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AGOSTOCRINUS AND *ACOLOCRINUS*, TWO NEW
ORDOVICIAN CRINOIDS WITH PECULIAR RAY
AND RESPIRATORY STRUCTURES

BY

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AGOSTOCRINUS AND ACOLOCRINUS, TWO NEW ORDOVICIAN CRINOIDS WITH PECULIAR RAY AND RESPIRATORY STRUCTURES

ROBERT V. KESLING AND CHRISTOPHER R. C. PAUL

ABSTRACT—Two new Early Middle Ordovician crinoids from east-central United States are characterized by greatly reduced rays and by unusual respiratory structures. In the first, *Agostocrinus*, the cup consists of three equal BB overlain by a circlet of six large plates (interpreted as five RR and an X); its flattened calyx is capped by six OO plates, offset from the underlying plates and radially situated around the large circular mouth opening, two of which share the anal opening and the other four each have a central perforation; its arms consist of five series of PBrBr forming main axils wholly recumbent (clockwise in ventral view) upon the RR and X to which they are firmly attached, completely encircling the rim of the cup, each PBr bearing a free upright pinnule; and radial subsurface canals or channels in the cup plates, presumably respiratory, may have external pores. In the second genus, *Acolocrinus*, the cup consists of three BB overlain by circlets of five iRR and five sRR, in which two iRR and two sRR enclose an ovate X; the flattened cap of the calyx is composed largely of inward extensions from the upper edges of the sRR, which bear convergent ambulacral grooves from the pinnules; anus, if any, is unknown; arms are absent and erect pinnules articulate directly with sRR, their circlet interrupted only by winglike processes from the upper right corners of sRR; and serrate sutures along BB-iRR, iRR-iRR, iRR-sRB, and sRR-sRR junctions serve as adits to a complicated system of subsurface canals and channels, which exit through an open pore on each iR-iR junction. Relationships of the new genera to each other and to previously described disparate crinoids cannot be ascertained.

INTRODUCTION

IN RECENT YEARS enough new fossils have been collected in the central Appalachian area to dramatically demonstrate that this was the home water of numerous Early Middle Ordovician echinoderms which, by comparison with known faunas, may be described as odd, peculiar, or bizarre. To themselves, of course, they fitted none of these terms, for they seem in all respects to have been temporarily well-adjusted and successful populations. Nevertheless, they introduce to paleontology such unusual structures and organization that the inadequacy of the current classification is readily apparent. Many of the discoveries await publication.

Here we present two genera of crinoids from this striking group of echinoderms. They possess ambulacral and respiratory arrangements markedly different from any described previously. No ancestors and no descendants can be identified in the fossil record. We are tempted to say that they were dead-end "off-shoots" from the main stem of crinoid evolution, that they were creatures so delicately adjusted in obtaining food and oxygen that the slightest change in environment brought their extinction, and that

they provide interest only as two examples of early crinoid experimentation with unique morphology. This would be premature. The fact that such crinoids as these are still being found makes us realize that early crinoid history is just beginning to come to light.

We greatly appreciate the opportunity to study some of the specimens collected by James Sprinkle and placed in the Museum at Harvard. Our sincere thanks are due to Karoly Kutasi for photography, Helen Mysyk for typing, and Gladys Newton for proofreading. Types are deposited in The University of Michigan Museum of Paleontology (UMMP) and the Harvard University Museum of Comparative Zoology (MCZ).

LOCALITIES

All specimens are from exposures of the Benbolt Formation, Lower Ordovician Ottosee Group, in southwestern Virginia and northeastern Tennessee.

1. Field exposure between Middle and South Forks of Moccasin Creek, about $\frac{1}{4}$ mile south of County Road 676, $1\frac{1}{2}$ miles due south of Hansonville, and about $\frac{1}{8}$ miles west of eastern edge of Hansonville Quad-

- rangle (TVA 205-SW, N3645-W8207.5/.5), southern Russell County, Virginia.
2. Flat vacant lot between houses on north side of Route 71 near Slabtown gas station, 2¼ miles northeast of Gate City, Gate City 7.5' Quadrangle, Scott County, Va.
 3. Small shale bank on north side of Route 74 (now 613), 0.9 mile west of Mt. Hagan School, Hilton 7.5' Quadrangle, Scott County, Va.
 4. Limestone slabs on hillside on north side of roadcut at curve in Routes 58 and 23, about 6.9 miles west of Gate City, Clinchport 7.5' Quadrangle, Scott County, Va.
 5. Small shale bank near northeast end of roadcut at curve on Route 131 (north side), 2¼ miles northeast of road intersection at Lee Valley, Pressman's Home 7.5' Quadrangle, Hawkins County, Tenn. (From 3" upper bed in which holotype of new parablattoid was found.)

SYSTEMATIC DESCRIPTIONS
Subclass INADUNATA

Order DISPARATA Moore & Laudon 1943

Until more is known about the functional and structural morphology of this group of crinoids, we decline to indicate families for their reception. We do not know, for example, if the recumbent arms of *Agostocrinus* eventually fused with the cup and gave rise to a group of crinoids with only pinnules in the food-gathering system. Or if armless crinoids evolved from more than one stock. Or if the respiratory adaptations should carry as much taxonomic weight as the ambulacral. Or if the monocyclic-dicyclic dichotomy has the same value among inadunates as among camerates. It would seem that *Acolocrinus* on the one hand devoted as much of its cup to respiration as did the dicyclic *Porocrinus* and on the other hand developed a pinnule organization like that of the much later *Catillocrinus*. In the absence of clear phylogenies, we can only place the new genera among the very diverse monocyclic inadunates.

AGOSTOCRINUS n. gen.

Type species.—By monotypy, *Agostocrinus xenus* n. sp.

Diagnosis.—Monocyclic inadunate with a

cup containing three BB, and a circlet of six nearly equal plates (five RR and an X). Arms five, each consisting of a main axil of PBrBr, curved clockwise (in ventral view) and firmly attached to plates of the uppermost circlet of the cup; the arms together exactly filling the upper rim and not overlapping. Each PBr sharing a facet with the succeeding PBr, the facet bearing a pinnule. Top of calyx composed of six main plates (classed as OO), offset from those of the RR-X circlet and radiating from a large mouth opening; anal opening large, shared by two OO. Actual tegmen apparently consisting of numerous tiny plates.

Remarks.—Whenever additional crinoids of this general organization are discovered, the generic diagnosis may be slightly altered. We have omitted reference to respiratory structures, simply because they have not been emphasized in the current classification.

The name of the crinoid is derived from the Greek ἀγοςτος, m. ("the bent arm"), referring to the bent and recumbent main axils of the arms.

AGOSTOCRINUS XENUS n. sp.

Text-figs. 1, 2; pl. 1, figs. 1-8; pl. 2, figs. 1-7;
pl. 3, fig. 9

Description.—Cup rotund, bowl-shaped with high sides, its upper part subprismatic to subcylindrical, its lower end bluntly acuminate (pl. 1, figs. 3-8; pl. 2, figs. 2-7). Cup composed of three BB and a circlet of five RR and an X (text-figs. 1, 2a), capped by six OO (text-fig. 2b). All sutures slightly and irregularly serrate (pl. 1, figs. 2-8).

BB equal, each hexagonal, arranged around a rather large basal opening into the lumen of the proximal part of the column (pl. 1, fig. 2). X and RR of B and E rays each in contact with only one B (pl. 1, figs. 4, 6, 8; pl. 2, figs. 3, 5, 7); RR of A, C, and D rays each with obtuse dorsal (lower) end inserted between a pair of BB (pl. 1, figs. 3, 5, 7; pl. 2, figs. 2, 4, 6).

RR and X forming a circlet of six nearly equal very large plates, extending from BB to recumbent arms (text-figs. 1, 2a). All R-R and R-X sutures vertical as seen in direct lateral view; the circlet subhexagonal in cross section at all levels. Each plate more than twice as

EXPLANATION OF PLATE 1
All figures $\times 6$

FIGS. 1-8—*Agostocrinus xenus* n. sp. UMMP 57587, holotype. 1, tegmental view; an adhering mass of pinnulars obscures the anal opening (compare with paratype shown in pl. 2, fig. 1). 2, basal view showing three equal BB. 3-8, lateral views centered on each of six plates in the RR circlet: A, B, C, X, D, and E; note recumbent arms forming axils.

