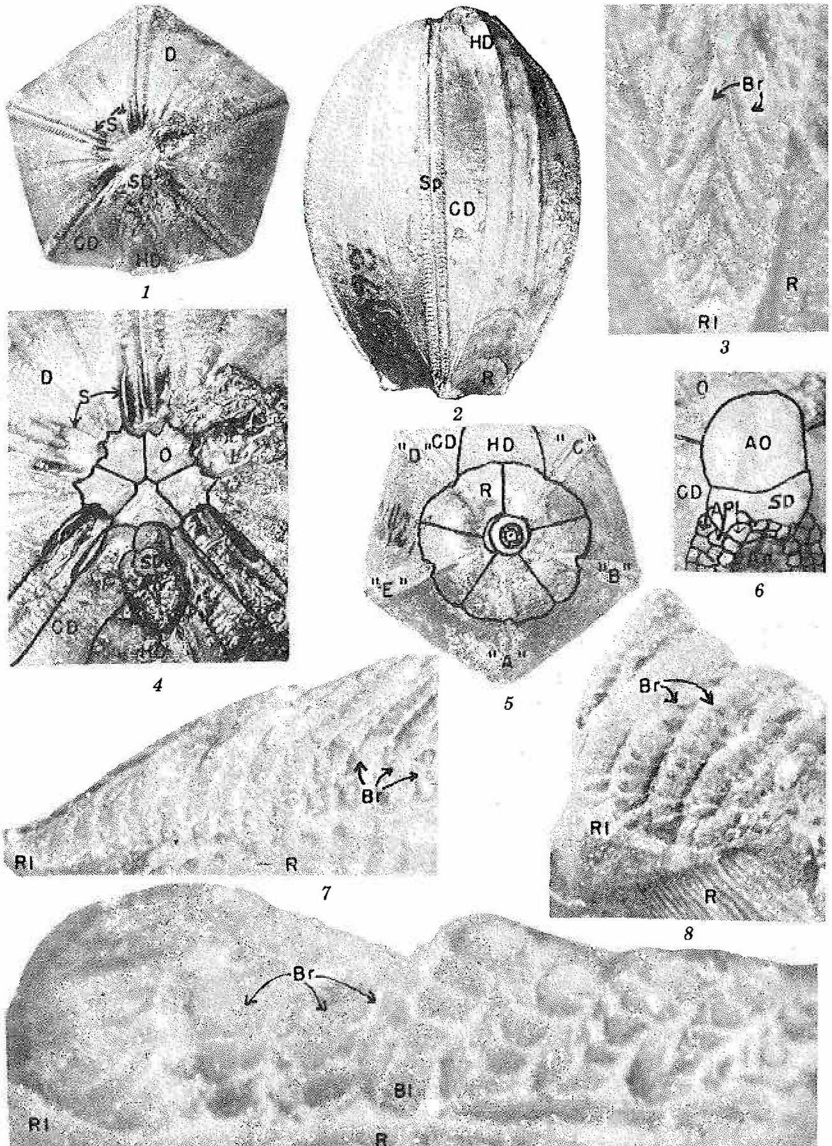
6, paratype, University of Michigan, 44,087; enlarged view, showing anal plates, x17.3.

Figures 8, 9. Eleutherocrinus cassedayi **Shumard and Yandell. Moscow Shale, Kashong Shale Member, near salt shaft, Wadsworth, Livingston County, New York. Plesiotype, Buffalo Society of Natural Sciences, E 15,822.**

8, side view of "D" ambulacrum, x13.7.

9, side view of "E" ambulacrum, x26.8.

Plate I



D
S
SD
CD
HD
1
HD
Sp
CD
R
2
Br
R
Rl
3
D
S
O
SD
CD
4
"D"
CD
HD
"C"
R
"E"
"B"
"A"
5
O
AO
CD
APl
SD
6
Br
Rl
R
7
Br
Rl
R
8
Br
Bl
Rl
R
9

(termed brachiolets by Reimann, 1945), apparently confined to the region around the main food groove, attached to the side plates but not attached to the oral or thecal plates. These spiny structures apparently protected the food groove when the brachioles were extended. The striations appear to be in short pairs, spirally arranged, with a small groove extending longitudinally along one side of a spine. The striations thus appear as small spiral bundles, one above the other, with one bundle on one side paired with a similar one on the other side of the median groove. Each brachiolar pair is subelliptical in cross section, about 0.5 mm long by 0.25 mm wide, extending many millimeters above the theca. In one specimen the preserved part of the brachioles was at least 3 mm high. Each brachiole is composed of a biserially arranged set of alternating plates, termed *brachiolar* plates. Each brachiolar is hemielliptical in cross section (across height), and subquadrangular in side view, approximately 0.5 mm long by 0.125 mm wide. The terms length and width are here used consistently with those of the side plates; that is length is measured at right angles or normal to the main food groove of the theca and width is measured parallel to that groove. The *brachiolar food groove* is adorally placed on the brachiole, facing the main food groove, and thus is not seen on the exterior of specimens with brachioles in natural position where folded together. The brachiolar food groove meets the side food groove between the side plates at the brachiolar pit, and each side food groove meets the main food groove in an alternating series. The entire system was presumably covered by small plates termed *cover plates,* which are rarely preserved in place. The adoral cover plates probably fitted firmly against the large oral plates, thus the food grooves and mouth were probably enclosed. For the living animal the cover plates were probably opened, allowing food to pass down the ciliated food groove.

Remarks.—*P. ehlersi* differs from *P. angularis* and *P. eriensis* in that the shape in top view is pentagonal and the theca is larger, whereas *P. angularis* has slightly concave interambulacra and *P. eriensis* has rounded or convex outward interambulacra. *P. lucina* is small and more nearly spherical, and *P. obovatus* is narrow and elongate, and much larger. The species is named in honor of Dr. George M. Ehlers who collected the holotype and who recently retired from the Geology Department and Museum of Paleontology, University of Michigan.

Types and occurrence.—Holotype, 26,427; paratype, 44,087, University of Michigan Museum of Paleontology; paratype, E 15,339, Buffalo Society of Natural Sciences. Devonian, Dock Street Shale, Thunder Bay quarry, Alpena, Michigan.

