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NEW AMERICAN PALEOZOIC ECHINOIDS

(WITH EIGHT PLATES)

By

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and Paleobotany  
United States National Museum  
Smithsonian Institution



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## NEW AMERICAN PALEOZOIC ECHINOIDS

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### INTRODUCTION

Seven new species and one new genus of Paleozoic echinoids are described in this paper. One of the two new species of *Archaeocidaris*, *A. immanis*, is represented by a magnificent specimen, remarkable not only for its size, being the largest cidarid ever recorded, fossil or Recent, but is the first specimen of the genus showing the original shape of the echinoid. Furthermore, it is the first certain *Archaeocidaris* from the Pennsylvanian. A study of the ambulacral plates of this species, and of other species of the genus, shows that the plates are highly imbricate, a feature not previously known.

*Archaeocidaris aliquantula* and *Lepidechinus cooperi* are new species from the Gilmore City formation. The numerous specimens of these species in the United States National Museum were collected by Dr. Lowell R. Laudon at the same locality where he collected his beautifully preserved crinoids.

In the Jackson collection at the Museum of Comparative Zoology at Harvard, the author found several specimens of a new species from Crawfordsville, Ind., which clearly represent a new cidarid genus. This genus, herein named *Polytaxicidaris*, is the first cidarid known with more than four columns in each interambulacrum. Also, as its interambulacral plates are similar to those of *Archaeocidaris*, its discovery makes unwise the referring of isolated interambulacral plates or spines to *Archaeocidaris*, as has been done frequently in the past.

A new species of *Palaechinus*, *P. tetrastichus*, is described from the Mississippian of Montana. This is the first species of this genus found in the United States, and is based on several specimens collected by R. M. Stainforth of the Carter Oil Co.

One of the two new species of *Lepidesthes*, *L. grandis*, is of considerable interest not only because of its great size, but also as it has

more columns (20) in each ambulacrum than any other member of the genus. The plates of the holotype are very well preserved, and from a study of them it is evident that although the plates do imbricate, the test was not flexible, as has been presumed in all echinoids with imbricating plates. The other new *Lepidesthes*, *L. alta*, is represented by one specimen, and is the first one of the genus preserving its original shape. The test is extremely high, being one of the highest in proportion to its width of all known echinoids.

A specimen of *Archaeocidaris blairi* (Miller) is described in which the apical system has been revealed by removal of the interambulacral plates which had shifted over the apical area. The apical system was hitherto unknown in this genus. This species was placed by Jackson in synonymy with *Archaeocidaris legrandensis* Miller and Gurley, but is here separated and redescribed. Finally, a specimen of *Lepidesthes colletti* White from a new locality is figured.

#### ACKNOWLEDGMENTS

I am greatly indebted to Dr. G. Arthur Cooper who had, several years ago, cleaned, photographed, and tentatively described the Gilmore City echinoids. The photographs used in this paper of these two species were taken by him. I also acknowledge his helpful suggestions made during the writing of this paper, and express my great appreciation for his part in making it possible for me to study echinoderms at the United States National Museum.

Dr. M. H. Nitecki, curator of the Walker Museum at the University of Chicago, very kindly lent me the type specimen of *Archaeocidaris legrandensis*, and Dr. N. D. Newell sent to me from the American Museum of Natural History a cotype of *Archaeocidaris wortheni*. I am indebted to Dr. L. R. Laudon for the echinoids from Gilmore City, and to B. H. Beane for specimens from Gilmore City and LeGrand, Iowa. Mrs. J. H. Renfro collected the specimens of *Lepidesthes grandis*, and J. L. Borden and Dr. N. D. Newell collected the specimen of *Archaeocidaris immanis*. Dr. J. Thomas Dutro, Jr., brought to my attention the specimens of *Palaechinus tetrastichus*, and Dr. Donald W. Fisher and Clinton F. Kilfoyle very kindly searched through their Crawfordsville material at the New York State Museum and located two specimens of *Polytaxicidaris dyeri*.