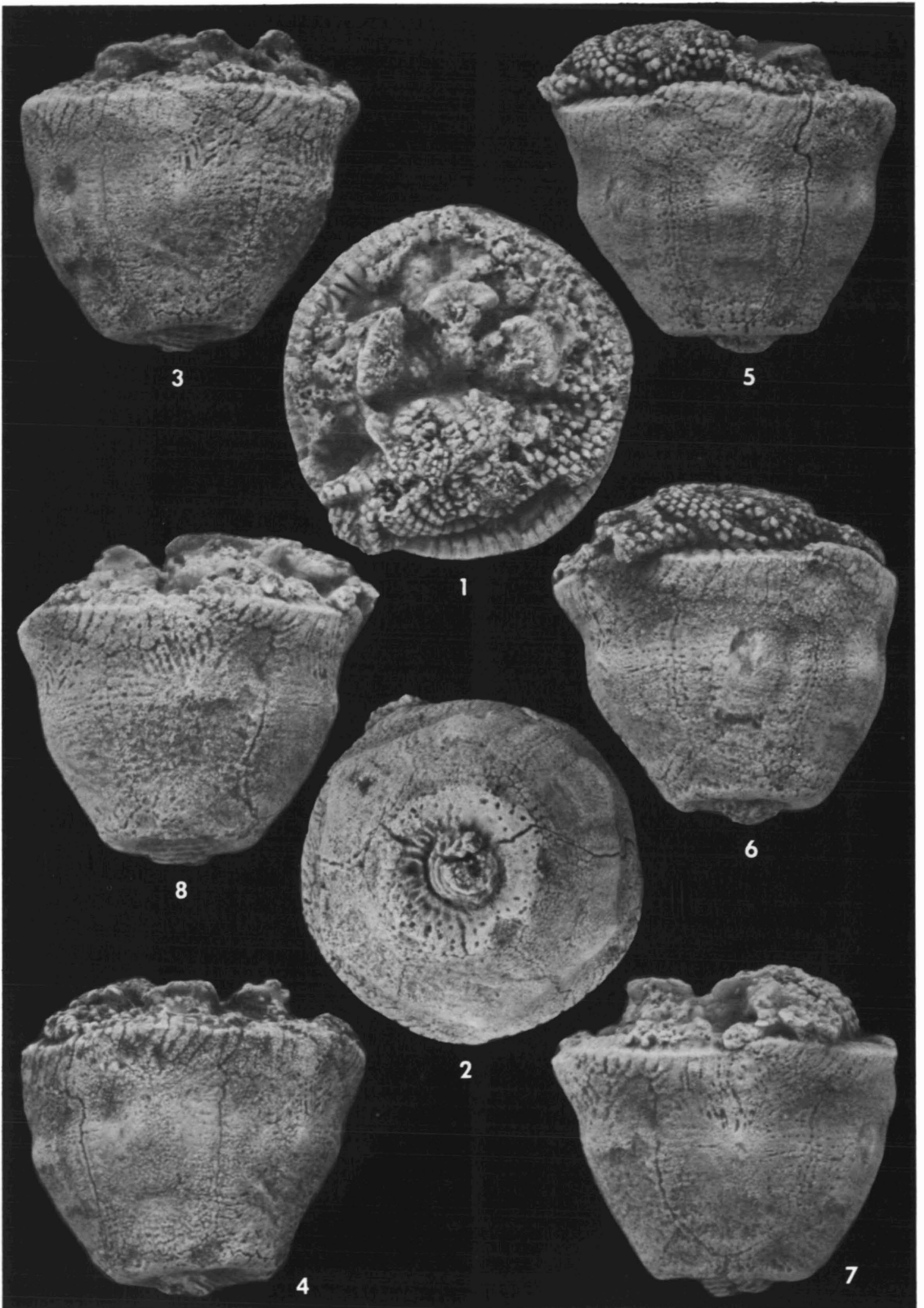


PLATE 1



PLATE 2

high as BB, vertically elongate, slightly trapezoidal (except for blunt lower acuminations of RR in A, C, and D rays and for serrate upper junction with PBrBr in all plates), wider at top than at bottom. Plates in smaller specimen very gently convex, in large specimen also gently convex but bearing a low boss centered on the midline and about two-thirds the height above the BB.

Arms all bent clockwise (as seen from above), consisting of a main axil or uniramous series of PBrBr, totally recumbent on plates of RR-X circlet but not overlapping sufficiently to exclude any PBr from the area of pinnular facets (text-fig. 2a). PBrBr tapering distally in each axil as seen laterally, arranged to form an even upper border and recessed into underlying plates along an irregular serrate suture, firmly joined to RR and X to form part of cup; in top view (text-fig. 2b) PBrBr extending inward into OO plates without respect to position of the latter and regardless of relative position in the arm, being widest at O-O junctions and narrowest at midpoints of OO; the PBrBr forming an arc around the two posterior OO and arcs around each of the other four OO (pl. 2, fig. 1). In lateral view, PBr₁ of each axil much larger than the next PBr. PBr₁ of D ray attached to the right of the midline of the R (pl. 1, fig. 7); those of E, A, and B rays shifted progressively to left; and PBr₁ of C ray originating at left corner of R (pl. 1, fig. 5), the axil extending across the top of X (text-figs. 1, 2a; pl. 1, fig. 6; pl. 2, fig. 5).

Each PBr sharing a facet with the succeeding PBr (pl. 2, fig. 1), the facet supporting a free upright pinnule. Pinnules forming complete circle around upper perimeter of cup. Length of pinnules unknown.

Calyx capped by six plates classed as OO, radially arranged around large central mouth opening (text-fig. 2b). O-O sutures offset from R-R and R-X sutures below. Four OO nearly equal, approximately in AB, CD, DE, and AE interrays but offset toward B, D, E, and A rays respectively; each of these plates with a large central elevation rising proximally to a very prominent ovate hump, and with a small sub-

elliptical perforation (of unknown function) just distal to the hump (text-figs. 2b, c). Other two OO smaller, indented to share the large anal opening, each with an elevation around the opening rising proximally to a very prominent hump (pl. 2, fig. 1). Humps of the six OO situated to form an interrupted ring around the mouth area, the ring a little less than half the diameter of the cup.

Facets of pinnules somewhat elevated as a rim around OO circlet, not coincident with larger areas of PBrBr on oral surface (text-figs. 2b, d), and, with coating of ammonium chloride, somewhat more conspicuous than PBrBr-OO sutures. Shallow ambulacral grooves extending orad from each facet, convergent with other grooves to lie in the low marginal areas of the OO, skirting the edges of the central elevations and following courses completely independent of O-O sutures, combining near mouth to form two main grooves per ray (text-fig. 2d).

System of grooves in each ray lying on a flat area, the sides bordered distally by the central elevations and proximally by very low shelf (almost paper thin). Shelf edge provided with notches (text-fig. 2c), suggesting articulations with tiny covering plates (probably constituting the true tegmen), but no such plates preserved. No plates found covering the mouth opening.

Anal opening with cylindrical lining extending down inside cup at least half-way to base, formed of extensions from the two bordering OO and perhaps from PBr₁ of C ray.