Genus *Eleutherocrinus* Shumard and Yandell, 1856

Eleutherocrinus cassedayi Shumard and Yandell, 1856

Plate I, figures 8-9

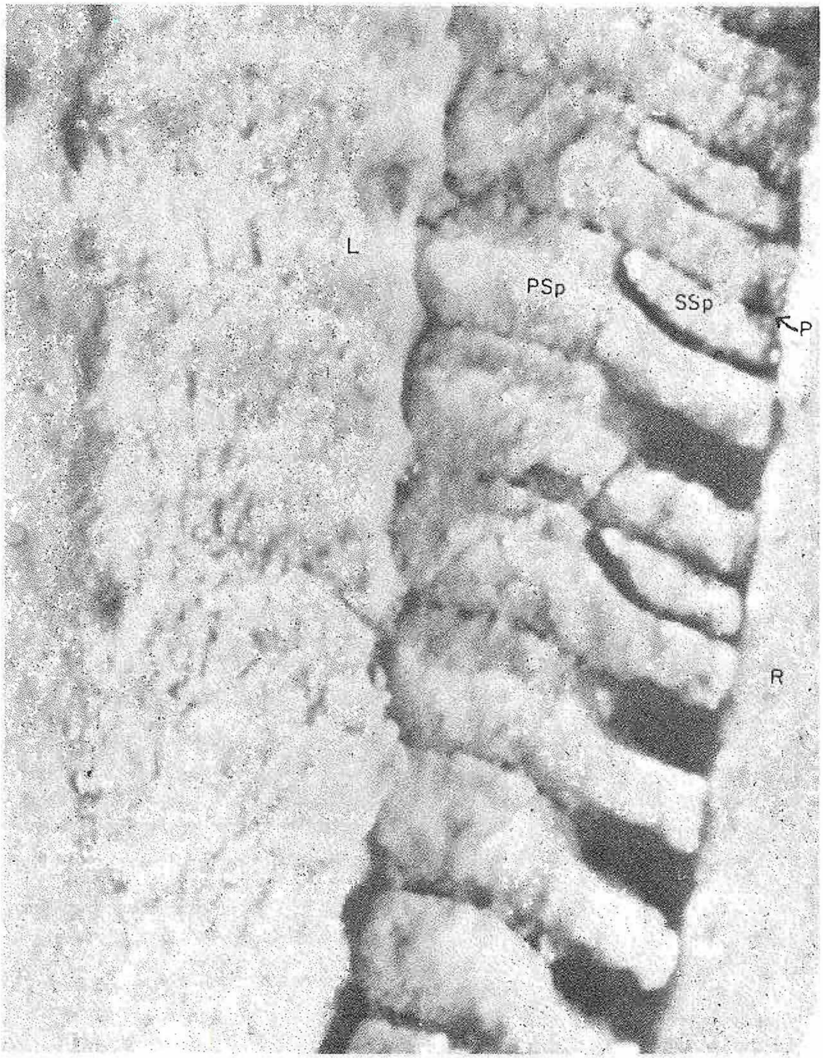
The brachioles of the short "D" ambulacrum are the same as those of the normal ambulacra. The basal brachiolar plates are extremely long and narrow, each 1 mm long by 0.25 mm wide by 0.125 mm high, and are elongate hemielliptical in cross section (across height). Each brachiole appears like a short stubby cone, with the length decreasing to 0.5 mm in 2 mm height of a brachiole. The biserial arrangement of the brachioles can be seen from the side of the calyx because of the slight angle made by the brachiolar facet with the main food groove. The shape of each brachiolar near the tip is subquadrangular whereas those near the base are elongate subquadrangular. The brachiolar plate resting upon the secondary side plate appears slightly larger than the one on the primary side plate, and partially conceals the latter where seen in side view. Each brachiolar is ornamented with a reticulate network of irregularly spaced polygonal ridges, arranged crudely in parallel rows, parallel to the surface of the brachiolar facet. One brachiole 6 mm high shows that the distal brachiolars are shorter and narrower than those adjacent to the side plates, but that most of the taper takes place in the proximal 2 mm adjacent to the side plates.

Type and occurrence.—Plesiotype, E 15,822, Buffalo Society of Natural Sciences. Devonian, Kashong Shale, near salt shaft, Wadsworth, Livingston County, New York.

Genus *Devonoblastus* Reimann, 1935
Devonoblastus leda (Hall), 1862
Plate II, figures 1-6
Devonoblastus whiteavesi? Reimann, 1935
Plate IV, figures 1-3

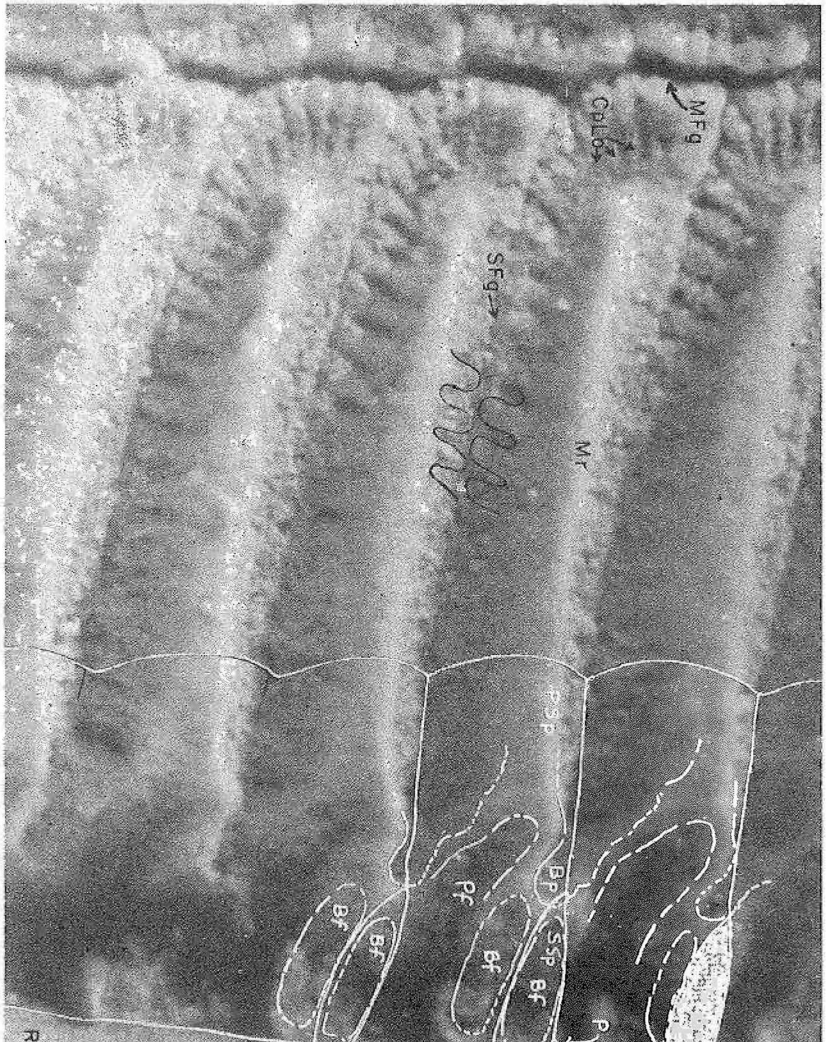
The brachiolar and ambulacral structures of specimens of these species are similar to those of the preceding genera, differing slightly in ornamentation and shape. Of note is the extremely elongate radial lip seen in figure 1 of plate II. Each brachiole is biserially arranged, 40-50 mm high, attached to the side plates so that the brachioles set on the secondary side plate are seen in side view, covering the set on the primary side plate. In top view, the brachioles are alternately arranged in an imbricate pattern so that one on the left is overlapped by one on the right and the next adoral pair is overlapped in reverse manner. Each brachiolar plate is approximately 0.25 mm long by 0.25 mm high, and four times longer than wide, subquadrangular in side view, and hemi-elliptical in cross section (across height). The adoral surface is covered by a double set of alternating cover plates, with approximately four cover plates per brachiolar plate seen in side view. The surface of each brachiolar plate is ornamented with fine striations and reticulations, aligned parallel to the brachiolar food groove. There are about 24 rows per brachiolar plate, and each row is composed of a raised ridge, the middle third of which is composed of irregular polygonal ridges with depressed center, forming a reticulate area in the middle third of each brachiolar plate (pl. II, fig. 3). The brachiolar plates adjacent to the side plates are longer and narrower than those farther away, giving a tapering effect to the brachioles from near the point of attachment. The region adjacent to the thecal main food groove, between the food groove proper and the admedial walls of the brachioles (medial referring to the line of the main food groove), is covered with small striated ambulacral spines, apparently arranged in rows and clusters upon the admedial portions of the side plates, on the cover-plate lobes. Each spine is approximately 1 mm long by 0.1 mm in diameter, and many evidently extended over the oral area, adjacent to the mouth (l. II, fig. 5). It is evide t that if these spines are associated with the cover-plate lobes, the spi es may be expected to be found on lancet stipes an deltoid lips if cover-plate lobes extend to these plates.

