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ECHINODERMS OF THE MIDDLE DEVONIAN
SILICA FORMATION OF OHIO

BY

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CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

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INTRODUCTION

THE echinoderms of the Middle Devonian Silica formation, exposed in the south quarry of the Medusa Portland Cement Company, are described in this paper. The quarry is located slightly less than 3 miles southwest of the business district of Sylvania, Lucas County, Ohio. The

quarry, which is not being worked at this time, is in the NE. $\frac{1}{4}$ sec. 18, Sylvania Township, just west of Centennial Road and south of Brint Road. The south end, which formerly was worked by the Sandusky Cement Company, is about one-half mile north of the cement plant at a place locally known as Silica.

Previous Work

The Silica formation and its fauna were first described by Grace A. Stewart in 1927. Stewart (1927, pp. 5-10) assigned $10\pm$ feet of shale to this formation and reported the occurrence (pp. 22-25) of *Arthroacantha carpenteri* (Hinde), *Hexacrinus* (?) sp., and crinoid fragments in her description of the Silica shale fauna. In a subsequent paper on the ostracods of the Silica shale, Stewart (1936, pp. 739-40) included in the formation strata above and below the $10\pm$ feet of shale previously assigned to this formation. In 1940 Stewart (pp. 53-59) described *Gilbertocrinus ohioensis* Stewart and *Euryocrinus* ? *laddii* Stewart from the Silica shale and presented information on the structure of the arms of a specimen of *Arthroacantha carpenteri* (Hinde) obtained from this formation. In 1951 Ehlers, Stumm, and Kesling (pp. 18-20) published a detailed description of the Silica formation and indicated the stratigraphic positions of some of the echinoderms.

Material

The material on which this study is based is in the Museum of Paleontology of the University of Michigan.

Acknowledgments

The author wishes to thank Professor G. M. Ehlers, of the Museum of Paleontology of the University of Michigan, for his very helpful assistance in the identification of the echinoderms and in the writing of this paper. To Professor Lowell R. Laudon, of the Department of Geology of the University of Wisconsin, Professor R. C. Moore, of the Department of Geology of the University of Kansas, and James Wright, of Edinburgh, Scotland, the author is indebted for opinions regarding the taxonomic position of one of the inadunate crinoids. To Irving G. Reimann, Prefect of Exhibits of the University Museums of the University of Michigan, the author is grateful for aid in the identification of the blastoids.

OCCURRENCE OF ECHINODERMS

The stratigraphic occurrence of the echinoderms of the Silica formation and the lithology, thickness, and characteristic fossils of the associated rock units of this formation are indicated in the following description by Ehlers, Stumm, and Kesling (1951, pp. 18-20):

Description of Silica Formation Exposed in South
Quarry of Medusa Portland Cement Company

<i>Unit</i>	<i>Feet</i>	<i>Inches</i>
25. "Cement Rock" (argillaceous limestone)—noted in drill cores	6±	0
24. Limestone, very argillaceous, gray, containing scattered marcasite; on weathering, rock breaks into small angular fragments. Unit contains cryptostomatous and trepostomatous bryozoa, an aulopoid, <i>Stropheodonta</i> sp., and <i>Mucrospirifer</i> sp.		6
23. Limestone, argillaceous, lighter gray than Units 20, 21, and 22, harder than overlying limestone, grading into overlying and underlying units, and having numerous specimens of <i>Leiorhynchus kelloggi</i> Hall and some specimens of <i>Mucrospirifer</i> sp.		8
22. Limestone, argillaceous, dark gray, with <i>Chonetes</i> sp., <i>Leiorhynchus kelloggi</i> Hall, <i>Mucrospirifer</i> sp., and other fossils		4
21. Limestone, slightly argillaceous, dark gray, harder than Units 22 and 20, containing much marcasite and numerous large tubed auloporids		5
20. Limestone, argillaceous, dark gray, containing <i>Stropheodonta</i> sp. and few auloporids		3
19. Limestone, argillaceous, gray, hard, containing <i>Leiorhynchus kelloggi</i> Hall, <i>Mucrospirifer</i> sp., and <i>Stropheodonta</i> sp. Base of limestone contains low discontinuous ridges similar to those at base of Unit 14		7
18. Covered—noted in drill cores as shale; upper 2 feet, bluish-gray shale with pyrite nodules, exposed in ditch beside road at south end of South Quarry of Medusa Portland Cement Company	20	0
17. Limestone, very argillaceous, dark gray, containing an abundance of <i>Ambocoelia umbonata</i> (Conrad) and a smaller number of <i>Leiorhynchus</i> sp., <i>Rhipidomella</i> sp., and <i>Mucrospirifer</i> sp.	1	0
16. Limestone, argillaceous, gray, grading into Unit 17	1	0
15. Shale, gray, containing many specimens of <i>Mucrospirifer</i> sp.		3
14. Limestone, argillaceous, dark gray. Top of limestone contains many specimens of <i>Rhipidomella</i> sp. Base of limestone has discontinuous, low ridges of calcareous material containing numerous crinoidal columnals and a smaller number of fragments of other fossils; ridges are 1 to 2 inches in width and one-half to three-quarters of an inch in height. Base of limestone also has discontinuous straplike ridges of argillaceous material containing few fragments of fossils; the ridges average one-half inch in thickness. The two types of ridges intersect each other in a haphazard manner. At some places they underlie or overlie each other and at other places cut through each other	1	10
13. Shale, dark gray, containing <i>Arthroacantha carpenteri</i> (Hinde), <i>Gilbertocrinus ohioensis</i> Stewart, <i>Euryocrinus</i> ? <i>laddii</i> Stewart, undescribed genera and species of crinoids, and two species of blastoids. The shale contains many well-preserved echinoderms only where it rests on the limestone of Unit 12; it has comminuted echinoderms at other places in the quarry where Unit 12 is represented by shale		¼—1¼
12. Limestone, argillaceous, gray, containing many cryptostomatous bryozoa and constituting a lens. The lens is exposed in quarry wall for a distance of about 40 feet about one-tenth of a mile south of Brint Road. Elsewhere in the quarry the lens is represented by shale.		3-4