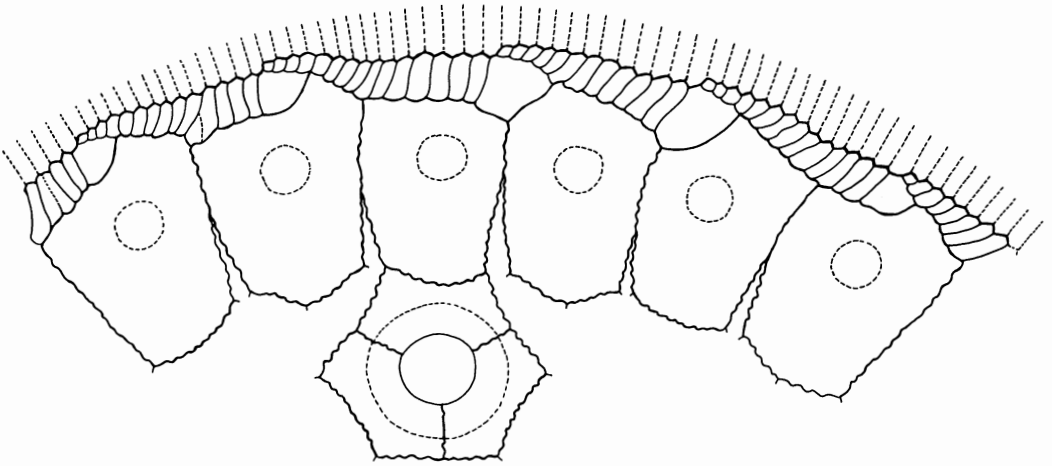
Plates of cup with more or less radially arranged subsurface structures, either canals within plate material or deep channels on interior surface of plates. Lines of tiny pores possibly adits and exits to respiratory structures, rather than products of papillae abrasion.

Ontogeny.—Comparison of the holotype with the much smaller (and presumably younger) paratype reveals that the facets for pinnules are nearly the same width in each specimen. The holotype has more facets filling the perimeter of its cup. Thus, it would seem that growth of the cup is accompanied by additions of

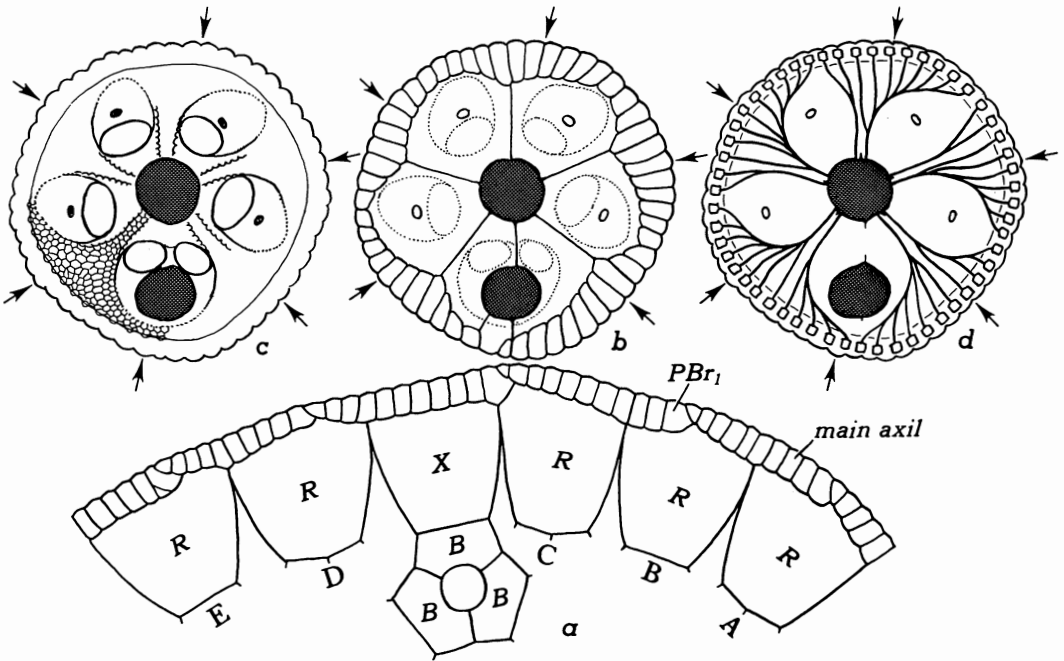
EXPLANATION OF PLATE 2
All figures $\times 6$

FIGS. 1-7—*Agostocrinus xenus* n. sp. MCZ 606, paratype. 1, tegminal view as a stereogram, lightly coated with ammonium chloride to show the ambulacral grooves and perforations through the orals. 2-7, lateral views centered on each of the major plates in succession: A, B, C, X, D, and E, showing recumbent arms joined to RR and X; another lateral view in pl. 3, fig. 9.

8-11—*Acolocrinus hydraulicus* n. sp. MCZ 620, holotype, a well-preserved calyx. Lateral views of A, B, C, and D rays respectively; note pores on iR-iR sutures; the ovate plate bounded by iRR and sRR of C and D rays is X. Other views of this specimen in pl. 3, figs. 1-4.



TEXT-FIG. 1—*Agostocrinus xenus* n. sp. Plate diagram of holotype, a large (presumably adult) cup. In it the arm of the A ray contains 15 PBrBr, the B ray 13 PBrBr, the C ray 16, the D ray 15, and the E ray 13 PBrBr. Dashed circles on RR and X indicate general locations of bosses.

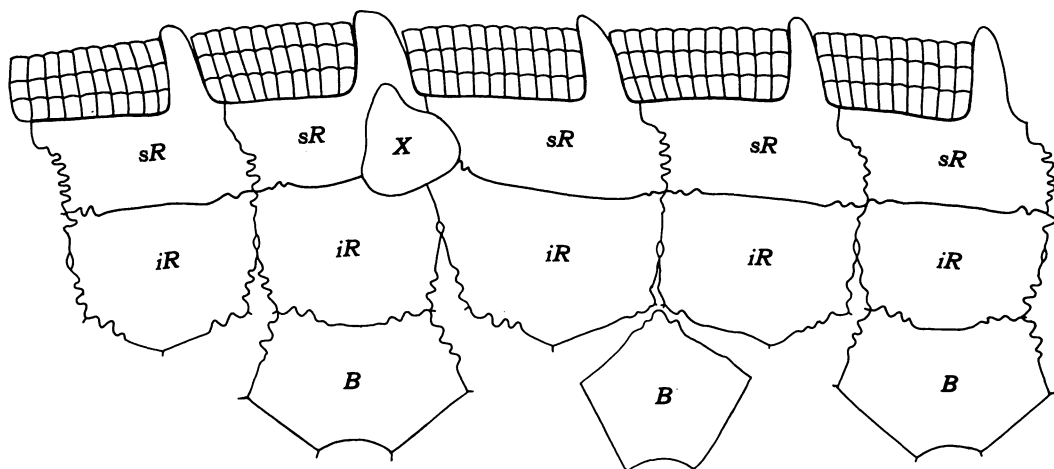


TEXT-FIG. 2—*Agostocrinus xenus* n. sp. Paratype MCZ 606. *a*, plate diagram of cup, somewhat stylized; arm of the A ray contains 10 PBrBr, the B ray 11, the C ray 11, the D ray 10, and the E ray 11 PBrBr. *b*, top view showing plate boundaries; mouth and anal openings shaded; arrows point to R-R and R-X sutures below. *c*, top view showing topography of OO plates; at lower left, hypothetical tiny tegminal plates drawn as indicated by notches of shelf edge. *d*, top view showing system of ambulacral grooves.