Finally, through the courtesy of Dr. C. O. Dunbar, I was able to study the Paleozoic echinoids at the Peabody Museum at Yale, and through the kindness of Dr. H. B. Whittington, the echinoids of the Jackson collection at the Museum of Comparative Zoology at Harvard.

## Family ARCHAEOCIDARIDAE McCoy

## Genus ARCHAEOCIDARIS McCoy, 1844

*Type species.*—*Cidaris urii* Fleming, by subsequent designation, Bather, 1907, p. 453. Generic name *Archaeocidaris* validated in Opinion 370 under plenary powers by suppression under same powers of generic name *Echinocrinus* Agassiz, 1841. Opin. Internat. Comm. Zool. Nomencl., vol. 11, pp. 301-320, 1955.

## ARCHAEOCIDARIS IMMANIS Kier, new species

Plates 1, 2, 3A; text figures 1, 2

*Diagnosis.*—Species characterized by large size, slightly developed basal terrace, and frequent occurrence in ambulacra of plates separated from perradial suture.

*Material.*—The specimen occurred in a dense oolitic limestone, and was cleaned by grinding away this matrix with a dental machine. As the secondary spines were in place on the test before cleaning, the echinoid was obviously little disturbed during its burial by oolitic sands. The test is complete except for the peristomal plates, the lantern, and most of the apical system. The original calcite of the plates is present, with the only change being the filling of the interstices of the plates with clear calcite making their microstructure remarkably clear.

*Shape.*—Specimen showing no sign of crushing, presumably retaining original shape. Test low, 145 mm. in horizontal diameter, 55 mm. high, with concave apical and peristomal regions. Largest cidarid described with largest previously known (Mortensen, 1928, p. 10) only 110 mm. in horizontal diameter.

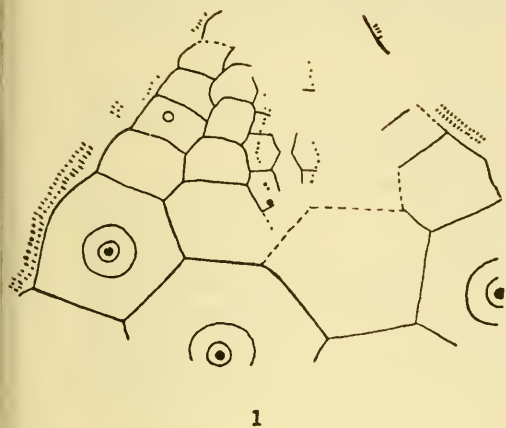
*Apical system.*—Most plates of apical system missing except in oral portion of one interambulacrum having along its midline three columns of small plates with outer columns perforated by longitudinal series of pores, three to five in each plate (text fig. 1). Plate arrangement not clear as this part of test dissolved during fossilization with many plates now absent or only partially preserved. Pores, because of regular pattern, symmetrical occurrence, probably original with echinoid, being unlikely that boring animal would drill such orderly series of holes. Plates perhaps representing single genital plate split into smaller plates, pores being genital pores, as frequently occurring in the Echinothuridae (Agassiz and Clark, 1909, p. 147).

*Ambulacra.*—Extremely narrow, each approximately 6.5 mm. wide at midzone, one-thirteenth width of interambulacrum, sinuous, reflect-