<i>Unit</i>	<i>Feet Inches</i>	
11. Shale, gray, breaking into angular fragments on weathering. Unit contains many specimens of <i>Chonetes</i> sp. and ostracods, few fragments of <i>Rhinocaris</i> sp., and very few valves of a <i>Paraspirifer</i>	2	2
10. Limestone, argillaceous, gray, containing cryptostomatous bryozoa in abundance. The most characteristic bryozoa are <i>Acanthoclema ohioensis</i> McNair, <i>Helopora inexpectata</i> McNair, <i>Streblotrypa anomala</i> McNair, and <i>Sulcoretepora deissi</i> McNair.		4
9. Shale, bluish-gray with variously shaped concretionary masses of pyrite and many pyritized fossils; strata 2 to 6 inches in thickness. Shale weathers to a clay which becomes sticky when wet. <i>Mucrospirifer prolificus</i> (Stewart) and <i>Paraspirifer bownockeri</i> (Stewart) are two common species, shells of which are very numerous in the lower 1 foot of unit. Most of the fossils described from the Silica shale come from this unit	7	6
8. Limestone, argillaceous, bluish-gray, relatively hard, containing considerable pyrite and many pyritized fossils; limestone grades into shale of Unit 9. The most abundant fossil is <i>Mucrospirifer prolificus</i> (Stewart).		8
7. Shale, calcareous, bluish-gray and very fossiliferous; many fossils worn by wave action at time of burial. <i>Protoleptostrophia</i> sp. and <i>Stropheodonta</i> sp. are abundant; <i>Hercostrophia robusta</i> Williams is rare and known only from this unit; a large species of <i>Atrypa</i> is abundant in lower 1 foot of unit.	2	6
6. Limestone, argillaceous, bluish-gray, shaly at top and bottom. Many specimens of a large <i>Atrypa</i> sp. and a smaller number of simple corals, <i>Athyris</i> , <i>Mucrospirifer</i> sp. and other spiriferids, <i>Schizophoria</i> sp., <i>Lophonychia cordata</i> Stewart, <i>Limoptera</i> sp. and other pelecypods, <i>Platyceras</i> sp., and trepostomatous bryozoa	1	0
5. Limestone, bluish-gray, crystalline and argillaceous at top, containing a large number of <i>Heterophrentis</i> sp. and other simple corals, a smaller number of compound tetracorals and tabulate corals, and numerous specimens of <i>Cyrtina</i> sp., <i>Spinocyrtia</i> sp. and other brachiopods; <i>Lophonychia cordata</i> Stewart at top of unit; weathers brown	4	0
4. Limestone, very argillaceous, weathering to clay		3
3. Limestone, bluish-gray, weathers brown. Unit contains <i>Hexagonaria anna</i> (Whitfield), <i>H. tabulata</i> Stumm, numerous simple tetracorals and tabulate corals, and many specimens of <i>Atrypa</i> sp., <i>Cyrtina</i> sp., <i>Stropheodonta</i> sp., and spiriferids.	1	0
2. Limestone, bluish-gray to brownish-gray, containing <i>Favosites</i> sp. and some large <i>Chonetes coronatus</i> (Conrad) at base		10
1. Limestone, bluish-gray, containing many specimens of <i>Chonetes coronatus</i> (Conrad) and <i>Tropidoleptus carinatus</i> (Conrad) associated with <i>Atrypa</i> sp., <i>Megastrophia</i> sp., <i>Protoleptostrophia</i> sp., a few spiriferids, <i>Paracyclas</i> sp., and <i>Gosselettia triquetra</i> (Conrad)	1	4
Total thickness	54' 8¼"–54' 10¼"	

Units 1 to 17 inclusive are well known in most of the length of the quarry wall (see Pl. I, Fig. 1); Units 18 to 24 inclusive are shown along a road entering the south end of the quarry from the southwest. The position of Unit 13, which contains most of the echinoderms of the Silica shale, is indicated in Plate I.

The echinoderms occurring in large numbers in the thin shale of Unit 13 are remarkably well preserved, but occur in unbroken condition only where this shale rests on the limestone of Unit 12. In life probably most of the echinoderms were attached to the material composing the limestone, although no remains of stem attachments were found; possibly some were eleutherozoic. Regardless of their relation to the substratum, the echinoderms were buried by a rapid deposition of mud as indicated by the fine preservation of the arms of the crinoids and the very minute and fragile brachioles of the blastoids.

SYSTEMATIC DESCRIPTIONS

Phylum ECHINODERMATA

Subphylum PELMATOZOA

Class BLASTOIDEA

Order Eublastoidea Bather

Suborder Spiraculata Jaekel

Family Nucleocrinidae Etheridge and Carpenter

Genus *Nucleocrinis* Conrad

Nucleocrinis Conrad, 1842, p. 280.

Genotype.—By monotypy, *Nucleocrinis elegans* Conrad, 1842, p. 280, Pl. 15, Fig. 17. Middle Devonian. Western New York.

Nucleocrinis sp. cf. *N. elegans* Conrad

(Pl. IV, Fig. 8)

Only one specimen of *Nucleocrinis* was obtained from the Silica shale. It resembles specimens of *N. elegans* Conrad (1842, p. 280) collected from the Middle Devonian Hungry Hollow formation of Ontario. More Silica shale specimens are necessary for the identification of the species and the determination of its relationship to other species of *Nucleocrinis*.

Occurrence.—Middle Devonian. Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Figured Specimen.—No. 27677.

Family Pentremitidae d'Orbigny

Genus *Pentremitidea* d'Orbigny

Pentremitidea d'Orbigny, 1850, p. 102.

Genotype.—By subsequent designation of Etheridge and Carpenter

(1882, p. 222), *Pentremites pailletti* Verneuil, 1844, p. 213. Lower Devonian. Spain.

***Pentremitidea reimanni* Kier, sp. nov.**

(Pl. IV, Figs. 9-13)

Description.—Calyx pyriform, more elongate in young than in mature specimens. Length below base of ambulacra ranging from three-fifths length of calyx in young forms to less than one-half length of calyx in mature forms. Base triangular. Ambulacra linear to slightly tapering, occupying slightly more than half the length of radials in young forms, to two-thirds length of radials in mature forms. About twenty pairs of side plates in ambulacrum of a calyx, the holotype, having a length of 10.6 mm. Inter-radial areas flat to slightly concave throughout their length. Deltoids very small, visible only on summit of calyx. Hypodeltoid longer than wide, more acute aborally, wide above. Mouth small; shaped like a five-pointed star. Spiracles relatively large; anus larger than spiracles. Brachioles in some specimens two to three times length of calyx; biserial, without brachiolets, flattened. Plates ornamented with lirae.

Remarks.—*Pentremitidea reimanni* resembles *P. cooperi* Reimann (1945, p. 36) from the Norway Point formation of the Traverse group of Michigan. It differs from the latter in not having a rounded summit and in lacking brachiolets on the brachioles. *P. reimanni*, although resembling *P. goldringae* Reimann (1935, p. 26) from the *Pleurodictyum* beds of the Ludlowville shale of New York, differs from it in having flat instead of concave interradii and linear ambulacra. *P. goldringae* has a more constricted basal cup. *P. bellatula* Reimann (1945, p. 34) from the Bell shale of the Middle Devonian Traverse group of Michigan has a smaller summit and narrower ambulacra than *P. reimanni*. *P. bellatula* has a strongly concave profile below the radial shoulders.