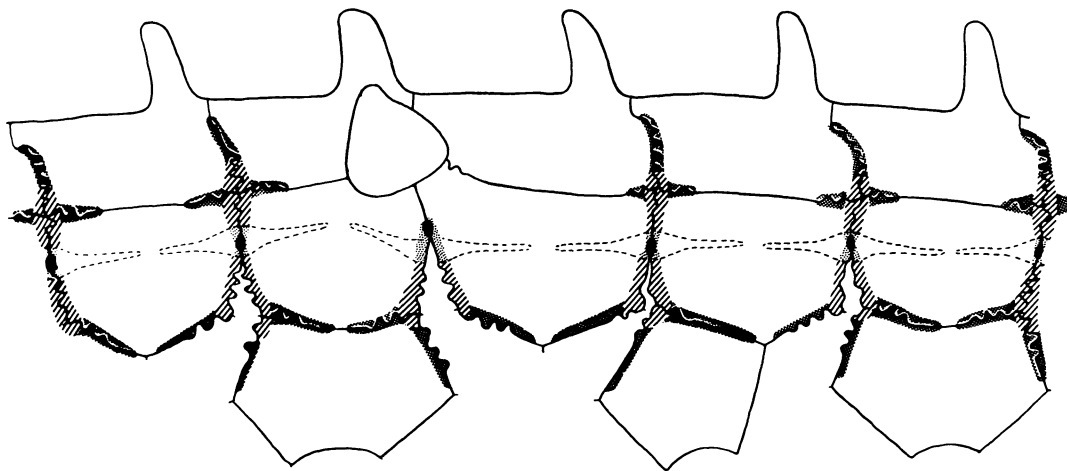
PBrBr at the ends of the arm axils. Inasmuch as the facets always fill the perimeter of the cup, each stage of growth must necessarily be accompanied by shifting of the junctions of PBrBr with RR-X plates below and with OO plates on the inner edge; because these sutures are serrate, considerable resorption and resecretion must take place throughout the period of growth. This may explain some of the irregularities observed in the boundaries of the visible portions of the PBrBr. Some do not fit well in the generally graduated series and a few seem to have aborted before reaching full development.

Remarks.—The whole organization of the animal seems to show effects from the torsion introduced by the recumbent arms. The OO are not nicely centered in the interrays, nor are the ambulacral grooves upon the OO symmetrical and regular.

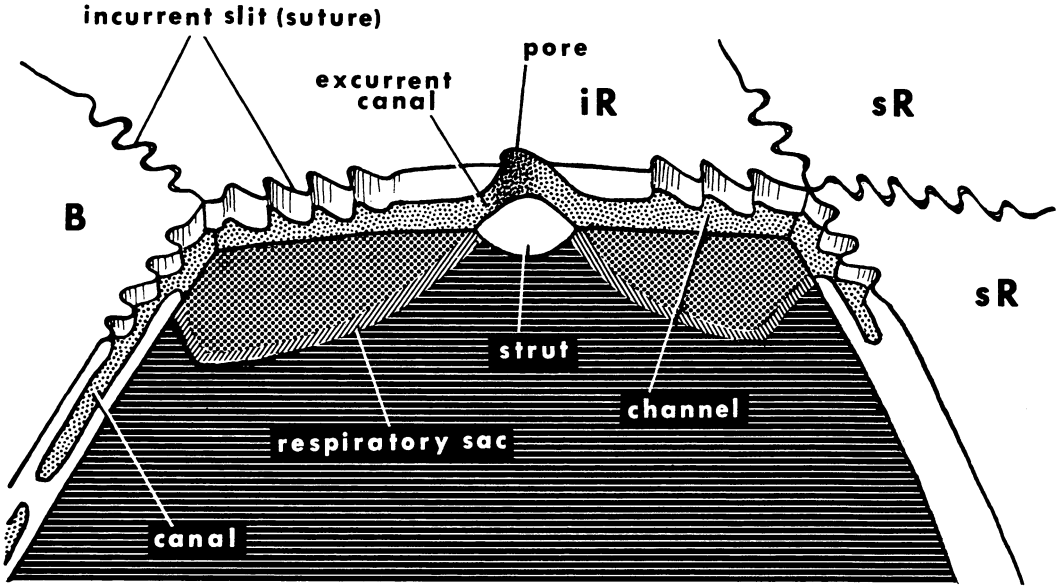
The subsurface system of canals or channels has not been worked out. The passageways, distinct where they have been filled with a substance different from the plate material, were undoubtedly connected with respiration. The four perforations through OO plates might also be involved with respiration; they seem to have been permanently open to admit sea water. If



TEXT-FIG. 3—*Acolocrinus hydraulicus* n. sp. Plate diagram of holotype.



TEXT-FIG. 4—*Acolocrinus hydraulicus* n. sp. Plate diagram with added details of subsurface respiratory structures. Canals indicated by dense stippling, channels by cross hatching, and excurrent canals by light stippling; outlines of struts dashed.



TEXT-FIG. 5—*Acolocrinus hydraulicus* n. sp. Inclined view of part of cup with one iR plate removed to expose details of respiratory system; hypothetical respiratory sac indicated. Somewhat diagrammatic.

this was indeed their function, we are at a complete loss to explain their evolutionary development, for the plates show no traces of sutures leading to the perforations.

The OO were evidently plates below the tegmental covering, for they bear ambulacral grooves on their outermost surfaces. If (as we suggest above) the actual tegmen consisted of small covering plates embedded in an integument, it appears to have been confined to the marginal valleys of the OO, surrounding the prominences but not encroaching onto and across them.

The anal opening is poorly situated for use, being at the level of the pinnule bases and completely encircled by them. We suspect that some kind of chimney, perhaps only weakly plated, extended upward beyond the limits of the food-gathering pinnules.

Thus, despite two well-preserved cups, there are points about the functional morphology to which we have no satisfactory answers.

The name of the species is derived from Greek ξενος ("strange"), referring to the unfamiliar kind of ambulacral organization. It is incidentally an anagram of *nexus* ("connected series"), which might be used to describe the main axils.

Types and occurrence.—Holotype UMMP 57587 (pl. 1, figs. 1–8), a large calyx, collected by junior author at Locality 1. Paratype MCZ 606 (pl. 2, figs. 1–7; pl. 3, fig. 9), a small calyx, collected by James and Gloria Sprinkle at Locality 2.

ACOLOCRINUS n. gen.

Type species.—By monotypy, *Acolocrinus hydraulicus* n. sp.

EXPLANATION OF PLATE 3

All figures $\times 6$

FIGS. 1–8—*Acolocrinus hydraulicus* n. sp. 1–4, MCZ 620, holotype; 1, 2, lateral views centered on E ray and X, showing pores on iR-iR sutures and zigzag sutures; 3, top view, much of surface of sRR shelves obscured by pinnules; note central pentagon of five plates with curved sutures; position of X at top of figure; 4, basal view, showing very small columnal; position of X at bottom of figure; other views of specimen in pl. 2, figs. 8–11. 5, MCZ 627a, a very large calyx; side view, sRR not well preserved. σ , UMMP 57873, an isolated iR of C ray; exterior, showing corner beveled to fit against X, serrate sutures with BB and adjoining iRR; another view of specimen in pl. 4, fig. 1. 7, 8, MCZ 622b, isolated sR of D ray; 7, exterior, showing deep embayment for X and modification of alate extension; 8, top view, showing pinnule facets and ambulacral grooves.

9—*Agostocrinus xenus* n. sp. MCZ 606, paratype. Lateral posterior view centered on suture between posterior OO; other views of specimen in pl. 2, figs. 1–7.