Types and occurrence.—D. leda, plesiotypes, E 12,859 E 14,132, Buffalo Society Natural Sciences; 44,088, U ive sity of Mic igan Mu-



Text-figure 1. Pentremites rusticus **Hambac . Plesiotype, Univers ty of Kansas, 7,385. Enlarged view of one side of the "D" ambulacrum, s owing the side plates and outer side plates in place, x44.7. Brentw od Limestone, C sec. 10, T. 13 N., R. 20 E., Greenleaf Lake, southwest of Braggs, Oklaho a.**

seum of Paleontology. Middle Devonian, Moscow Shale, Kashong Shale Member from Darien (E 12,859), Bowen Brook (E 14,132), salt shaft, Wadsworth ([illegible]4,088), New York. *D. whiteavesi*, plesiotype, E 15,[illegible]57, Buffalo Society Natural Sciences. Wanakah Shale, *Pleurodictym* beds, Bay View, New York.



Text-figure 2. Pentremites godoni (Defrance). Plesiotype, The University of Oklahoma, 4,350. Enlarged view of "D" ambulacrum, showing cover-plate lobes and brachiolar sockets, x74.7. Paint Creek Formation, 1.25 miles west of Floraville, Illinois.

Genus *Pentremites* Say, 1820

Pentremites rusticus Hambach, 1903

Text-figure 1

Pentremites godoni (Defrance), 1819

Text-figure 2

Pentremites conoideus? (Hall), 1858

Plate III, figures 8-9

Photographs showing details of side plates and cover-plate lobes have never been published and therefore the large pictures of these structures are here given. In *Pentremites* the lancet plate is exposed to the outside, whereas in the previous mentioned genera, the lancets are covered by side plates. This means that the cover-plate lobes along the main food groove are excavated in the lancet plate in *Pentremites,* but are present in the admedial margins of the primary side plates in *Placoblastus, Eleutherocrinus,* and *Devonoblastus.* In *Pentremites* the side plates are some distance from the main food groove, thus showing that these structures are not necessarily associated with cover plates along the main food groove. A close inspection of these plates (text-fig. 1) reveals that each primary side plate is basically elongate subquadrangular with a curved or convex outward admedial side adjacent to the lancet plate and a straight abmedial side adjacent to the deltoid and radial plates. The adoral and aboral sides are curved in a gentle S-shaped pattern. The abmedial half of each primary side plate may be subdivided into two parts: the aboral part, termed *side-plate handle* because it resembles a handle of a pan, and the adoral part which is bevelled like one-eighth of a sphere to receive the secondary or outer side plate. Thus each primary side plate has an associated secondary side plate on the bevelled adoral-abmedial corner. The pore is a small opening along the ambulacral margin between a secondary side plate and the next adorally disposed side-plate handle. It is common for outer side plates to be missing and it is here suspected that they may have functioned as semiflexible supports for one-half of a brachiole, thus

---

Explanation of Plate II

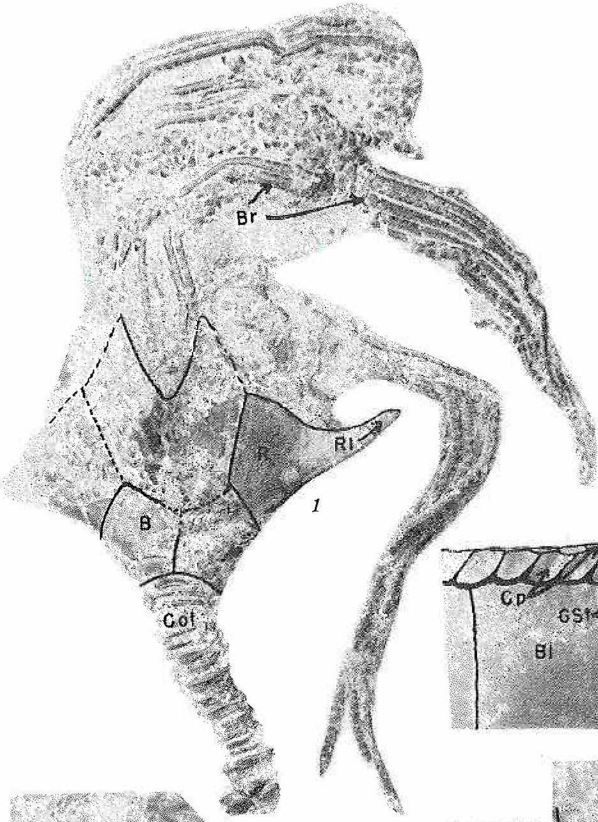
Figures 1-6. Devonoblastus leda **(Hall). Moscow Shale, Kashong Shale Member, New York.**

1, 2, plesiotype, Buffalo Society of Natural Sciences, E 12,859, Darien, New York; 1, "D" ambulacral view, showing form of calyx with brachioles attached and large radial lip, x3.4; 2, enlarged portion of brachioles of "D" ambulacrum, showing biserial nature of brachioles, x6.9.

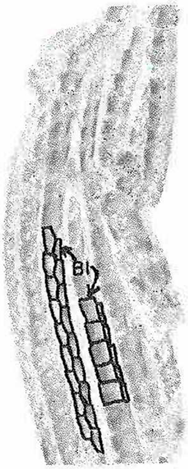
3, plesiotype, Buffalo Society of Natural Sciences, E 14,132, Bowen Brook, New York; enlarged side view of brachiole, showing cover plates along "E" food groove and granulostriated brachiolar plates, x35.2.

4-6, plesiotype, University of Michigan, 44,088, near salt shaft, Wadsworth, Livingston County, New York; 4, "D" ambulacrum, showing brachioles in place, x9.2; 5, oral view with anal side toward bottom of page, showing ambulacral spines on summit, x9.9; 6, "A" ambulacrum with ambulacral spines in groups or clusters, x17.6.

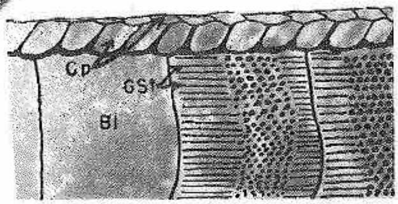
Plate II



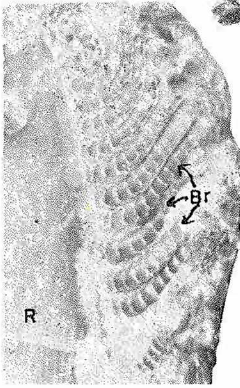
1



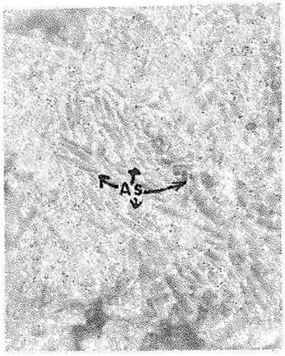
2



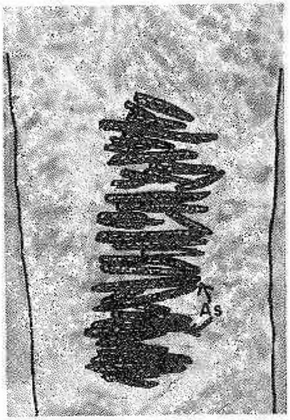
3



4



5



6

allowing the brachiole to have some degree of freedom in movement at the base.