The species is named after Irving C. Reimann who has contributed much to the knowledge of American Devonian blastoids.

Occurrence.—Middle Devonian. Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Types.—Holotype No. 27678; paratypes No. 27679, 27680, and 27681.

CLASS CRINOIDEA

Subclass Camerata Wachsmuth and Springer

Order Monobathra Moore and Laudon

Family **Opsiocrinidae** Kier, fam. nov.

Description.—Monocyclic; basals, five; radials not in contact with each other; interbrachials regular and depressed; posterior interradius divided

by medial row of plates elevated above small plates on each side; arms free above second secundibrachials.

Remarks.—This family differs from the Xenocrinidae in having five regularly shaped basals instead of four irregularly shaped basals, a smaller number and a regular arrangement of the interbrachials, and the arms free above the second secundibrachials instead of above the fifth or sixth secundibrachials.

Occurrence.—Middle Devonian; Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Opsiocrinus Kier, gen. nov.

Description.—Dorsal cup: cup-shaped; height slightly less than width in only species known.

Basals: five, large, posterior basal larger than others.

Radials: slightly smaller than basals, not in contact with each other.

Primibrachials: first, hexagonal; second, axillary.

Secundibrachials: first two apparently quadrangular, incorporated in dorsal cup; higher secundibrachials within arms.

Interbrachials: depressed below level of brachial plates; very small, irregularly shaped, indented at sutures, especially at their corners; one plate in first row, two in second and three in third; plates above third row variable in number and not arranged in definite rows.

Intersecundibrachials: one plate in first row; two to four in second row.

Posterior interradius: composed of medial row of plates with small plates on each side; anal X, octagonal, larger than radials, about same size as basals except posterior basal; right anal plate and left anal plate pentagonal, about one-third size of anal X; anal plate above anal X, octagonal; three or four small anal plates on right side and on left side side of second anal plate.

Tegmen: probably elevated; two or three anal plates above second anal plate of dorsal cup and aligned with the second anal plate and anal X; plates on sides of the two or three anal plates very small and variable in number; other tegmenal plates small; anal opening unknown.

Arms: Ten slender arms; uniserial in immature specimens, biserial in mature specimens; free above second secundibrachials, closely pinnulate; pinnulate on second secundibrachial.

Column: composed of pentagonal nodal and internodal columnals; nodal columnals thicker than internodal columnals and extending out beyond them; internodal columnals of two sizes, larger alternating with smaller; smaller number of internodal columnals in proximal part of column than in distal part.

Ornamentation: plates smooth; indented at sutures and corners of interbrachial plates.

Remarks.—This genus, known only from one species, is related to *Xenocrinus*, which has been recorded as occurring only in Upper Ordovician strata. The two genera have radials which are not in contact with each other, interbrachials which are depressed below the level of the brachials, a similar alignment of anal plates, and ten arms. *Opsiocrinus* differs from *Xenocrinus* in having five regularly shaped basals instead of four irregularly shaped basals, a much smaller number of interbrachials, biserial instead of uniserial arms in mature specimens, and arms free on second secundibrachials instead of the fifth or sixth secundibrachials.

Genotype.—*Opsiocrinus mariana* Kier, sp. nov.

Opsiocrinus mariana Kier, sp. nov.

(Pl. III, Figs. 2-3)

Description.—Dorsal cup: cup-shaped, height slightly less than width.

Basals: five, hexagonal, largest plates of dorsal cup, posterior basal larger than others.

Radials: heptagonal, slightly smaller than basals, height less than width and about four-fifths height of basals; not in contact with each other.

Primibrachials: first, hexagonal, height much less than width and about three-fifths height of radial; second, axillary, all pentagonal except right anterior, which is hexagonal.

Secundibrachials: first two apparently quadrangular, incorporated in dorsal cup; higher secundibrachials within arms.

Interbrachials: depressed below level of brachial plates; very small, regularly shaped, indented at sutures, especially at their corners; one plate in first row, two in second and three in third; plates above third row variable in number and not arranged in definite rows.

Intersecundibrachials: one plate in first row; two to four in second row.

Posterior interradius: composed of medial row of plates elevated above smaller plates on each side; anal X, octagonal, higher than wide, larger than radials, about same size as basals except posterior basal; right anal plate and left anal plate pentagonal, about one-third size of anal X; anal plate above anal X, octagonal, about two-thirds height of anal X; three or four small anal plates on right side and on left side of second medial anal plate.

Tegmen: probably elevated, two or three anal plates above second anal plate of dorsal cup and aligned with the second anal plate and anal X;

plates on sides of the two or three anal plates very small and variable in number; other tegmental plates, observed only adjacent to the dorsal cup, very small; anal opening unknown.

Arms: Ten slender arms, with rounded backs; uniserial in immature specimens, biserial beginning on eleventh secundibrachials of immature specimens; free above second secundibrachials; closely pinnulate; pinnulate on second secundibrachials; at least twelve segments on longest pinnule.

Column: incomplete, composed of pentagonal nodal and internodal columnals; nodal columnals thicker than internodal columnals and extending out beyond them; internodal columnals of two sizes, larger alternating with smaller: number of internodal columnals smaller in proximal part of column than in distal part.

Ornamentation: plates smooth; depressions at sutures and corners of interbrachial plates.

Occurrence.—Middle Devonian. Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Remarks.—This species is named after the author's wife, Mary Kier, who prepared many of the specimens and typed the manuscript.

Types.—Holotype No. 27682; paratype No. 27683.

Family Periechocrinitidae Bassler
Genus *Corocrinus* Goldring

Corocrinus Goldring, 1923, p. 202.

Genotype.—By original designation, *Corocrinus ornatus* Goldring, 1923, pp. 203–5, Pl. 26, Figs. 2, 3, 4; Fig. 47.

***Corocrinus nodosus* Kier, sp. nov.**

(Pl. IV, Figs. 2–3)

Description.—Dorsal cup: cup-shaped, slightly wider than high.

Basals: three, relatively large, about equal in size; lower parts thickened to form a pronounced rim, circular except for three indentations at sutures of basals.

Radials: anterior, right posterior and left posterior hexagonal; right anterior and left anterior heptagonal; large, higher than wide, and with anal X composing the largest plates of dorsal cup; in contact except on anal side.

Primabrachials: first hexagonal, height one-half to slightly more than one-half that of radial; second, axillary, pentagonal, hexagonal or heptagonal, height one-third to slightly more than one-third that of radial.

Secundibrachials: two, upper one axillary.

Interbrachials: one relatively large hexagonal plate in first row; two hexagonal or heptagonal plates in second row, each about one-half the height of plate in first row; three hexagonal or heptagonal plates in third row, each about one-third the height of plate in first row.