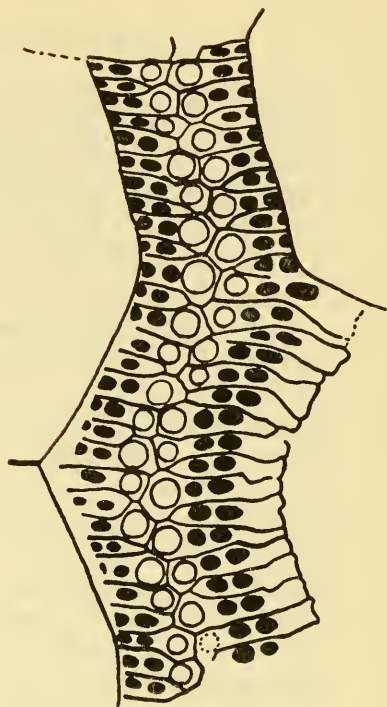
ing curved surface of adambulacral plates, with 20-25 plates to each adambulacral plate at midzone. Pore pairs uniserial, outer pore larger, more elongated transversely than inner pore. Plates imbricating strongly orally, and under adambulacral plates, extension or flange of each ambulacral plate (pl. 3A, fig. 2) extending aborally from near junction of aboral ambulacral suture and perradial suture. Flange thin, sloping slightly inward, not visible where plates in proper position but seen only where plates displaced away from perradial suture. Ambulacral plate figured in plate 3A, figure 2, revealed by removal of two plates immediately aboral to it. Every second or third plate in a series separated (text fig. 2) from perradial suture by expansion of tubercle-bearing portion of adjacent ambulacral plate. This arrangement of ambulacral plates never described before in any other archaeocidarid, and not found during author's examination of many species of genus. In portion of ambulacra aboral to last tubercle-bearing interambulacral plate, ambulacra nearly straight, with lower plates, outer pore of pore pair more elongated, being slitlike in appearance.

*Interambulacra*.—Broad, each averaging 85 mm. in width at midzone, with four columns in each area. Plates of two inner columns hexagonal, at midzone each being approximately 25 mm. wide, 17 mm. high. Adambulacral plates narrower, pentagonal with adradial side of plate curved, plate at midzone 22 mm. wide, 17 mm. high. Most interambulacral plates bearing one large perforated tubercle with diameter approximately one-half height of plate. Each tubercle with steep-sided boss, well-developed parapet, straight neck, deeply perforated mame-lon, with perforation extending to base of boss. Tubercle illustrated in plate 3A, figure 1, not showing deep perforation because plates not broken in vertical section through perforation but at angle to it. Most of plates with no basal terrace or scrobicule although slightly developed in several. Secondary tubercles in row around margin of each plate with approximately 30 on plate at midzone. Aboral interambulacral plates much smaller, lacking tubercles, one of most oral bearing incipient tubercle with slightly developed boss, no perforation. In nearly complete column, five small aboral plates without tubercles, seven large plates with tubercles. Plates imbricating strongly over ambulacra, very slight imbrication of plates of median columns over adambulacral plates. No evidence of aboral imbrication except in small, thin, tubercleless plates in aboral region.

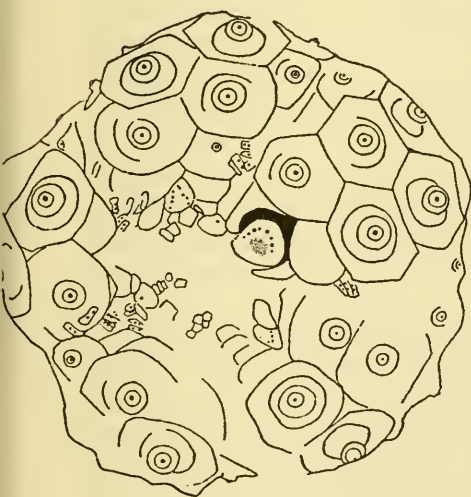
*Spines*.—Portions of several primary spines visible in matrix; circular in section, hollow, longitudinally finely striate, long, tapering, with well-developed ring. Longest portion of spine 35 mm. long, but less