The general relationships of ambulacral structures on the lancet and side plates are shown in text-figure 2. The main food groove is a deep narrow slot along the median line of the lancet plate, about 0.1 mm wide, in alternate curves parallel with the biserially arranged alternating side plates. On either side of the main food groove is a depressed area, totally 0.5 mm wide, with small lobes about 0.25 mm long at right angles to the groove. These *cover-plate lobes* are rounded admedially (medial referring to the line of the main food groove), and merge abmedially into a high ridge, termed *median ridge*. Each median ridge is approximately 1.25 mm long, bifurcating abmedially on each primary side plate, meeting the extension of the bifurcation of the next one to form a small pit, termed *brachiolar pit,* along the midline of adjacent primary side plates. The *side food grooves* extend admedially from the brachiolar pit between the median ridges, and are bordered by cover-plate lobes. There are approximately 6 cover-plate lobes per side plate along the main food groove and 17 cover-plate lobes along each side of each side food groove. The lobes are alternately arranged on either side of the side food groove so that a cover-plate socket on one side corresponds with a cover-plate lobe on the opposite side. The *brachiolar facet,* or place of attachment for a brachiole, is approximately 0.5 mm long and composed of two parts, each part generally elliptical. The facet is abmedial to the brachiolar pit, with one portion on the primary side-plate handle and the

---

Explanation of Plate III

Figures 1, 3-5. Orophocrinus conicus **Wachsmuth and Springer. Kinderhookian beds, Le Grand, Iowa. Plesiotype, University of Chicago, 13,595.**

1, **"E" ambulacral view, x4.0.**

3, **side view of "D" ambulacrum, x13.8.**

4, **"A" ambulacrum, top view, x13.8.**

5, **anal area, x16.1.**

Figures 2, 6. Orophocrinus fusiformis **(Wachsmuth and Springer). Kinderhookian beds, Le Grand, Iowa.**

2, **plesiotype, University of Chicago, 13,594; cross section of a brachiole, x55.**

6, **plesiotype, University of Illinois, 403; side view, showing form of calyx where brachioles are attached to the theca, x2.4.**

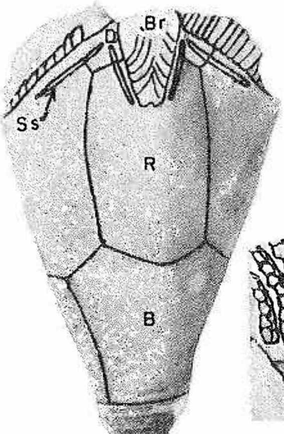
Figure 7. Pleuroschisma lycorias **(Hall). Kashong Shale, near salt shaft, Wadsworth, Livingston County, New York. Buffalo Society of Natural Sciences, E 15,987. "A-E" interambulacral view, x7.7.**

Figures 8, 9. Pentremites conoideus? **Hall. Pella Formation, quarry one mile north of Oskaloosa, Iowa. Plesiotype, The University of Oklahoma, 4,348.**

8, **oral view with "A" ambulacrum toward bottom of page, x16.8.**

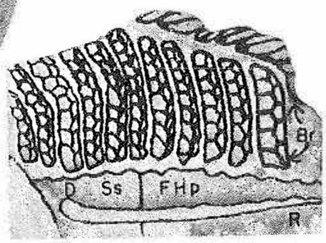
9, **anal view of oral pyramid, x16.8.**

Plate III

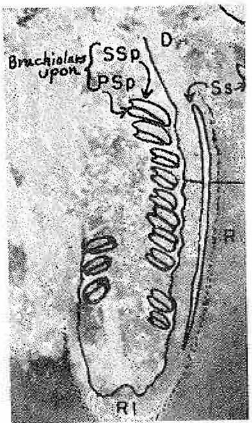


1

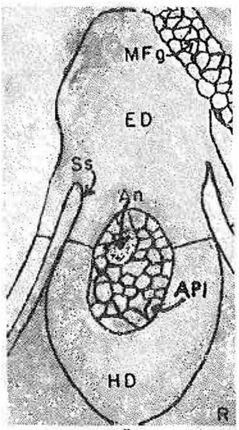
2



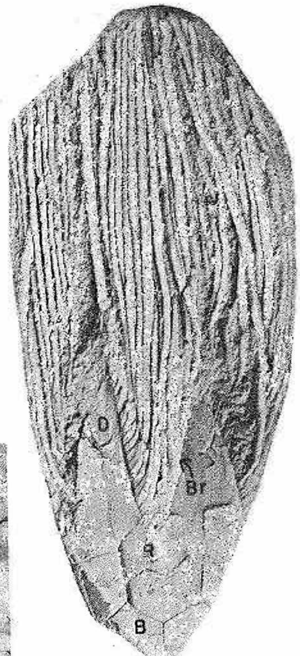
3



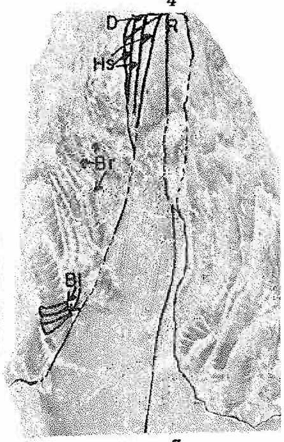
4



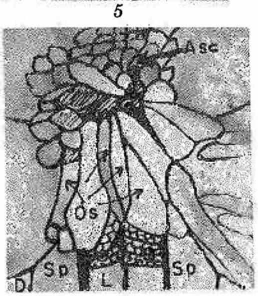
5



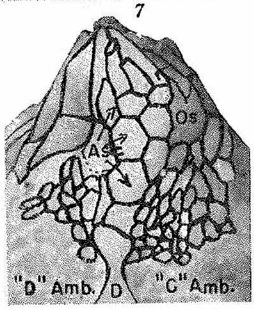
6



7



8



9

other on the secondary side plate. A large depression occurs on each primary side-plate handle, between the brachiolar facets, extending admedially between the bifurcating ridges of each median ridge. These depressions are termed *pore furrows* because they lead to the pores between the side plates. The primary side plate is approximately 1 mm long by 0.5 mm wide and the brachiolar facet is approximately 0.5 mm long by 0.25 mm wide.

The brachiolar plates are similar to those of *Devonoblastus,* being subquadrangular in side view and hemielliptical in cross section (across height), with fine striations parallel to the brachiolar food groove, alternately arranged in a biserial fashion. The summit of some specimens has a pyramidal set of conical structures covering the spiracles, anispiracle, and mouth (pl. III, figs. 8-9), collectively termed *oral pyramid.* In the one specimen examined, the theca is 5.5 mm long and the pyramid is 1.5 mm above the theca. The spiracles and mouth are tightly covered by a series of small polygonal plates and the anal opening is covered by a ventral sac of large polygonal plates, arranged in several rows. The long conical cover plates appear to be basally attached to the small polygonal cover plates, with about three conical plates per spiracle. On the anal side, there are approximately four short conical cover plates at the distal end of the ventral sac. The elongate cones appear to be well beyond the side plates, and appear to be attached in part to the lancet stipes, on either side of the main food grooves. Each cone is crystallographically one piece and is not biserially arranged like a brachiole. It is possible that some of the polygonal plates on one side near the base may be in contact with the side plates adjacent to the spiracles, but it is unlikely that the long conical plates are modified brachioles. Some of