Posterior interradius: anal X, heptagonal, large, equal in size to radials; three hexagonal plates in second row, height about one-half that of anal X; five hexagonal plates in third row, height a little more than one-third that of anal X.

Tegmen: unknown except for few small plates adjacent to dorsal cup; apparently little elevated above top of dorsal cup.

Arms: Twenty long slender arms, with rounded backs, becoming biserial on fourth to sixth tertibrachials; possibly free above axillary secundibrachial and without doubt free above first tertibrachial; curved inward at distal ends; closely pinnulate; lowest pinnule on second tertibrachial; longest pinnules with seven segments.

Column: incomplete, nodals and internodal columnals alternate in proximal part; secondary internodals intercalated distad.

Ornamentation: distinct: low rounded ridge extending from central part of each radial to the axillary primibrachial, there bifurcating, each branch continuing to the axillary secundibrachial and thence upward to merge with an arm; similar ridge extending from middle of anal X to tegmen without a bifurcation; most plates of dorsal cup with five to seven low rounded nodes located near sides of each plate; some of these nodes present on ridges extending upward from centers of radials and anal X, producing a nodal appearance to ridges of some specimens; some plates in upper part of dorsal cup with short ridges extending from nodes to suture lines and there abutting against similar ridges of adjacent plates; small plates near top of dorsal cup and adjacent tegmenal plates with single nodes at their centers; surfaces of plates of dorsal cup with very fine pits, except along ridges which bear minute aligned grooves possibly produced by coalescence of pits.

Remarks.—*Corocrinus nodosus* differs from the genotype *C. ornatus* Goldring (1923, pp. 203–5) from the Ludlowville shale of New York in having a rim on the basal part of the dorsal cup, basals of less height, two instead of five secundibrachials, and a predominance of nodes instead of radiating ridges on the plates. It also differs from *C. ornatus* Goldring in that the low rounded ridges extending downward from the arms terminate on the radials instead of the basals as seems to be the case in the genotype.

Corocrinus nodosus resembles *C. (?) calypso* (Hall) (Goldring, 1923,

pp. 205–6, and 1934, pp. 186–88) from the Moscow shale of New York and the Arkona shale of Ontario in the possession of a similar plate system. It differs from this species in having a nearly circular instead of trilobate rim on the basal part of the dorsal cup and a predominance of nodes instead of radiating ridges on the plates. It also differs from *C. (?) calypso* (Hall) in that the low rounded ridges extending downward from the arms terminate on the radials instead of the basals.

Occurrence.—Middle Devonian. Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Types.—Holotype No. 27684; paratype No. 27685.

Family Hexacrinitidae Bassler
Genus *Arthroacantha* Williams

Arthroacantha Williams, 1883, pp. 83, 85.

Genotype.—By original designation, *Arthroacantha ithacensis* Williams, 1883, pp. 83, 85; text figures.

Arthroacantha carpenteri (Hinde)
(Pl. III, Figs. 6–9)

The Silica shale specimens of *Arthroacantha carpenteri* (Hinde) studied by the author are similar in all respects to the specimens described by Stewart (1927, pp. 22–24, and 1940, pp. 35–56) from this formation. They were collected from Units 13 and 9. Others may have come from Unit 11. The Silica shale specimens are similar in most respects to specimens of *A. carpenteri* collected from the Arkona shale of the region near Arkona and Thedford, Ontario. They differ in having the calyx slightly more constricted at the radials.

Occurrence.—Middle Devonian. Silica formation; Units 13 and 9, and possibly Unit 11, Medusa Portland Cement Company quarry near Silica, Ohio. Arkona shale; Arkona—Thedford region, Ontario.

Types.—Hypotypes Nos. 27686–27689, inclusive.

Order Diplobathra Moore and Laudon
Family Rhodocrinitidae Bassler
Genus *Gilbertsocrinus* Phillips

Gilbertsocrinus Phillips, 1836, p. 207.

Genotype.—By subsequent designation of Bassler and Moodey (1943, p. 486), *Gilbertsocrinus calcaratus* Phillips, 1836, p. 207, Pl. IV, Fig. 22.

Gilbertsocrinus alpenensis Ehlers

(Pl. IV, Figs. 14-16)

Gilbertsocrinus alpenensis Ehlers, 1925, p. 99.

Revised description.—Dorsal cup: widest at first primibrachials, constricted between the tops of the first primibrachials and the axillary secundibrachials.

Infrabasals: unknown, covered by part of column.

Basals: hexagonal, smaller than radials, forming sides of basal cavity.

Radials: heptagonal, largest plates in calyx, surfaces extended into stout spines.

Primibrachials: first: hexagonal, slightly smaller than radials, surfaces extended into stout spines. In some specimens, left posterior primibrachial or left and right posterior primibrachials small, with rounded nodes instead of stout spines. Second: axillary, heptagonal.

Secundibrachials: first: hexagonal, slightly smaller than primaxils; second: axillary, arms arising from inner sides, interradian appendages from outer sides.

Interbrachials: variable in shape and arrangement, one in first row, three in second row, three to five in third and fourth rows, one or two in fifth row.

Posterior interradius: first anal plate hexagonal, followed by three plates in second row, three to five in third and fourth rows. Number of plates above fourth row uncertain.

Tegmen: low, made up of numerous small nodose plates of irregular appearance. Interambulacral areas depressed with exception of elevated posterior interradius.

Column: incomplete, composed of round nodal and internodal columnals.

Ornamentation: surface of radials and first primibrachials extended into stout spines. Spines tapering gently for about two-thirds their lengths, then sharply constricted and terminating in low rounded knobs or rounded conical tips. Many spines thickened immediately proximal to places of constriction to form circumferential ridges. In some specimens left posterior primibrachial or left and right posterior primibrachials not extended into spines, but having only small rounded nodes. Most of the interbrachial plates with one small rounded node at their centers. A radial ridge extending from spine or node on first primibrachials to center of primaxils where it bifurcates.

Remarks.—*Gilbertsocrinus alpenensis* Ehlers resembles *G. intersculptus* Goldring (1936, p. 15) and *G. spinigerus* (Hall, 1862, p. 100) in having spines on the radials and the first primibrachials. It differs from *G. inter-*

sculptus in lacking radiating ridges on plates and having a smaller column. *G. alpenensis* differs from *G. spinigerus* in having no spines on the lowest interbranchials.

Occurrence.—Middle Devonian. Silica formation, probably Unit 11, Medusa Portland Cement Company quarry near Silica, Ohio. Traverse group, Bell shale filling sinks in Rogers City limestone, Michigan Limestone and Chemical Company quarry, near Rogers City, Presque Isle County, Michigan.

Type.—Hypotype No. 27690.