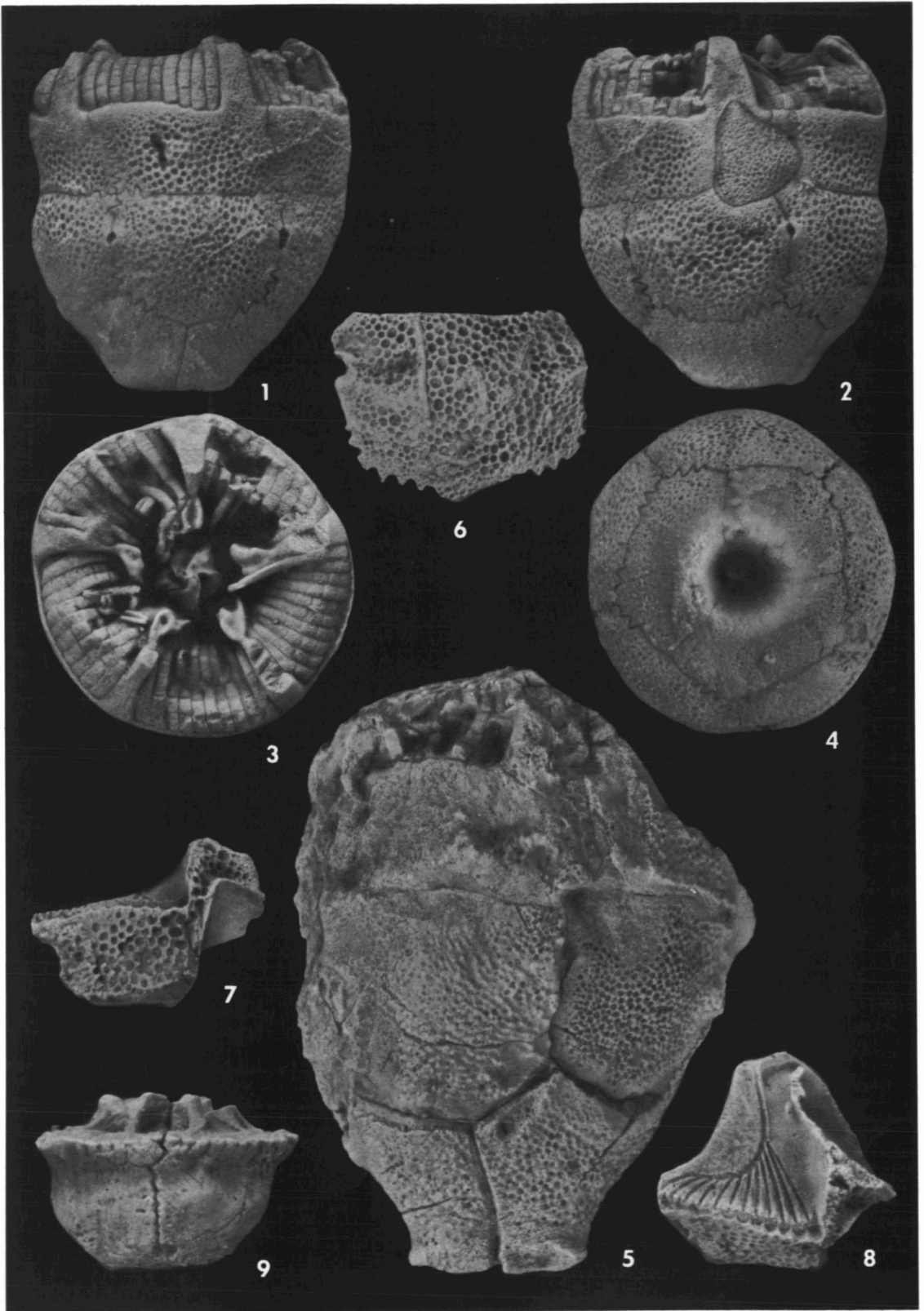


PLATE 3

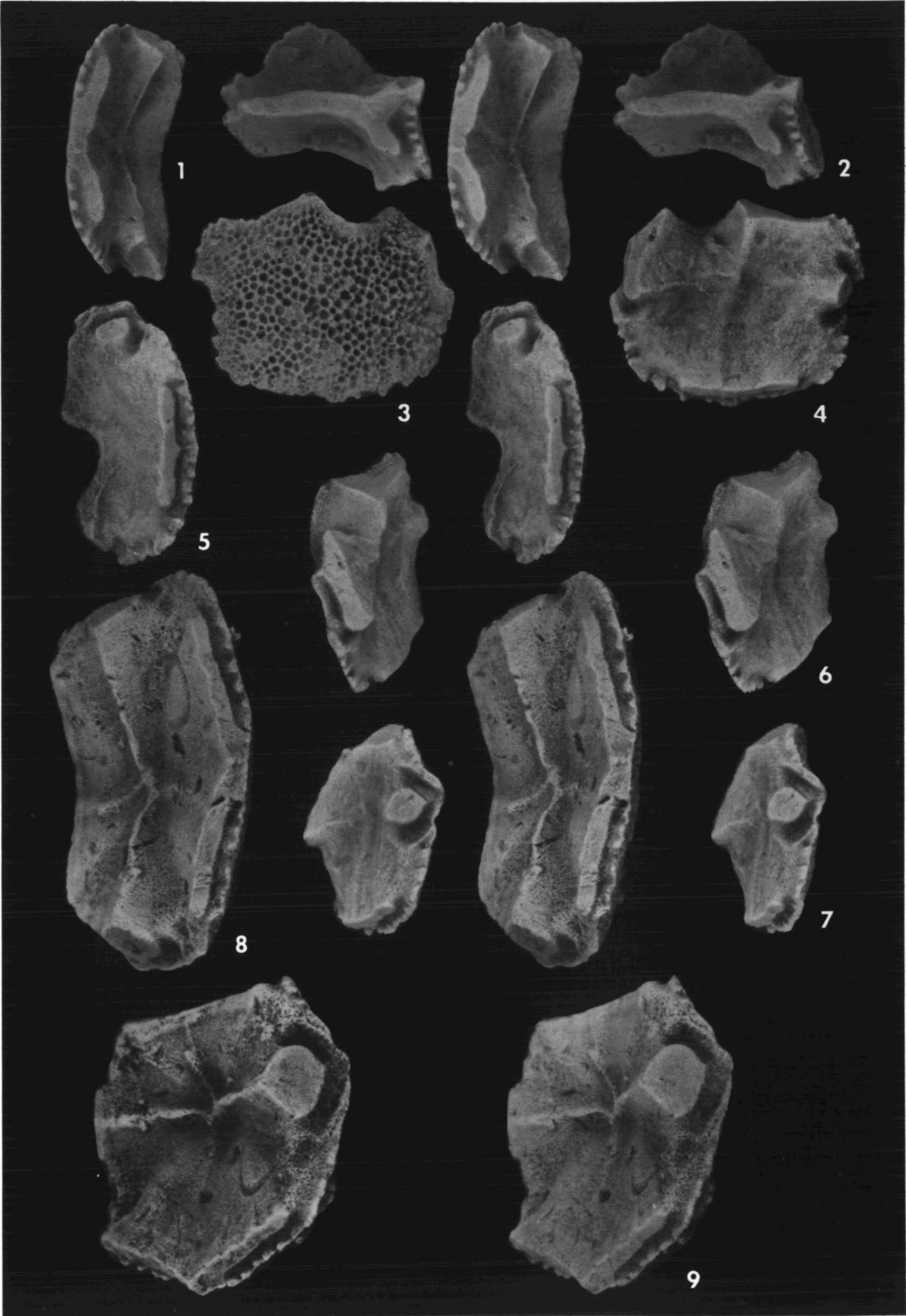


PLATE 4

Diagnosis.—Monocyclic inadunate with a cup containing three BB, five iRR, and five sRR. Arm plates absent, pinnules arising from the upper edge of the compound RR. X an isolated plate surrounded by iRR and sRR; anal opening, if any, unknown. Top of calyx consisting primarily of inward shelf-like projections from the sRR, arranged as five circular sectors around the central mouth opening. Tegmen unknown.

Remarks.—As in *Agostocrinus* above, references to respiratory structures have been left out of the generic diagnosis. When more is known about this kind of crinoid, this may be changed.

The name of the crinoid is derived from the Greek ακωλος ("armless"), referring to the complete elimination of BrBr in the ambulacral system.

ACOLOCRINUS HYDRAULICUS n. sp.

Text-figs. 3-5; pl. 2, figs. 8-11; pl. 3, figs. 1-8; pl. 4, figs. 1-9; pl. 5, figs. 1-14; pl. 6, figs. 1-11; pl. 7, figs. 1-10

Description.—Cup deep bowl-shaped, dorsally bluntly acuminate and ventrally pentagonal in cross section, each of the sides convex like the stave of a keg (pl. 2, figs. 8-11). Cup readily disarticulated despite strongly serrate sutures, and most specimens occurring as isolated plates. Cup composed of three BB, five iRR, five sRR, and an X (text-fig. 3).

BB large (pl. 3, fig. 4), in A and D rays hexagonal, B of BC interray smaller and pentagonal. Larger BB each in contact with three iRR; smaller in contact with two iRR. BB sutures straight; B-iR sutures strongly serrate in corner areas (text-fig. 3; pl. 5, figs. 4, 6; pl. 6, figs. 2, 4).