---

Explanation of Plate IV

Figures 1-3. Devonoblastus whiteavesi? **Reimann. Wanakah Shale, Pleurodictyum beds, Bay View, New York. Plesiotype, Buffalo Society of Natural Sciences, E 15,757.**

1, **aboral tip of "D" ambulacrum, x15.3.**

2, **"D" ambulacral view of entire calyx, x6.9.**

3, **oblique view of "C" ambulacrum, x11.5.**

Figure 4. Hyperoblastus decipiens **(Reimann). Arkona Shale, creek bank 0.25 miles north of brick and tile yard, north of Thedford, Ontario. Plesiotype, University of Michigan, 26,495. Side view of "E" ambulacrum, x14.5.**

Figures 5, 8. Hyperoblastus nuciformis **(Kier). Coral zone of Widder beds, Hungry Hollow Formation, Arkona, Ontario. Holotype, Buffalo Society of Natural Sciences, 13,066.**

5, **brachioles of "D" ambulacrum, x22.9.**

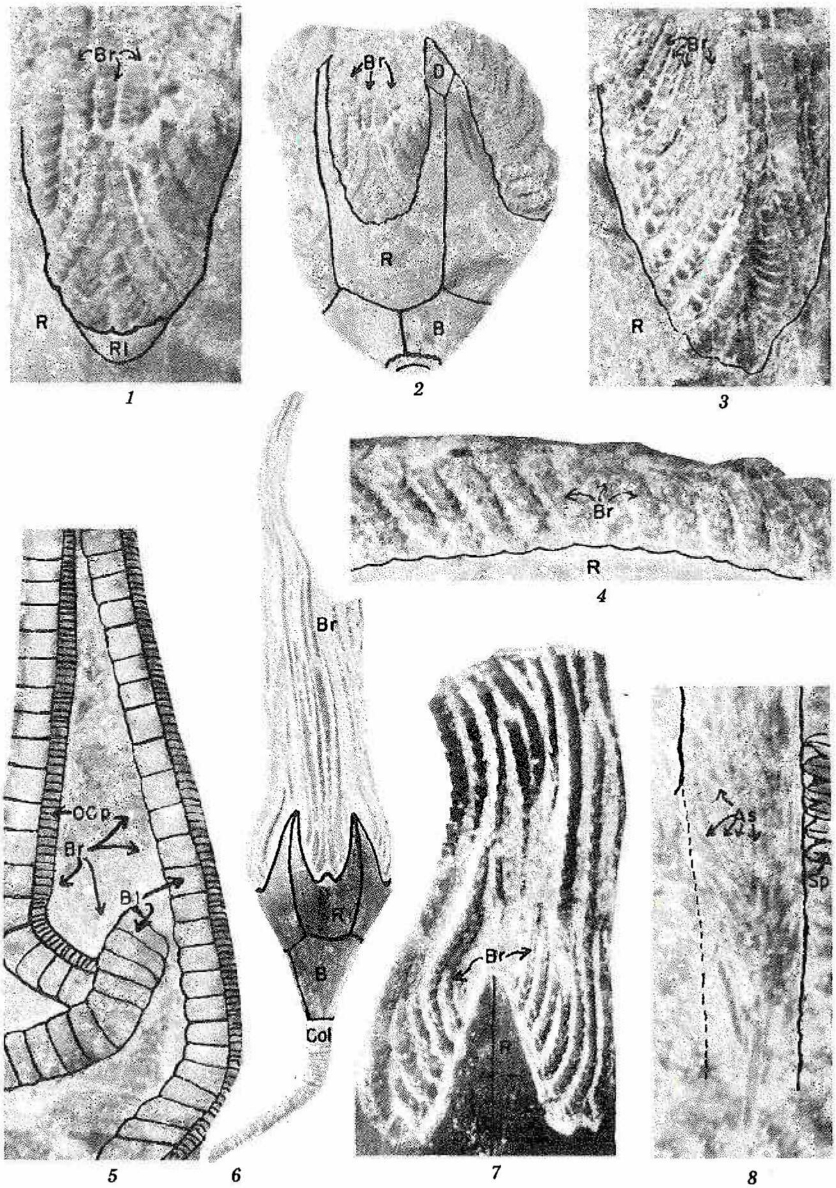
8, **ambulacral spines of "D" ambulacrum, x15.3.**

Figures 6, 7. Hyperoblastus reimanni **(Kier). Unit 13, Silica Shale, Medusa Portland Cement Company quarry, Silica, Lucas County, Ohio.**

6, **plesiotype, University of Michigan, 44,086; side view, showing form of calyx with brachioles attached to theca, x4.4.**

7, **paratype, University of Michigan, 27,681; enlarged view of "A-E" interambulacrum, x8.4.**

Plate IV



the elongate cones appear to originate adoral of the spiracles, in a position beyond the side plates, in line with the main food groove, suggesting that an inner set of five or more large conical oral plates must have covered the mouth, separating the mouth from the spiracles and anispiracle. In summary, the oral pyramid appears to be composed of two portions: an adoral portion of conical plates covering the mouth, and an aboral portion of polygonal plates over the spiracles and anispiracle above which conical cover plates are attached. The sutures between plates were probably flexible, allowing excreta to be removed without contaminating the food supply. It is quite possible that some of the ambulacral spines of *Devonoblastus* may have become modified and enlarged on the summit to form the oral pyramid of *Pentremites.*

Types and occurrence.—*Pentremites conoideus,* plesiotypes, 4,348 (one specimen), 4,349 (thirty specimens), The University of Oklahoma; Pella Formation (Meramecian), from quarry 1 mile north of Oskaloosa, Iowa. *Pentremites godoni,* plesiotype, 4,350 (one specimen), The University of Oklahoma; Paint Creek Formation (Chesterian), 1.25 miles west of Floraville, Illinois, north of Vogel School. *Pentremites rusticus,* plesiotype, 7,385, University of Kansas; Brentwood Limestone (Pennsylvanian), from center sec. 10, T. 13 N., R. 20 E., Greenleaf Lake, southwest of Braggs, Oklahoma.

Order FISSICULATA Jaekel, 1918

Genus *Orophocrinus* Von Seebach, 1864

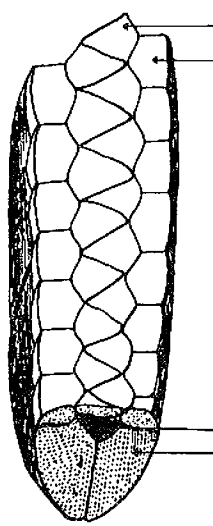
Orophocrinus conicus Wachsmuth and Springer, 1890
Plate III, figures 1, 3-5
Orophocrinus fusiformis (Wachsmuth and Springer), 1889
Plate III, figures 2, 6

Orophocrinus conicus and *O. fusiformis* differ mainly in that the ambulacra of *O. conicus* project outward and slightly downward from the mouth, and in *O. fusiformis* the ambulacra project downward. This means that the summit of the former is flatter and the ambulacra less visible from the side. The description is that of one specimen of *O. conicus* (pl. III, figs. 1, 3-5).