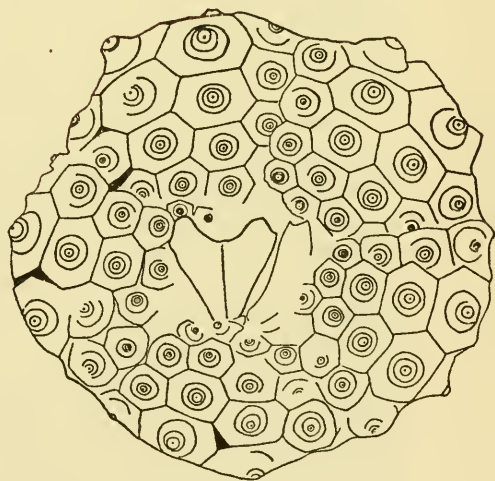
1



2



3



4

FIGS. 1-4.—1, 2, *Archaocidaris immanis* Kier, new species: 1, Aboral portion of interambulacrum showing small perforated plates between the two inner columns. These plates may represent a divided genital plate,  $\times 1$ . (See pl. 1.) 2, Portion of an ambulacrum showing every second or third plate in a series separated from perradial suture by expansion of tubercle-bearing portion of adjacent plate,  $\times 4$ . (See pl. 2, fig. 4.) Both holotype, U.S.N.M. 90763.

3, 4, *Archaocidaris blairi* (Miller): 3, Aboral surface showing portion of apical system, with genital plates revealed by removal of aboral interambulacral plates which had shifted over apical area during flattening of test,  $\times 2.6$ . (See pl. 4A, fig. 1.) Figured specimen U.S.N.M. S3828. 4, Same specimen, but showing oral surface,  $\times 2.6$ .

than one-third diameter of thickest spine which must have been considerably longer. Small spines attached to secondary tubercles on edge of interambulacral plates approximately 7 mm. long, longitudinally striated, hollow, nontapering.

*Type*.—Holotype, U.S.N.M. 90763.

*Horizon and locality*.—Pennsylvanian (Dewey limestone), NE $\frac{1}{4}$  sec. 33, T. 23 N., R. 12 E., Washington County, Okla.

*Discussion*.—This specimen is remarkable not only because of its great size, but also as it is the first specimen of *Archaeocidaris* showing its original shape and the first well-preserved member of the genus from the Pennsylvanian. It is easily distinguished from all the other species of *Archaeocidaris*, based on reasonably well-preserved specimens, by its large size, slightly developed basal terrace and scrobicule, and by the frequent occurrence in the ambulacra of plates separated from the perradial suture.

The presence of imbrication in the ambulacral plates of *Archaeocidaris* casts further doubt on any lineage of the Cidaroida from the Archaeocidaridae as proposed by Mortensen (1928, p. 58), and Durham and Melville (1957, p. 245). It seems more reasonable to consider, as Jackson did (1896, p. 237; 1912, p. 249), that the archaeocidarids are not ancestors of the post-Paleozoic cidarids, and that the cidarids never passed through a four-columned interambulacrum stage. Hawkin's series (1943, p. lxxv), with the cidarids passing through *Miocidaris*, is much preferred to any lineage through *Archaeocidaris*.

*Morphological note*.—In no other species of *Archaeocidaris* have ambulacral plates been described with a flange for perradial overlap. This flange, however, is probably present in all species of this genus, as the author has seen it in every specimen having ambulacral plates of every species studied including the following: *A. wortheni* Hall (American Museum Natural History, cotype, 7747/1), *A. agassizi* Hall (U.S.N.M. S3825), *A. legrandensis* Miller and Gurley (University of Chicago Museum, holotype, 6198), *A. aliquantula*, new species (U.S.N.M. 136453), *A. blairi* (Miller) (U.S.N.M. S3828), *A. newberryi* Hambach (U.S.N.M. S3899), *A. rossica* (Buch) (Mus. Comp. Zoology, Harvard, 3087). Jackson (1912, pl. 12, fig. 10) shows a vertical perradial suture in his figure of an ambulacral plate of *A. rossica*. However, I have examined this specimen and found the perradial suture to be oblique, not vertical, with each plate having a flange as described above.