Gilbertsocrinus ohioensis Stewart

(Pl. IV, Figs. 4-7)

Gilbertsocrinus ohioensis Stewart, 1940, p. 54.

The specimens of *Gilbertsocrinus ohioensis* Stewart studied by the author are similar in all respects to those studied by Grace A. Stewart. They were collected from Unit 13 and others may have come from Unit 11.

Occurrence.—Middle Devonian. Silica formation; Unit 13, and possibly Unit 11, Medusa Portland Cement Company quarry near Silica, Ohio.

Types.—Hypotypes Nos. 27691 and 27692.

Subclass Inadunata Wachsmuth and Springer

Order Cladoidea Moore and Laudon

Suborder Dendrocrinoidea Bather

Family **Proctothylacocrinidae** Kier, fam. nov.

Description.—Dicyclic; cup very small and conical; five infrabasals; radial facets wide; radianal beside right posterior radial; radianal and anal X in dorsal cup; sac prominent, thick-walled, strengthened by diagonal costae; arms slender, branching isotomously six or more times, non-pinnulate.

Remarks.—This family differs from the Dendrocrinidae in having its radianal beside the right posterior radial instead of below it. It also differs from known species of the Dendrocrinidae in having a smaller calyx and wider radial facets. The family Proctothylacocrinidae resembles the Poteriocritinidae and Botryocrinidae in the position of the radianal beside the right posterior radial, but differs from these families in having non-pinnulate arms and wide radial facets. Proctothylacocrinidae, although like the Glossocrinidae in plate structure, differs from this family in having nonpinnulate arms. Ampheristocrinidae differs from Proctothylacocrinidae in having a stout ventral sac and narrow radial facets.

Occurrence.—Middle Devonian.

Proctothylacocrinus Kier, gen. nov.

Description.—Dorsal cup: very small, indented at sutures.

Basals: five; right and left anterior and left posterior, hexagonal; right posterior and posterior, heptagonal; largest plates in calyx.

Radials: heptagonal, slightly smaller than basals, facets nearly as wide as radials.

Posterior interradius: radianal, pentagonal and situated at side of right posterior radial; plate following radianal, hexagonal; anal X hexagonal, equal in size to radianal, with highly rounded back; both anal X and plate above radianal followed by a series of rounded plates decreasing in size distally and aiding in support of ventral sac.

Tegmen: strongly inflated to form a ventral sac, extending to distal ends of arms; sac composed of numerous, small hexagonal, alternately interlocking plates of nearly equal size; sac strengthened by diagonal costae, so arranged as to present a lattice-like appearance to sac exterior; diagonal costae indistinct in lower part of sac in posterior interradius of young specimens.

Arms: slender, isotomous, nonpinnulate, bifurcating over six times, free above radials.

Column: composed of round nodal and internodal columnals.

Remarks.—This genus, known from only one species, differs from all other genera of the Cladoidea in having nonpinnulate arms and the radianal located beside the right posterior radial.

Genotype.—*Proctothylacocrinus longus* Kier, sp. nov.

Proctothylacocrinus longus Kier, sp. nov.

(Pl. II, Figs. 1-4; Pl. IV, Fig. 1)

Description.—Dorsal cup: very small, deeply conical, indented at all sutures; deepest indentations between basals.

Infrabasals: five, pentagonal, wider than high, the smallest plates of calyx.

Basals: five: right and left anterior and left posterior, hexagonal; right posterior and posterior, heptagonal; largest plates in calyx, higher than wide with highly rounded backs.

Radials: heptagonal, wider than high, slightly smaller than basals, facets nearly as wide as radials.

Posterior interradius: radianal, pentagonal, slightly smaller than basals and situated at side of right posterior radial; plate following radianal, hexagonal, slightly smaller than radianal; anal X, hexagonal, equal in size

to radial, with highly rounded back; both anal X and plate above radial followed by a series of rounded plates decreasing in size distally and aiding in support of ventral sac.

Tegmen: strongly inflated to form a ventral sac, extending to distal ends of arms; sac composed of numerous small, hexagonal, alternately interlocking plates of nearly equal size; sac strengthened by diagonal costae, so arranged as to present a lattice-like appearance to sac exterior; diagonal costae of ventral sac indistinct in lower part of sac in posterior interradius of young specimens; distal part of sac unknown; no anal opening observed.

Arms: slender, isotomous, nonpinnulate, bifurcating six to eight times, free above radials; three primibrachials in most right posterior arms, two or four in same arms of few specimens; four, rarely three, in other arms; brachials deeper than wide; four pairs of pentagonal, food-groove covering-plates on each brachial; number of brachial plates between bifurcations variable in different arms of same specimen and in same arms of different specimens.

Column: incomplete, composed of round nodal and internodal columnals; nodal columnals thicker than internodal columnals and extending out beyond them.

Ornamentation: plates of dorsal cup smooth, with highly rounded backs and indented sutures.

Occurrence.—Middle Devonian. Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Types.—Holotype No. 27693; paratypes Nos. 27694 and 27695.

Family Scytalocrinidae Moore and Laudon

Genus *Decadocrinus* Wachsmuth and Springer

Decadocrinus Wachsmuth and Springer, 1879, pp. 109, 119–20.

Genotype.—By original designation, *Poteriocrinites* (*Graphiocrinus* or *Scaphiocrinus*) *scalaris* Meek and Worthen, 1869, pp. 137, 139, 145–46.

***Decadocrinus stewartae* Kier, sp. nov.**

(Pl. III, Figs. 4–5)

Description.—Dorsal cup: low, almost twice as wide as high.

Infrabasals: five, pentagonal, smallest plates in dorsal cup, much wider than high.

Basals: hexagonal, slightly smaller than radials, wider than high.

Radials: all pentagonal except right posterior radial; right posterior radial hexagonal; largest plates in dorsal cup; wider than high; facets wide and curved.

Primibrachials: two, first quadrangular, wider than high; axillary pentagonal.

Posterior interradius: radianal, pentagonal, beside right posterior radial, slightly smaller than basals; anal X, hexagonal, slightly smaller than radianal; anal X and radianal each followed by two slightly smaller hexagonal plates.

Tegmen: unknown.

Arms: ten, uniserial, with brachials wider than high; pinnulate, longest observed pinnule with ten segments.

Column: incomplete; columnals just below dorsal cup pentagonal.

Ornamentation: plates rounded and smooth with slight indentation at sutures.

Remarks.—This species resembles *Decadocrinus crassidactylus* Laudon (1936, p. 64) from the Cedar Valley formation of Iowa, but differs from this species in lacking nodes on the basals and in having wider brachials. *D. stewartae* differs from *D. rugistriatus* Goldring (1923, pp. 432–34) from the Ithaca beds of New York in having shorter primaxils and in lacking striations on the arms. The species is named after Dr. Grace A. Stewart, who first made known the fauna of the Silica shale.