Theca calcitic, 13.5 mm long by 8.5 mm wide, strongly pentagonal in top view with depressed interambulacra, steeply conical in side view, with vault 2 mm long and pelvis 11.5 mm long. Stem round, 2 mm in diameter, crenellar, with about 45 crenellae extending one-third the radial distance from the margin toward the small (0.5 mm wide) round lumen. Each columnal has a rimmed border that projects outward from the stem proper, about 0.25 mm wide, giving a corrugated appearance to the stem in side view. Basalia conical, rounded pentagonal in basal view, 6 mm long by 6 mm wide, composed of 3 basals, normally disposed, with the small pentagonal azygous basal in the "A-B" position. The base is flattened abruptly to receive the stem. Radials five, each 7 mm long by 4 mm wide, elongate hexagonal, with short, wide, shallow radial sinus 3 mm long by 2 mm wide, flaring outward so that the radial body is 5 mm long, and the shape of the theca in top view is star-shaped. The radial limbs extend well upon the summit, overlapping the deltoids.

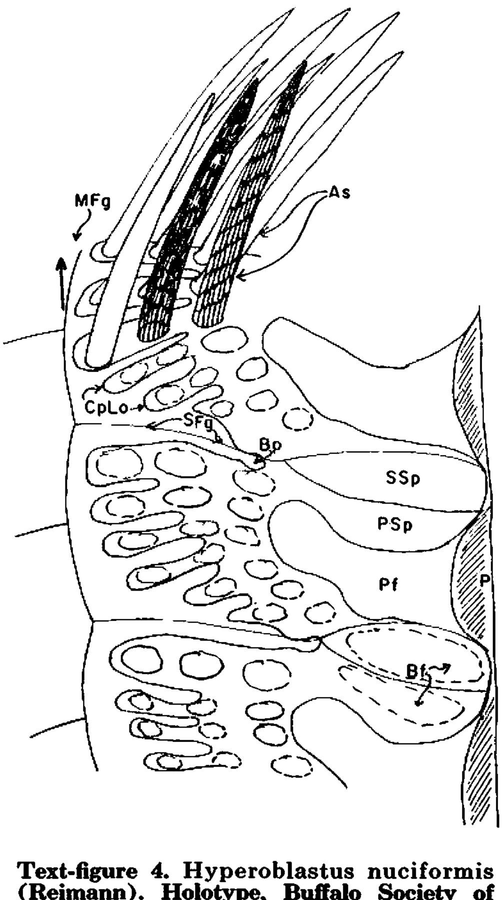
Deltoids four, each small, lancet-shaped, 2.5 mm long by 2 mm wide, with one large *spiracular slit* excavated along the ambulacral margins, well away from the ambulacra, extending to the adjacent radial limbs. The admedial portions of each deltoid and adjacent radial limbs are infolded to form hydrospires, and the last admedially folded portion is greatly thickened beneath the lancet plate aborally, and beneath the margins of the lancet plate adorally to form a *fused hydrospire plate,* formerly termed sublancet plate. Thus the hydrospires open externally into a common canal or spiracular slit, one on each side of an ambulacrum, separated from the ambulacra by a thick fused hydrospire plate. On the anal side, two large anal deltoids are present, the bluntly arrow-shaped seven-sided *epideltoid* adjacent to the mouth, and the V-shaped *hypodeltoid* on the aboral side of the anal opening, abutting against the adjacent radial limbs. The spiracular slits are excavated in the epideltoid limbs and adjacent radial limbs, with one slit on each side of the anal opening. Collectively the anal deltoids are 3.5 mm long by 2 mm wide. The anal opening is elliptical and is covered by many small polygonal *anal plates,* probably each with flexible sutures. The oral opening is surrounded by the wide deltoid lips and the lancet stipes are approximately 1.5 mm away from the mouth. The surfaces of the thecal plates are ornamented with widely spaced growth lines, subparallel to plate margins.

Ambulacra five, each subpetaloid, 4.5 mm long by 1.5 mm wide, with lancet exposed along area of main food groove, and 40 side plates in 10 mm length of an ambulacrum. Each side plate is approximately 0.5 mm long by 0.25 mm wide, with a biserial brachiole on each, oriented so that the brachiolar above the secondary side plate almost conceals the brachiolar above the primary side-plate handle, at a 65 degree angle with the main food groove, measured aborally from the side food groove and origin at intersection of side food groove with main food groove. Each



Text-figure 3. Hyperoblastus nuciformis (Reimann). Holotype, Buffalo Society of Natural Sciences, E 13,066. Diagram of a brachiolar fragment of "D" ambulacral brachiole, showing adoral surface, x35. Coral zone, Widder beds, Hungry Hollow Formation, near Thedford, Ontario.

brachiolar is approximately 0.3 mm long by 0.1 mm wide, hemielliptical in cross section (across height), subquadrangular in side view, averaging about 0.2 mm high. The surfaces of the brachiolar plates are ornamented with microstriations parallel to the brachiolar food groove, with many cross ridges at right angles, giving a striatoreticulate appearance to the surface. The brachiolars are arranged in a biserial fashion, alternately placed, with a deep brachiolar food groove on the adoral surface. Some brachioles are at least 28 mm long. The oral opening appears to be covered by 10 or more small polygonal plates with bluntly conical tops, apparently arranged in pairs at the adoral end of each ambulacrum, with possibly one interambulacral oral plate disposed between adjacent pairs. The main food groove is vaulted over by a series of similar



Text-figure 4. Hyperoblastus nuciformis (Reimann). Holotype, Buffalo Society of Natural Sciences, E 13,066. Composite diagram of side plates, showing probable position of ambulacral spines, x75. Coral zone, Widder beds, Hungry Hollow Formation, near Thedford, Ontario.

plates, each appearing as a bluntly rounded cone, apparently arranged in a double biserial set of alternating plates, as shown on plate III, figure 5. These cover plates appear to extend in the same manner onto the side food grooves. The nature of the cover plates on the brachioles could not be determined and only a generalized drawing is given on plate III, figure 2. It is possible that the brachiolar food groove was also covered by a double set of biserially arranged alternating plates.

Types and occurrence.—The illustrated fossils are listed as occurring in the Kinderhookian limestone (Mississippian), Le Grand, Iowa. Topotypes, *O. fusiformis* 13,594 (two specimens, one of which is a thin section of brachioles), *O. conicus* 13,595 (seven specimens, one of which is illustrated and used for above description), Gurley Collection, University of Chicago; *O. fusiformis* 403, University of Illinois.

Genus *Pleuroschisma* Reimann, 1945
Pleuroschisma lycorias (Hall), 1862
Plate III, figure 7

The illustrated specimen of *Pleuroschisma lycorias* is fragmentary and crushed, about 10 mm long by 8 mm wide, with brachioles in place. The proximal parts of the brachioles are similar to those of *Eleutherocrinus,* appearing as short stubby cones for the first 2-3 mm portions adjacent to the ambulacra, tapering to about one-half their length in that interval. The brachiolars are alternately arranged in a biserial series, each approximately 0.5 mm long by 0.125 mm wide by 0.125 mm high, elongate subquadrangular in side view, becoming almost square distally, and hemielliptical in cross section (across height). The surfaces of the brachiolars are ornamented with fine microstriations parallel to the brachiolar food groove, with small ridges at right angles, forming a reticulate network of ridges. The brachiolars adjacent to the ambulacra have a strong median ridge (two ridges in some) at right angles to the brachiolar food groove, and the microstriations are interrupted at the junction with the ridges, perhaps indicating that growth took place in slightly different directions as the plate grew distally.

Type and occurrence.—Plesiotype, E 15,987, Buffalo Society of Natural Sciences. Devonian, Kashong Shale, near salt shaft, Wadsworth, Livingston County, New York.