The ambulacral plates were removed and separated in a specimen of *A. agassizi* (see Jackson, op. cit. pl. 13, fig. 4). In Jackson's figure



and in plate 3B, figure 3, the overlapping of the plates is not apparent where the plates are in normal position, but their separation (pl. 3B, fig. 4) reveals the flange and perradial overlap.

This overlap in the ambulacral plates of *Archaeocidaris* results in a stronger suture between the plates than that found in plates with a vertical suture (see p. 23).

#### ARCHAEOCIDARIS ALIQUANTULA Kier, new species

##### Plate 3C

*Diagnosis.*—Species characterized by small size, with coarse radial plications on interambulacral plates extending from basal terrace to margin of plates.

*Material.*—There are many loose specimens and many crowded on slabs. All are flattened and covered with spines, and on many specimens the secondary spines are still attached. The presence of attached spines, and the occurrence of a thin layer of marl over the echinoids indicates that they were smothered and buried by a deposit of calcareous mud which prevented disturbance of the tests by scavengers and currents (Laudon, 1957, p. 963).

*Shape.*—Probably originally low, with shape similar to *Archaeocidaris immanis*.

*Apical system.*—On paratype U.S.N:M. 136467 two plates present: genital 2 with madreporic pores, ocular II with one pore.

*Ambulacra.*—Only short portions and isolated plates present with two columns of low uniserial primaries each bearing one secondary spine. Ambulacra narrow, apparently straight, beveling under adambulacral plates, with approximately four to five ambulacral plates for each adjacent adambulacral plate at midzone. Each plate bearing flange for perradial overlap.

*Interambulacra.*—Broad, composed of four columns of thin imbricating plates. Adambulacral plates pentagonal, higher than wide; plates of inner columns hexagonal, wider than high. Plates imbricating aborally and over ambulacra, each bearing one large centrally located tubercle deeply perforated with bottom of pit extending to near base of boss. Basal terrace slightly developed, not visible on many specimens. Secondary tubercles around margin of each plate with 25 to 30 on plate at midzone; coarse radial plications extending from tubercles, across slightly developed scrobiculate to basal terrace.

*Peristome.*—Large, 5 mm. in diameter on specimen 13 mm. in horizontal diameter, covered with numerous small, low plates imbricating orally.

*Lantern*.—Inclined with deep foramen magnum.

*Spines*.—Primary spines extremely long, over 30 mm., length greater than horizontal diameter of echinoid. Spines slightly striated, no spinules, well-developed milled ring, hollow from near tip to near milled ring with cavity approximately one-half width of spine. Secondary spines short, striated, present on ambulacral plates, peristomal plates, and around margin of each interambulacral plate.

*Types*.—Holotype, U.S.N.M. 136451; paratypes, U.S.N.M. 136452-3.

*Horizon and locality*.—Mississippian (Kinderhookian—Gilmore City formation) quarries of Northwestern States Portland Cement Co. and Pennsylvania Dixie Cement Co., about one mile northwest of Gilmore City, Pocahontas County, Iowa. Collector: Lowell R. Laudon.

*Discussion*.—Of all the species of *Archaeocidaris*, this species resembles most *A. blairi* (Miller) from the Meramecian of Missouri. It is distinguished from this species by its less developed basal terrace and scrobicule, and in having coarse radial plications extending from the secondary tubercle on the margin of each interambulacral plate to the basal terrace, as contrasted to *A. blairi* in which extremely fine radial plications occur along the basal terrace but do not reach these secondary tubercles.

#### ARCHAEOCIDARIS BLAIRI (Miller)

Plate 4A; text figures 3, 4

*Eocidaris blairi* Miller, 1891. Advance Sheets, 17th Rep. Geol. Surv. Indiana, p. 73, pl. 12, figs. 1, 2.