Occurrence.—Middle Devonian. Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Type.—Holotype No. 27696.

Subclass Flexibilia Zittel
Order Sagenocrinoidea Springer
Family Synerocrinidae Jaekel
Genus *Euryocrinus* Phillips

Euryocrinus Phillips, 1836, p. 205.

Genotype.—By monotypy, *Euryocrinus concavus* Phillips, 1836, p. 205, Pl. 4, Figs. 14, 15.

Euryocrinus ? laddii Stewart

(Pl. III, Fig. 1)

Euryocrinus ? laddii Stewart, 1940, pp. 57–59.

The specimens of *Euryocrinus ? laddii* Stewart studied by the author are similar in all respects to those studied by Grace A. Stewart.

Occurrence.—Middle Devonian. Silica formation; Unit 13, Medusa Portland Cement Company quarry near Silica, Ohio.

Type.—Hypotype No. 27697.

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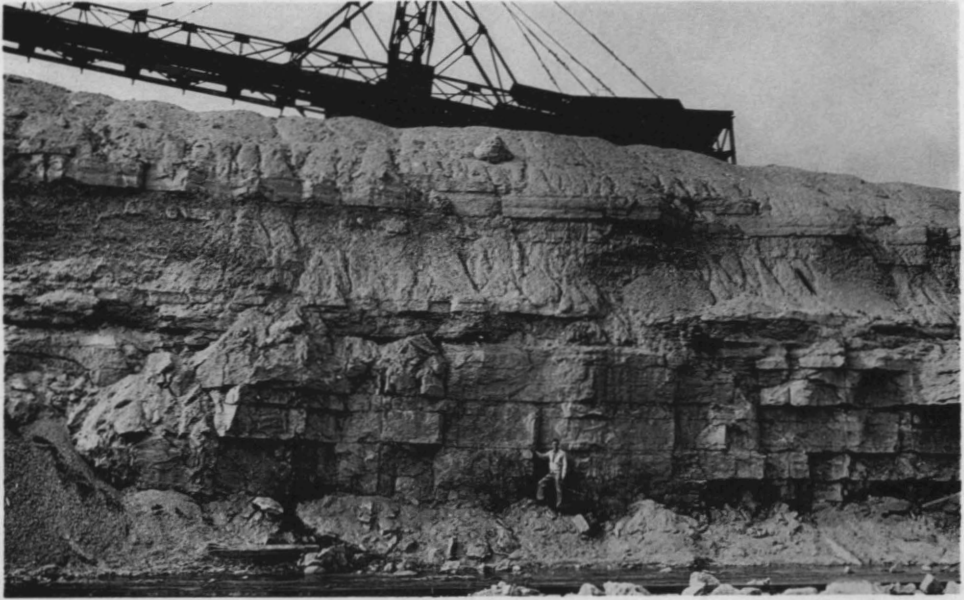
PLATES

EXPLANATION OF PLATE I

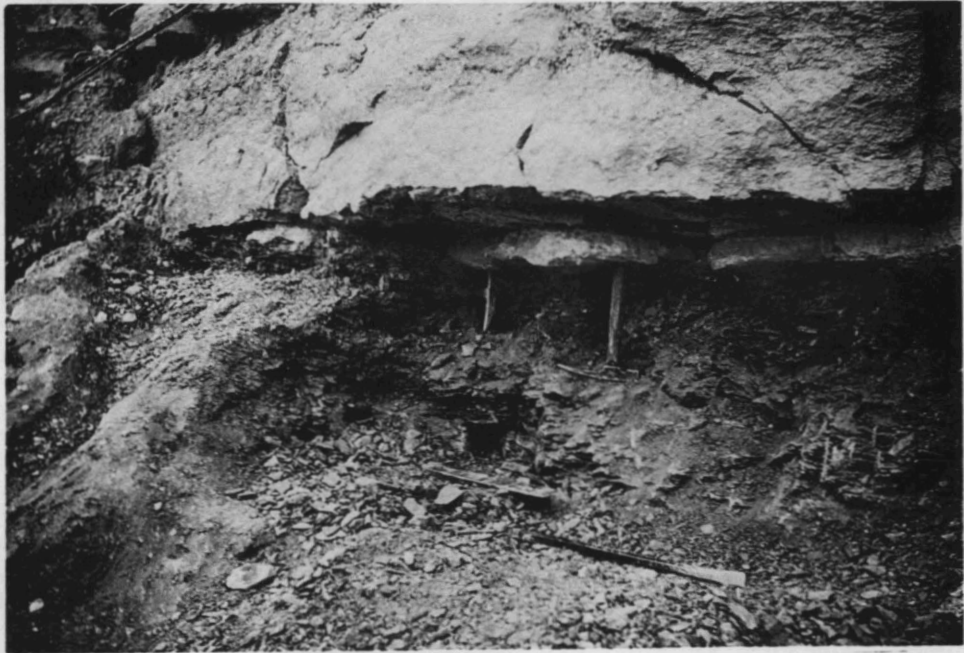
FIG. 1. Part of west wall of south quarry of Medusa Portland Cement Company, about one-fifth mile south of echinoderm bed illustrated in Figure 2. Dundee limestone strata, underlying Silica formation, are shown below man's right hand. Units 1 to 17, inclusive, of the Silica formation are shown above man's right hand. Prominent ledge near top of wall consists of Units 14, 15, 16, and 17 of Silica formation; most of shale on top of ledge was taken from shales beneath Unit 14; some of this shale may be from Unit 18. Unit 10, a thin though conspicuous layer of limestone occupying a position about $2\frac{1}{2}$ feet below the base of Unit 14, is recognizable in the view.

FIG. 2. Part of quarry wall in which echinoderms were found. The thick bed at the top of the view is Unit 14. Unit 12 is shown just above the hammer. Between these units is a thin black band, which represents the dark gray, echinoderm-bearing shale of Unit 13. The wrecking bar shown near the bottom of the view rests on talus material thinly covering Unit 10.