Genus *Hyperoblastus* Fay, 1961
Hyperoblastus decipiens (Reimann), 1945
Plate IV, figure 4
Hyperoblastus nuciformis (Reimann), 1945
Plate IV, figures 5, 8; text-figures 3, 4
Hyperoblastus reimanni (Kier), 1952
Plate IV, figures 6, 7

The brachiolar and ambulacral structures of *Hyperoblastus decipiens, H. nuciformis,* and *H. reimanni* are similar, differing in size and proportions, but basically arranged the same. Of importance is the fact that in *H. nuciformis* a fragment of a brachiole is preserved showing the adoral surface; and the ambulacral spines are clearly shown in small bundles and rows, in place along the food grooves. The brachioles are biserially similar to those of previously described genera, with each brachiolar near the ambulacra about 0.5 mm wide by 0.1 mm long by 0.1 mm high, hemielliptical in cross section, elongate subquadrangular in side view, becoming almost square distally because of distal taper in the basal 2 mm. The surface of each brachiolar is ornamented with fine microstriations parallel to the brachiolar food groove, with many small granular ridges in the middle portion, giving a reticulate appearance to the surface. The adoral surface is covered with a double series of alternating cover plates. The outer pentagonal ones, termed *outer cover plates,* are aligned along the adoral edges of the brachiolars, with about four outer cover plates per brachiolar plate. These outer cover plates are alternately arranged with respect to opposite sides so that one on the left side would fit between a pair on the right side (text-fig. 3). The brachiolar food groove is between these outer cover plates, and is covered by another series of biserial plates, alternately arranged, termed *inner cover plates.* Each inner cover plate is diamond- or kite-shaped, with the small V-shaped end *between* adjacent outer cover plates and the elongate V-shaped end *pointing to and meeting* the middle part of an opposite outer cover plate. This appears to be the same arrangement as that of the cover plates along the main food groove in *Orophocrinus conicus,* and may well be the common type of cover plate arrangement in blastoids.

Another structure observed in *H. nuciformis* is the ambulacral spine. In some specimens there are small pits or holes upon the surfaces of the side plates, extending to the cover-plate lobes, admedial to the brachiolar facet, on either side of the main food groove. In the above specimen, many small ambulacral spines may be observed on the "D" ambulacrum. Each spine is crystallographically a unit, about 1 mm long by 0.05 mm in diameter or larger, arranged in definite rows at right angles to the main food groove and generally aligned parallel to the main food groove in vertical rows. These appear to be basally attached to the region around the cover-plate lobes and therefore would be classed as ambulacral structures. The small pits on the lobes are probably the places of attachment for the spines. The pits appear to be aligned in vertical and horizontal rows, suggesting that the spines were evenly spaced over the region of the food groove, protecting the groove (text-fig. 4). The surface of each spine is ornamented with small striations that appear to be arranged in a spiral fashion on each half of the spine. One side of the spine has a small notch or groove extending longitudinally from the base to the top, and the small striations appear to be arranged in pairs along either side of the groove, one pair above the other. The next set of striations out from those adjacent to the groove appear to be staggered a little lower, and the next set slightly lower, giving the appearance of a left and right spiral set of striations, one set above the other.

These spines are scattered over the summit, adoral to the spiracles, showing that they are not necessarily restricted to the side plates, but are true ambulacral structures, associated with cover-plate lobes. The cover plates extend to the mouth and may be excavated in the lancet stipes and deltoid lips—thus one may expect to find ambulacral spines covering most of the summit upon these plates.

Types and occurrence.—Hyperoblastus decipiens, holotype, E 16,194, Buffalo Society Natural Sciences, from coral zone of Widder beds, Hungry Hollow Formation, Arkona, Ontario; plesiotype, 26,495, University of Michigan Museum of Paleontology, from Arkona Shale, creek bank 0.25 mile north of tile yard and 0.75 mile north of Thedford, Ontario. *Hyperoblastus nuciformis,* holotype, E 13,066, Buffalo Society Natural Sciences, from coral zone of Widder beds, near Arkona, Ontario. *Hyperoblastus reimanni,* 3 paratypes, 27,679-27,681, University of Michigan Museum of Paleontology and 1 plesiotype, 44,086, from unit 13, Middle Devonian Silica Shale, Medusa Portland Cement Co. quarry, Silica, Lucas County, Ohio.

SUMMARY

Ambulacral spines and brachioles appear to be arranged similarly in blastoids belonging to the orders SPIRACULATA and FISSICULATA. The spines appear to be associated with the main food groove, serving for protection. The brachioles are biserial, each composed of a set of alternating brachiolar plates, with a double row of alternating biserially arranged cover plates covering the brachiolar food groove. The main and side food grooves may have been similarly covered.

References Cited

Defrance, M. J. L., 1819, Encrines: Dictionnaire Sciences Naturelles, vol. 14, EA-EOU, p. 467.

Fay, R. O., 1961, Blastoid studies: Kansas., Univ., Paleontological Contributions, Echinodermata, Art. 3, 147 p., 54 pls., 221 figs.

Hall, James, 1858, Palaeontology of Iowa: Iowa Geol. Survey, Rept., vol. 1, pt. 2, Palaeontology, p. 473-724, 29 pls., text-figs. 53-118.

———— 1862, Contributions to palaeontology; comprising descriptions of new species of fossils from the Upper Helderberg, Hamilton and Chemung Groups: N. Y. State Cabinet, Ann. Rept. 15, p. 115-153, 11 pls., 2 text-figs.

Hambach, Gustav, 1903, Revision of the Blastoidea, with a proposed new classification, and description of new species: St. Louis Acad. Science, Trans., vol. 13, no. 1, 67 p., 6 pls., 15 text-figs.

Jaekel, O. M. J., 1918, Phylogenie und System der Pelmatozoen: Paläontologische Zeitschrift, vol. 3, no. 1, 128 p., 114 figs.

Kier, P. M., 1952, Echinoderms of the Middle Devonian Silica Formation of Ohio: Mich., Univ., Museum Paleontology, Contr., vol. 10, no. 4, p. 59-81, 4 pls.

Reimann, I. G., 1935, New species and some new occurrences of Middle Devonian blastoids: Buffalo Soc. Nat. Sciences, Bull., vol. 17, no. 1, p. 23-45, 4 pls.

———— 1945, New Devonian blastoids: Buffalo Soc. Nat. Sciences, Bull., vol. 19, no. 2, p. 22-42, pls. 5-9.

Say, Thomas, 1820, Observations on some species of zoöphytes and shells principally fossil: Amer. Jour. Science, vol. 2, p. 34-45.

Seebach, Karl von, 1864, Ueber **Orophocrinus,** ein neues Crinoideen-geschlecht aus der Abtheilung der Blastoideen: Koenigliche Gesellschaft Wissenschaft Georg-Augusts-Univ., Nachrichten for 1864, no. 5, p. 110-111.

Shumard, B. F., and **Yandell, L. P.,** 1856, Notice of a new fossil genus belonging to the family Blastoidea, from the Devonian strata near Louisville, Kentucky: Phila., Acad. Nat. Sciences, Proc., vol. 8, p. 73-75, pl. 2.

Wachsmuth, Charles, and **Springer, Frank,** 1889, in North American Geology and Palaeontology by Samuel Almond Miller: Cincinnati, Ohio, Textbook, p. 233, fig. 269.

———— 1890, New species of crinoids and blastoids from the Kinderhook Group of the Lower Carboniferous rocks at Le Grand, Iowa: Ill. Geol. Survey, vol. 8, p. 155-205, pls. 14-17.