Circlets of iRR and sRR, the former composed of five nearly equal plates (that of the C ray somewhat wider than the others), extending from BB to nearly even plane of contact with sRR. iRR of A and D rays subquadrate (pl. 2, figs. 8, 11), each bounded by one B below, two other iRR at sides, and the corre-

sponding sR above; iRR of B, C, and E rays subpentagonal (pl. 2, figs. 9, 10; pl. 3, fig. 1), each bounded by two BB below. iRR of C (pl. 3, fig. 6; pl. 6, fig. 8) and D rays (pl. 4, fig. 3; pl. 5, fig. 2) with slight indentations at their upper corners to accommodate the X plate. Except near X, all borders of iRR strongly serrate in corner areas; each iR-iR suture with a conspicuous pore at about mid-height (pl. 2, figs. 8-11; pl. 3, figs. 1, 2).

Five sRR, each set directly atop the corresponding iR, each with a ventral stout alate extension at its upper right corner (as seen laterally). sR of C ray somewhat wider than others, with concavity to accommodate X (pl. 5, fig. 13); sR of D ray with deep embayment for X (pl. 5, fig. 11). Alate extensions rising above pinnule bases by distance nearly equal to height of rest of sR plate (pl. 7, figs. 8, 9). Each sR with a large shelf-like section inward from its upper edge (pl. 7, figs. 1, 5, 7, 9, 10), the five sections arranged around the central mouth opening like sectors of a circle, together forming a flat cap across top of calyx except for sharp, inwardly decreasing radial prolongations of the alate extensions (lying along the edge of each sR plate as viewed from above). These sections serving the same structural function as OO plates in other inadunates.

Shelf-like section of each sR with convergent series of curved ambulacral grooves across its upper surface, leading to mouth opening from the pinnule facets. Grooves branching from one side of the main groove, the system in each ray asymmetric.

X an ovate plate on side of cup, completely cut off from ventral edge of cup by the bordering sRR, surrounded by two sRR and two iRR (pl. 2, figs. 10, 11; pl. 3, fig. 2). No anal opening observed, and function of X unknown. However, at center of ventral surface (pl. 3, fig. 3) five small plates forming a pentagon, their inner corners spiraling inward to a common point of juncture.

Outer surfaces of all cup plates except X deeply reticulate, especially in middle area of

EXPLANATION OF PLATE 4
All figures $\times 6$

FIGS. 1-9—*Acolocrinus hydraulicus* n. sp. Isolated plates, all paratypes. 1, UMMP 57873, iR of C ray; bottom view, showing canals shared with BB and asymmetric struts at the sides; another view of specimen in pl. 3, fig. 6. 2, UMMP 57874, sR of D ray; left edge, showing canal and channel below serrate sR-sR suture; other views in pl. 5, figs. 10, 11. 3-7, UMMP 57871, iR of D ray; 3, exterior showing notch to accommodate X; 4, interior, showing asymmetric struts and excurrent canals at the two sides; 5, bottom edge, showing canals, channels, and asymmetric excurrent canals; 6, right edge, showing long excurrent canal leading to the pore below X; 7, left edge, showing strut, excurrent canals, and pore. 8, 9, UMMP 57880, large iR; 8, bottom edge, showing long canals leading to corner channels; 9, left edge, inclined, showing details of respiratory system. All figures except 3 and 4 are stereograms.

each plate. X granulose, nearly smooth. Shelf-like sections of sRR smooth except for ambulacral grooves.

Pinnules attached to upper edges of sRR, their total length unknown; circle of pinnules interrupted by alate extensions at edge of each ray (pl. 2, figs. 8–11). Proximal pinnulars (and perhaps others) much higher than wide, their outer faces gently curved and their edges sharply curved.

Cup with complex set of structures below margins of plates, undoubtedly involved in circulation of sea water taken in along serrate sutures and expelled through the five pores on the iR-iR sutures. Structures include canals, inside channels, and pores (text-figs. 4, 5); details well exposed on edges of isolated plates (stereograms, pls. 4–7). Respiratory system divided into five unconnected parts, alike except for the area around X. Each part including incurrent slits (serrate sutures), in the vicinity of the iR-B-iR junction below and in the vicinity of the iR-iR-sR-sR junction above; parts of slits farthest from junctions leading to canals within plates (each canal shared by two plates throughout its length), and parts of slits adjacent to junctions leading to channels on inside of cup plates; no external expression of canals or channels. Channels extending most of length of iR-iR sutures, those from above and those from below leading through short sloping excurrent canals to common external pore at middle of suture (text-fig. 5). For structural strength of each iR-iR sutural surface, the pore underlain by a strut (text-fig. 5); on inner surface of iR plate, strut expressed as a tapering ridge originating near center of plate and expanding to junction with strut of adjacent iR plate (text-fig. 4).

Columnar facet extremely small. Column thin, homomorphic, round.

Remarks.—Extensive marginal areas of the cup plates in this species are underlain by sub-surface structures for respiration. In contrast to many other echinoderms, the structures have very little external expression, being seen as serrate sutures and five lateral pores. Even the struts to strengthen the cup are internal. Were it not for the occurrence of isolated plates, details of the canals and channels could not be established. We suppose that circulation was in through the serrate sutures and out through the pores, and that gas exchange was through membranous sacs inside the channels. This was the general plan in other echinoderms that have been functionally analyzed.

The attachment of pinnules to the cup with no intervening arms suggests that the evolutionary history of this crinoid was marked by the arms progressively decreasing in size and/or fusing with cup plates. There is no evidence that all armless inadunates constitute one lineage. However, the combination of compound RR and directly attached pinnules in the Devonian *Anamesocrinus* suggests phylogenetic as well as functional relationship. The 15 genera of the family Allagecrinidae (Devonian to Permian) have similar armless pinnules, but they are characterized by solid RR (in many genera of drastically unequal width).

The name of the species is derived from the Greek ὕδραυλος, m. ("water pipes") and refers to the respiratory system.

Types and occurrence.—Holotype MCZ 620, an excellently preserved cup, collected by James Sprinkle and Gary Stuckey in July, 1967, at Locality 5. Paratypes MCZ 627, seven crushed and damaged cups, collected by James Sprinkle in April, 1967, at Locality 4. Paratypes MCZ 623, two sRR, collected by James and Gloria Sprinkle in April, 1968, at Locality 2. Paratypes MCZ 622, eight sRR, collected by James

EXPLANATION OF PLATE 5

All figures $\times 6$

FIGS. 1–14—*Acolocrinus hydraulicus* n. sp. Isolated plates, all paratypes. 1, 2, UMMP 57882, iR of D ray; 1, left edge, showing details of respiratory structures leading to pore; 2, interior, showing asymmetry of struts and excurrent canals, as well as prominent notch for X; another view in pl. 6, fig. 11. 3–5, UMMP 57869, B of BC interray; 3, inclined top view, showing symmetrical canals leading to central channel at apex; 4, exterior, showing basal ridge and ornamentation; 5, interior, showing thick base and notch for channel at top corner. 6–8, UMMP 57868, hexagonal B; 6, exterior, showing serrate sutures; 7, interior, showing thick base around opening; 8, upper edge, showing symmetrical arrangement of canals leading to corner channels. 9, UMMP 57879, iR; interior, showing symmetrical development of respiratory structures and struts. 10, 11, UMMP 57874, sR of D ray; 10, bottom of plate, showing short canal shared with iR and deep indentation (at right) for X; 11, exterior, showing deep sutural surface for X and the modified alate extension; another view in pl. 4, fig. 2. 12, MCZ 622c, sR of D ray; exterior, showing serrate sutures and notch for X; other views in pl. 7, figs. 6, 7. 13, 14, UMMP 57875, sR of C ray; 13, exterior, showing notch (at left) for X and very narrow sR-sR suture above; 14, top surface, showing pinnule facets and converging ambulacral grooves; other views in pl. 7, figs. 1, 2. Figures 1, 3, and 8–10 are stereograms.