PLATE I

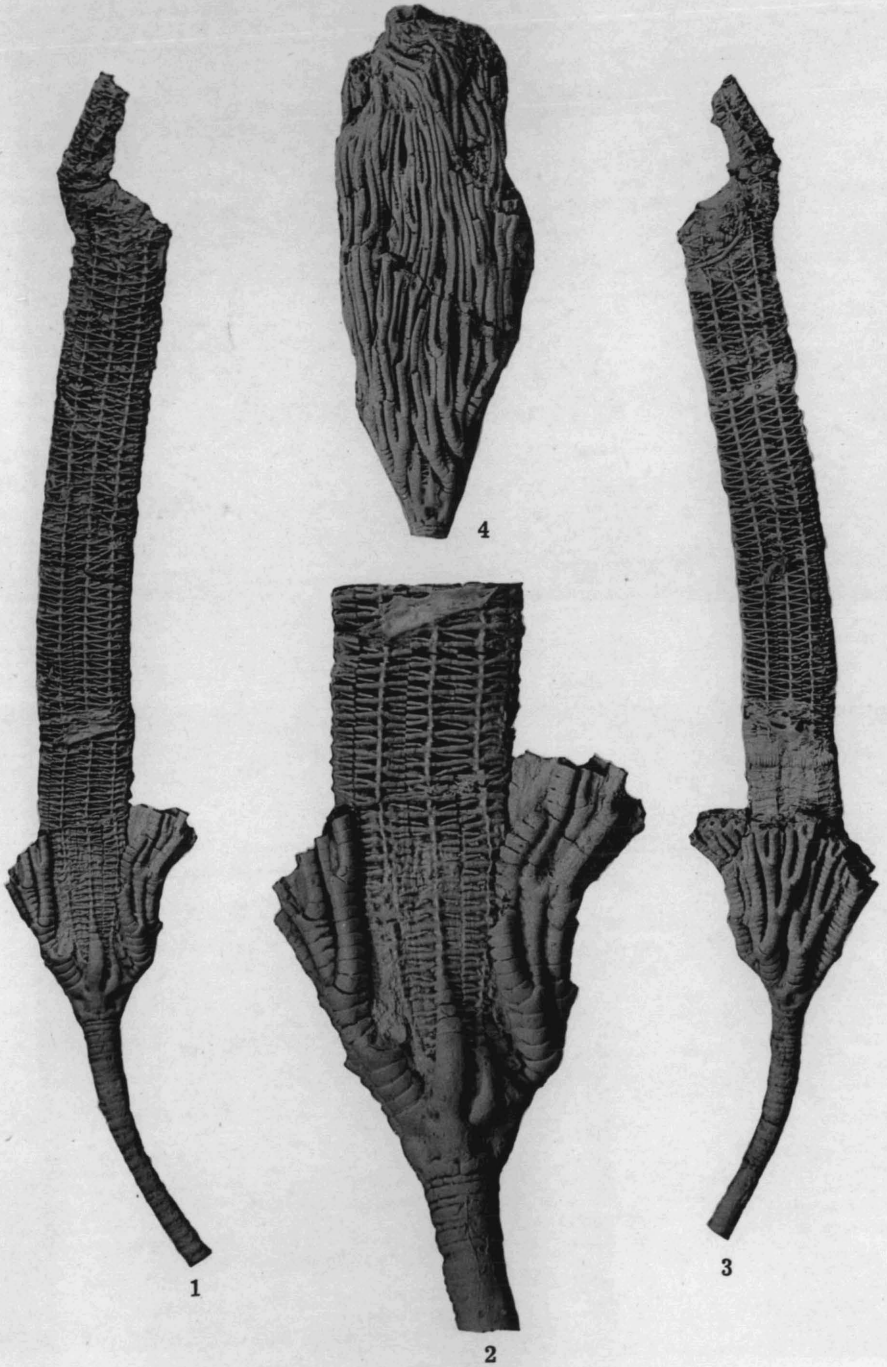


1



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PLATE II



EXPLANATION OF PLATE II

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FIG. 1. Posterior view showing wide posterior interradius and lattice-like appearance of ventral sac. Holotype No. 27693. Unit 13. \times 1.	
FIG. 2. Posterior view showing presence of radianal beside right posterior radial, and the series of rounded plates above radianal and anal X. Holotype No. 27693. \times 2.	
FIG. 3. Anterior view. Holotype No. 27693. \times 1.	
FIG. 4. Posterior view showing nonpinnulate arms with their numerous bifurcations. Paratype No. 27694. Unit 13. \times 1.	

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FIG. 9. View of two specimens, one with calyx missing, showing character of arms. Hypotype No. 27689. Loose specimen from Unit 9, 11, or 13. \times 1.	