The Paradeltoid Plates of *Polydeltoideus*

Robert O. Fay and Irving G. Reimann

In a previous paper on *Polydeltoideus,* a Silurian blastoid from Oklahoma (Reimann and Fay, 1961), none of the illustrated specimens had a complete set of anal deltoid plates. One specimen in the U. S. National Museum has a complete set and is here illustrated.

Polydeltoideus enodatus Reimann and Fay, 1961
Plate 1, figures 1-3

The specimen is 21 mm long by 10.5 mm wide, with vault 2 mm long and pelvis 19 mm long, with an average pelvic angle of 35 degrees. Basals 3, each 12 mm long, forming a steeply conical basalia. Radials 5, narrow pentagonal, each 10 mm long by 4.5 mm wide, with wide short radial sinus, 3.5 mm wide by 3 mm long, confined to summit. Angle formed along radiodeltoid suture, with center at intersection with interradial suture, 105 degrees. Radials overlap deltoids.

Deltoids 4, each broadly diamond-shaped, 3.5 mm wide by 3 mm long, confined to summit, with deltoid lips adjacent to mouth. Hydrospire slits in 10 fields, one on each side of an ambulacrum, with 7 to 8 or more slits in each field, except on the anal side where they are reduced in number. The slits extend to the adjacent radial plates. On the anal side there are six anal deltoid plates. The broad arrow-shaped superdeltoid is adjacent to the oral opening. The two long cryptodeltoids rest upon the aboral face of the superdeltoid, each receiving the hydrospire slits, and each supporting the adjacent parts of the lancet plates. The anal opening is bordered adorally by the superdeltoid and laterally by the adoral parts of the cryptodeltoids. The short wide hypodeltoid rests aborally upon the adjacent radial limbs and laterally upon the cryptodeltoids, with bevelled adoral facets upon which rest the paradeltoid plates. The two paradeltoids also rest upon the cryptodeltoids laterally, and border the aboral edge of the anal opening. Each paradeltoid is irregularly triangular, with small facets on the anal side, which suggests that other smaller anal plates were probably present that covered the anal opening.

The lancet is covered by the side plates, as shown in the (B) ambulacrum. Other features have been discussed in the previous paper and descriptions are not here repeated.

Explanation of Plate I

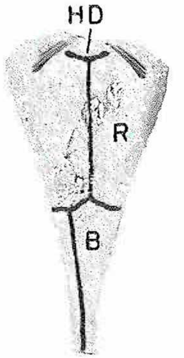
Polydeltoideus enodatus **Reimann and Fay, 1961. Metatype, 139,567, U. S. National Museum. Silurian, Henryhouse Shale, N½ SW¼ sec. 4, T. 2 N., R. 6 E., Pontotoc County, Oklahoma.**

Figure 1. Anal (C-D) view, x2.1.

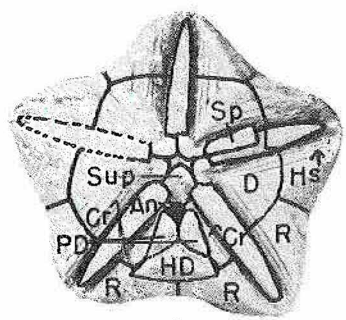
Figure 2. Oral view, x4.2.

Figure 3. Detailed anal view from above, x15.5.

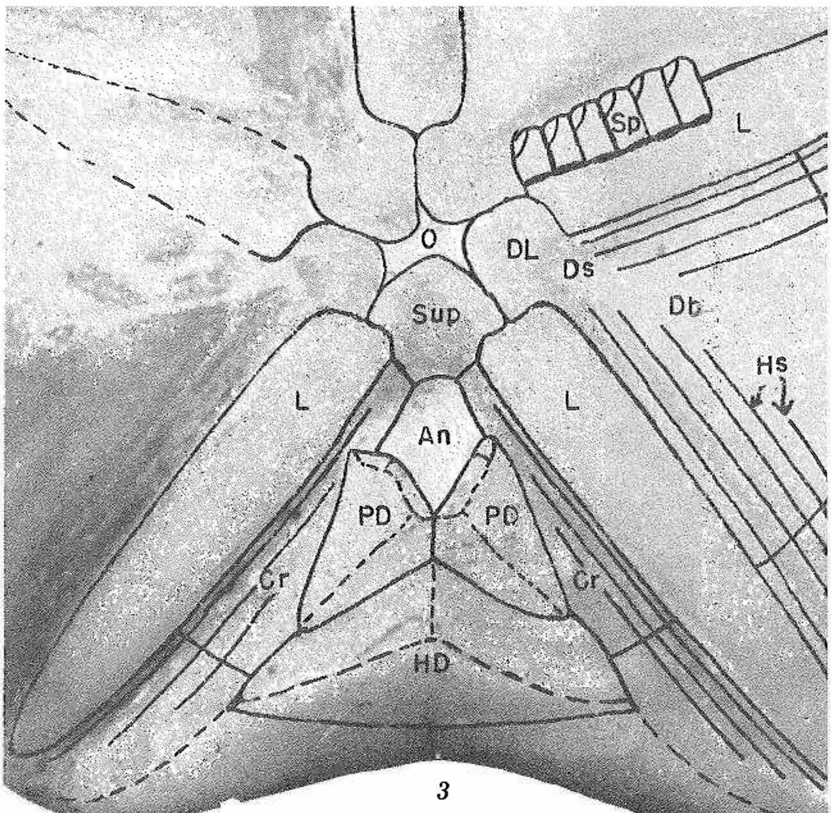
Plate I


HD
R
B

1


Sp
Sup
D
Hs
Cr
An
PD
Cr
R
HD
R
R

2


Sp
L
O
DL
Ds
Db
Sup
Hs
L
L
An
PD
PD
Cr
Cr
HD

3

Remarks.—Until quite recently, little has been known about the structure of the plates on the anal side. The suggestion is here made that a form like *Polydeltoideus* is primitive and that other types may be derived from this type due to fusion of anal deltoid plates. For instance, the two cryptodeltoids may fuse medially to form a subdeltoid plate. A subdeltoid plate may fuse with a superdeltoid to form an epideltoid plate. An epideltoid plate may fuse with a hypodeltoid to form one anal deltoid plate. The position of the paradeltoids upon the cryptodeltoids, on the aboral side of the anal opening, suggests that they probably fused with the hypodeltoid and became part of that plate. It is unlikely that they formed part of the cryptodeltoids because the latter have hydrospire slits and paradeltoids lack slits. Thus it can be understood that Permian fissiculate blastoids with one or two anal deltoid plates are actually highly advanced forms.

Types and occurrence.—Five metatypes, all from the upper coral beds of the Henryhouse Shale, Pontotoc County, Oklahoma, are on deposit in the U. S. National Museum. These are: 139,566 (one specimen), east side of road in bluff, NW¼ SW¼ sec. 4, T. 2 N., R. 6 E., G. A. Cooper, collector; 139,567 (two specimens, one here illustrated), N½ SW¼ sec. 4, T. 2 N., R. 6 E., A. R. Loeblich, collector; 139,568 (one specimen), SW¼ sec. 4, T. 2 N., R. 6 E., H. A. Lowenstam, collector; 139,569 (one specimen), SW¼ NW¼ NW¼ sec. 33, T. 3 N., R. 6 E., A. R. Loeblich, collector.

Reference Cited

Reimann, I. G., and **Fay, R. O.**, 1961, **Polydeltoideus**, a new Silurian blastoid from Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 21, p. 86-89, 1 pl.

OKLAHOMA GEOLOGY NOTES

Volume 22 February 1962 Number 2

In This Issue