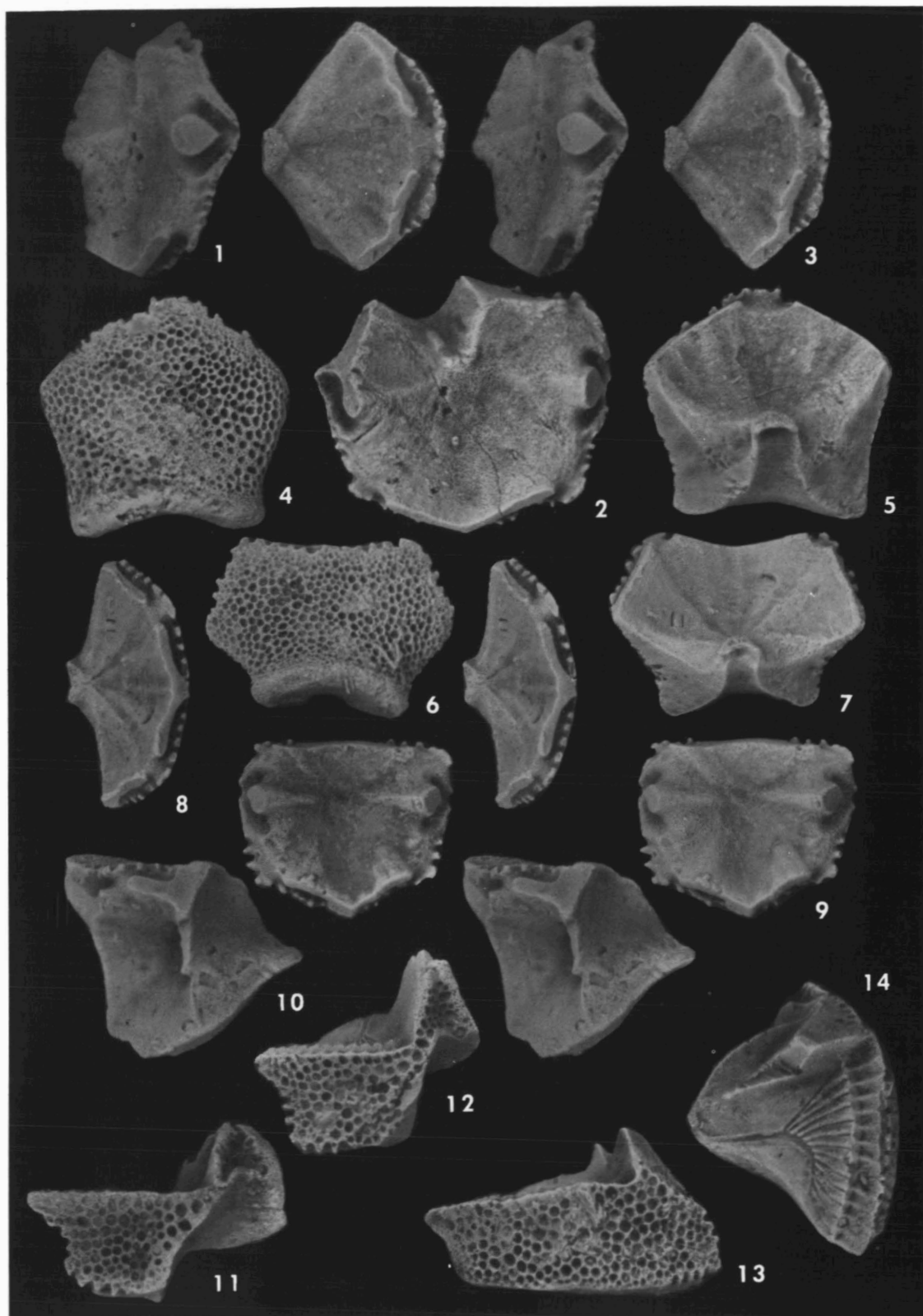


PLATE 5

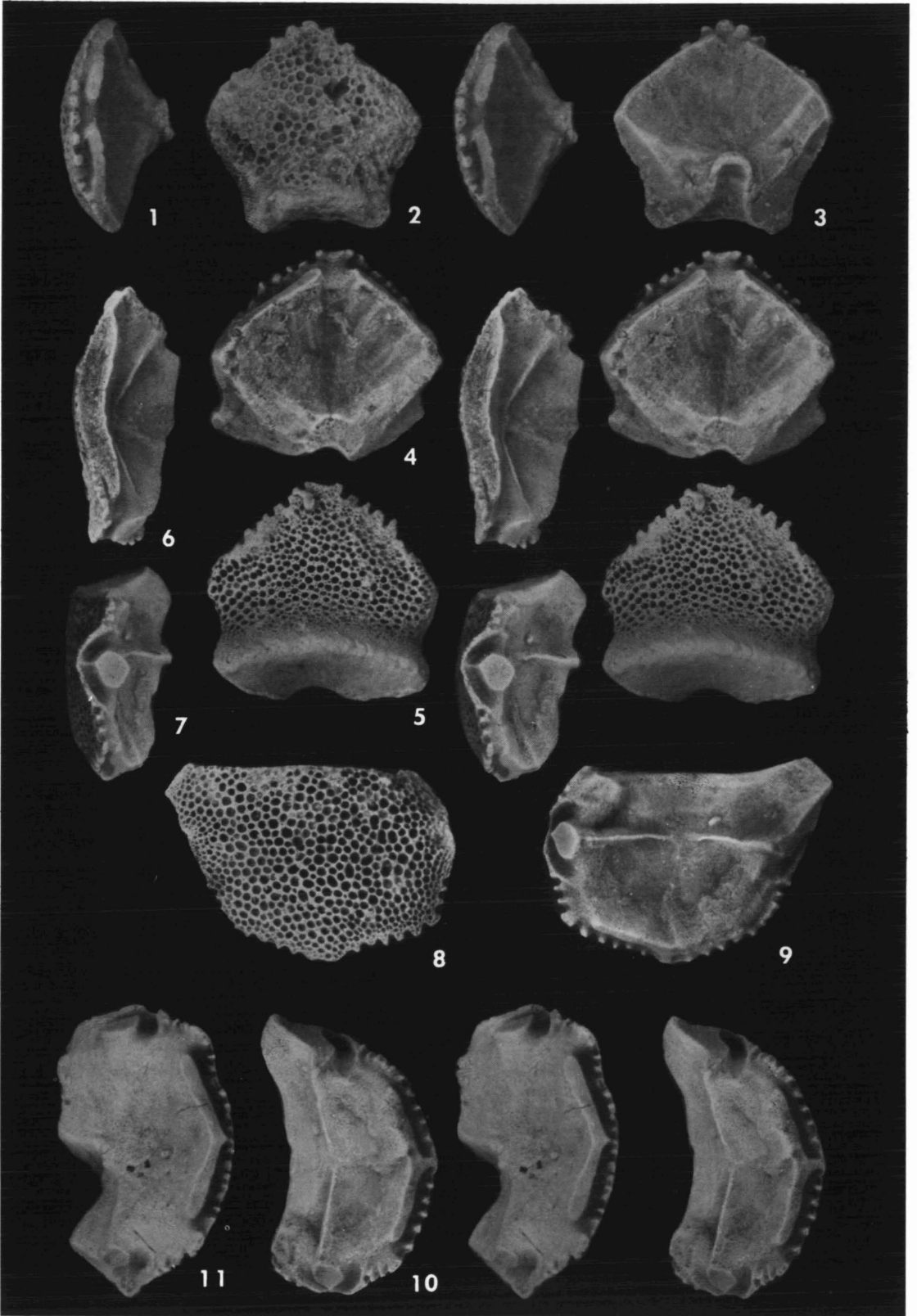


PLATE 6

and Gloria Sprinkle in April, 1968, at Locality 3. Paratypes UMMP 57868–57882, fifteen well-preserved cup plates (including 3 BB of BC interray, 2 other BB, 2 iRR of D ray, 1 iR of C ray, 3 other iRR, 1 sR of C ray, 1 sR of D ray, and 2 other sRR), collected by junior author at Locality 1.