PLATE III

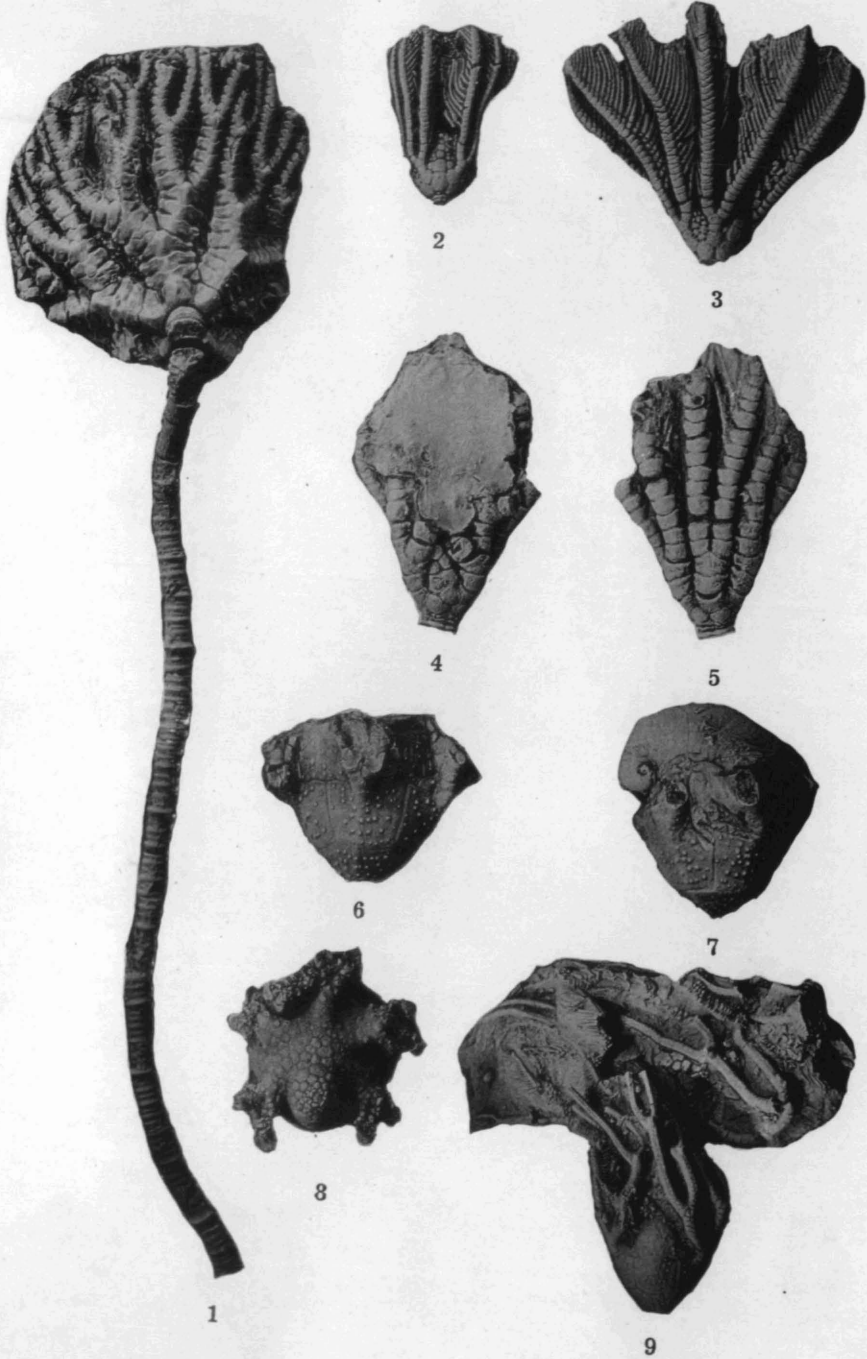
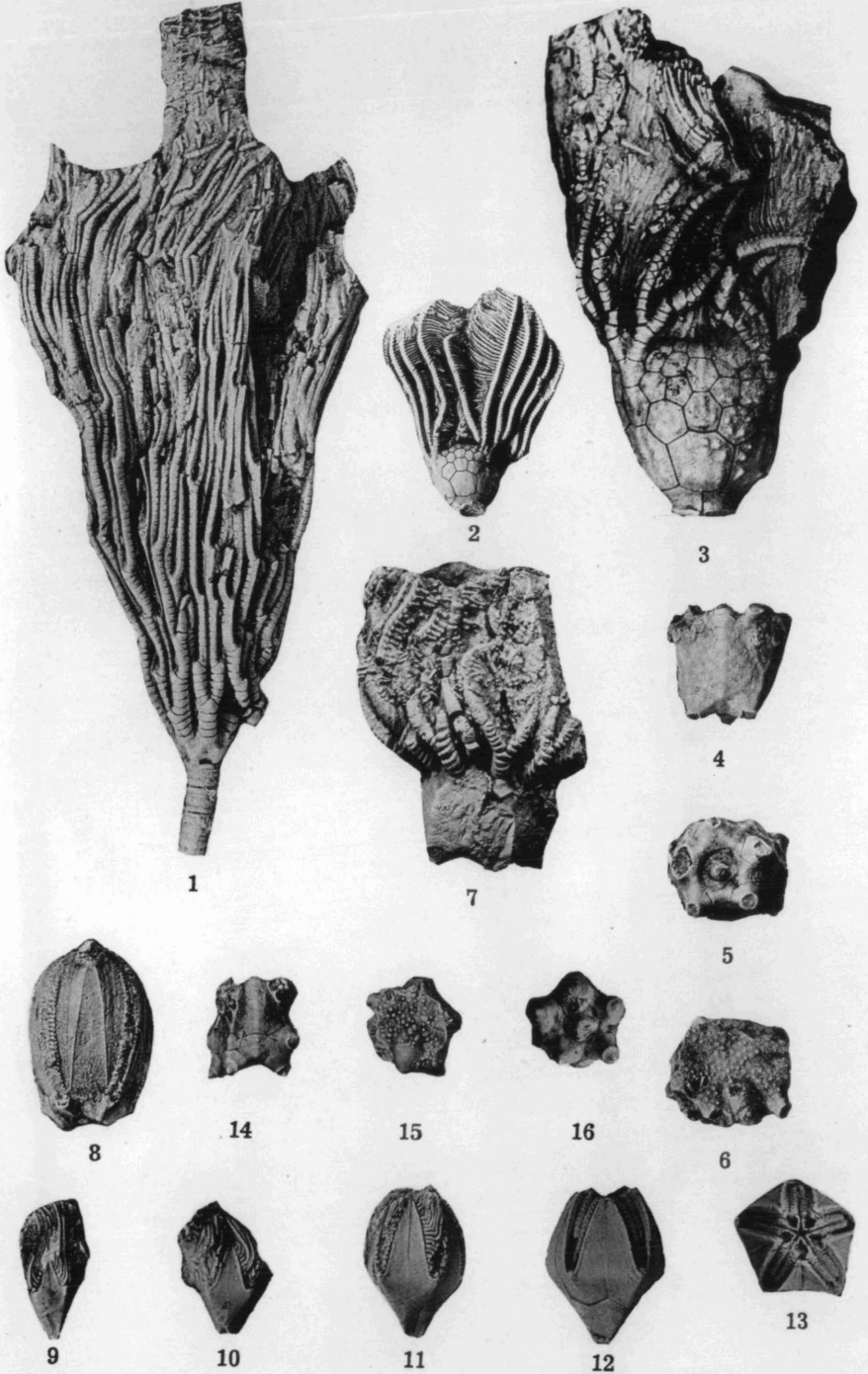


PLATE IV



EXPLANATION OF PLATE IV

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|--|------|
| <i>Proctothylacocrinus longus</i> Kier, sp. nov. | 72 |
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| FIG. 2. Posterior view, with sutures retouched, showing biserial arms with long slender pinnules. Paratype No. 27685. Unit 13. \times 1. | |
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| FIG. 4. Posterior view. Hypotype No. 27691. Loose specimen from Unit 11 or 13. \times 1. | |
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| FIG. 6. View of tegmen showing nodes on plates. Hypotype No. 27691. \times 1. | |
| FIG. 7. Lateral view showing arms and interradial tubular appendages. Hypotype No. 27692. Unit 13. \times 2. | |
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| FIGS. 9-13. Four specimens showing relative increase in width of calyxes from youth to maturity. Views of Paratype No. 27681 (Fig. 9), Paratype No. 27680 (Fig. 10), and Paratype No. 27679 (Fig. 11), show brachioles. Views of Holotype No. 27678 (Figs. 12 and 13) show ambulacra, small mouth, spiracles, and anus. Unit 13. All \times 2. | |
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| FIG. 14. Posterior view of specimen showing anal plates and stout spines on radials and first primibrachials. Hypotype No. 27690. Probably from Unit 11. \times 1. | |
| FIG. 15. Ventral view of same specimen as in Figure 14, showing nodes on tegmenal plates. \times 1. | |
| FIG. 16. View of base of same specimen as in Figure 14, showing spines on radials. \times 1. | |

VOLUME X

1. Ostracods of the Families Leperditellidae, Drepanellidae, Glyptopleuridae, Kloedenellidae, Bairdiidae, Barychilinidae, and Thlipsuridae from the Genshaw Formation of Michigan, by Robert V. Kesling and John E. Kilgore. Pages 1-19, with 4 plates. Price \$.60.
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