Types are illustrated as follows:

MCZ 620, calyx—pl. 2, figs. 8–11; pl. 3, figs. 1–4
 MCZ 627a, calyx—pl. 3, fig. 5
 MCZ 622a, sR—pl. 7, figs. 8–10
 MCZ 622b, sR of D ray—pl. 3, figs. 7, 8
 MCZ 622c, sR of D ray—pl. 5, fig. 12; pl. 7, figs. 6, 7
 UMMP 57868, B—pl. 5, figs. 6–8
 UMMP 57869, B of BC interray—pl. 5, figs. 3–5

UMMP 57870, B of BC interray—pl. 6, figs. 1–3
 UMMP 57871, iR of D ray—pl. 4, figs. 3–7
 UMMP 57873, iR of C ray—pl. 3, fig. 6; pl. 4, fig. 1
 UMMP 57874, sR of D ray—pl. 4, fig. 2; pl. 5, figs. 10, 11
 UMMP 57875, sR of C ray—pl. 5, figs. 13, 14; pl. 7, figs. 1, 2
 UMMP 57876, B of BC interray—pl. 6, figs. 4, 5
 UMMP 57877, sR—pl. 7, figs. 3–5
 UMMP 57879, iR—pl. 5, fig. 9
 UMMP 57880, iR—pl. 4, figs. 8, 9
 UMMP 57881, iR of C ray—pl. 6, figs. 6–10
 UMMP 57882, iR of D ray—pl. 5, figs. 1, 2; pl. 6, fig. 11.

MANUSCRIPT SUBMITTED AUGUST 3, 1970.

EXPLANATION OF PLATE 6
 All figures $\times 6$

FIGS. 1–11—*Acolocrinus hydraulicus* n. sp. Isolated plates, all paratypes. 1–3, UMMP 57870, B of BC interray; 1, upper edge, showing canals leading to central channel; 2, exterior, showing basal ridge and serrate suture at iRR junctions; 3, interior, showing thick basal section around basal opening. 4, 5, UMMP 57876, B of BC interray; 4, exterior, inclined to show thick base and serrate sutures; 5, interior, showing canals below serrate sutures leading to central channel. 6–10, UMMP 57881, iR of C ray; 6, upper edge, asymmetric with canal only on right (lower in photo) side; 7, right edge, showing excurrent canals leading around strut to pore; 8, exterior, showing serrate sutures and narrow edge to fit against X; 9, interior, showing asymmetric struts and excurrent canals; 10, bottom edge, showing canals separated by thin partition; note difference between right side (below in photo) and left side (above) of this plate. 11, UMMP 57882, iR of D ray; inclined bottom view, showing long canals (nearly confluent) and deep notch for insertion of X; other views of this specimen in pl. 5, figs. 1, 2. Figures 1, 4–7, 10, and 11 are stereograms.

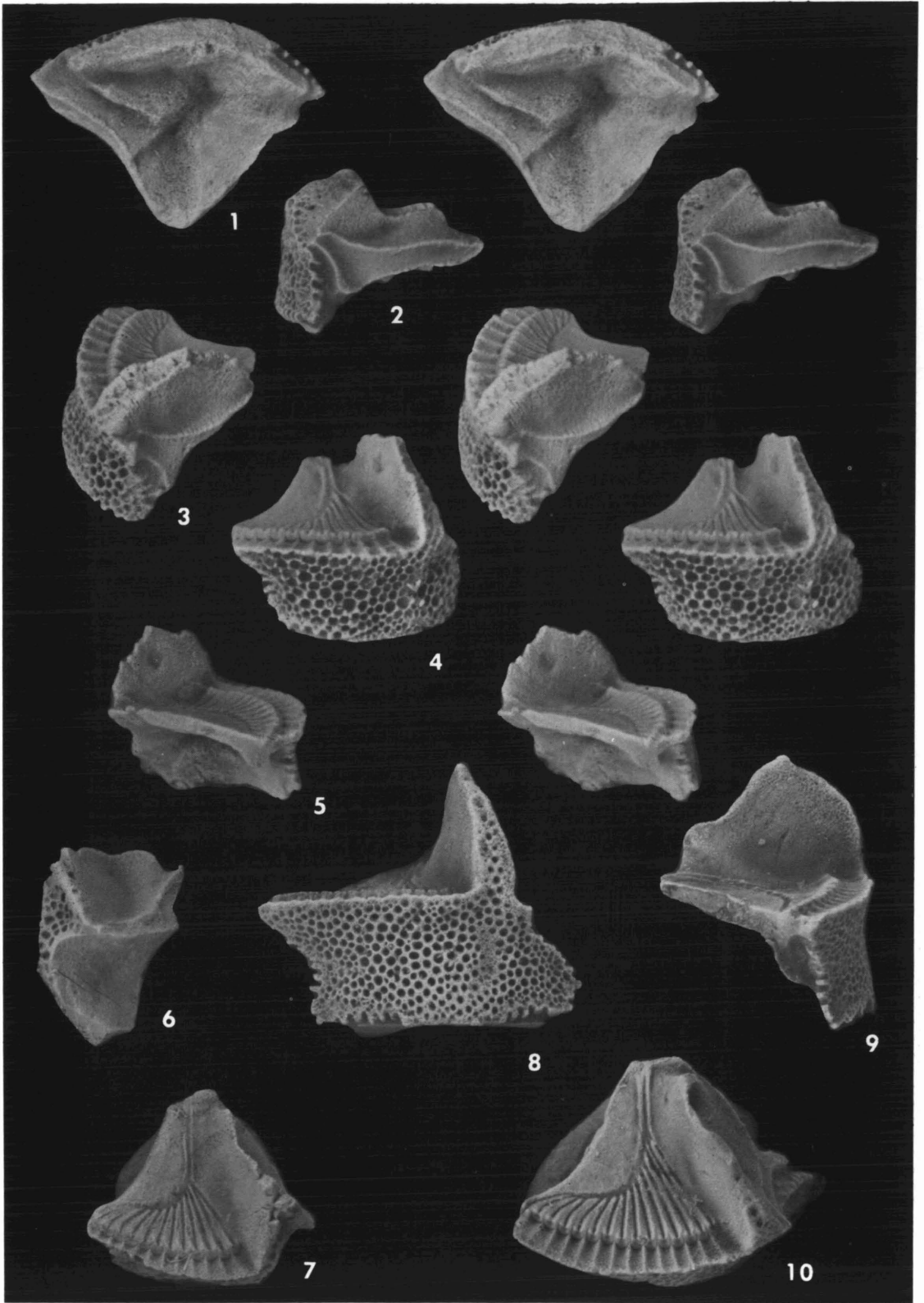


PLATE 7

EXPLANATION OF PLATE 7
All figures $\times 6$

FIGS. 1-10—*Acolocrinus hydraulicus* n. sp. Isolated plates, all paratypes. 1, 2, UMMP 57875, sR of C ray; 1, bottom of plate, showing short canal at right and large triangular shelf-like section; 2, right edge, showing canal leading down to channel at corner; broken edge of alate extension demonstrating depth of ornamentation; other views in pl. 5, figs. 13, 14. 3-5, UMMP 57877, sR; 3, inclined top view, showing pinnule facets on one side of alate extension; 4, inclined lateral view showing convergent ambulacral grooves from pinnule facets; 5, left edge, showing long edge of shelf, the alate extension, and pinnule facets. 6, 7, MCZ 622c, sR of D ray; 6, right edge, showing depth of sutural surface for X; 7, top view, showing ambulacral grooves and alate extension modified by notch for X; another view in pl. 5, fig. 12. 8-10, MCZ 622a, large sR; 8, exterior showing long alate extension and serrate sutures below level of shelf; 9, left edge, showing shelf and alate extension; 10, top view, showing pinnule facets and ambulacral grooves. Figures 1-5 are stereograms.