*Archaeocidaris legrandensis* (part) Jackson, 1912. Mem. Boston Soc. Nat. Hist., vol. 7, pp. 260-261, pl. 8, figs. 7, 8, pl. 9, figs. 12, 13.

In order to explain the function of the pore-bearing plates in the aboral interambulacrum of *Archaeocidaris immanis* described above, it was essential to learn the nature of the apical system in *Archaeocidaris*. Except for several possible genital plates described by Jackson (1912, pp. 265-266) the apical system is unknown in the genus. A search was made of all the specimens in the U. S. National Museum and any specimen that might have the plates was cleaned. On a specimen of *A. blairi* occurred a plate larger than the others, pierced with one pore, and located on the edge of the periproctal area. As this plate beveled under adjacent interambulacral plates, these plates were removed, revealing seven more pores of what was obviously a genital plate. The removal of similar plates at the aboral extremities of the

ambulacra and interambulacra revealed two more genitals, including the madreporite and two oculars. It is apparent that the flattening of the test of an *Archaeocidaris* forces the thin, nontuberculate aboral interambulacral plates up and over the genitals and oculars, thus hiding the apical system from view.

As the above-mentioned specimen of *A. blairi* is from the same locality, Boonville, Mo., as Miller's type specimen, and as it shows features not visible on his types, it warrants description.

*Material.*—There is one well-preserved specimen, which, although flattened, shows most of its interambulacral plates. It is 24 mm. in horizontal diameter, 7 mm. at its greatest height.

*Apical system.*—Genitals 1, 2, 3; oculars I, III visible. Genital 2 broad, rounded (text fig. 3), width nearly equal to height, larger than other genitals, pierced with eight genital pores and numerous madreporic pores. Genital 3 narrow, with eight or nine pores; genital 1 partly uncovered, six pores visible. Genital pores extremely small being of approximately same size as ambulacral pores. Ocular plates small relative to genitals, each pierced in oral region by one small pore. Both ocular and genital plates thin, beveling under interambulacra. Imbrication relationship of oculars to ambulacra not clear. Many small, irregularly shaped periproctal plates within ocular-genital ring.

*Ambulacra.*—On most of test not visible due to slippage of interambulacral plates over ambulacra at time of flattening of specimen. Plates thin, beveled for perradial imbrication.

*Interambulacra.*—Four columns in each area with from 9 to 11 plates in a column; plates of median columns hexagonal, wider than high, largest plate approximately 5 mm. wide, 4 mm. high. Adambulacral plates pentagonal, narrow, width less than height, imbricating over ambulacra. Large perforated tubercle with well-developed basal terrace and wide scrobicule on each plate except near apical area. Extremely fine radial plications on edge of basal terrace. Aborally, first three or four plates in a column bearing no tubercles; here plates thin, strongly imbricating aborally. In area 3, most oral plate bearing one incipient perforate tubercle, no basal terrace.

*Lantern.*—Portions of two pyramids visible; foramen moderately deep.

*Figured specimen.*—U.S.N.M. S3828.

*Horizon and locality.*—Mississippian (Meramecian—Warsaw formation), from Boonville, Mo.

*Discussion.*—Jackson (1912, p. 260) placed *A. blairi* in synonymy with *A. legrandensis*, as he was unable to see any difference between

Miller and Gurley's type specimens of *A. legrandensis* and Miller's of *A. blairi*. However, I have studied the type specimens of *A. legrandensis*, and they are so poorly preserved that it is not possible to determine whether or not the specimens represent the same species as *A. blairi*. Considering the difference in the age of the specimens, *A. legrandensis* being Kinderhookian and *A. blairi* Meramecian, it seems best to maintain the two species.

#### POLYTAXICIDARIS Kier, new genus

Two columns in each ambulacrum ; numerous columns in each interambulacrum. Interambulacral plates thin, imbricating slightly aborally, beveling over ambulacra ; adambulacral plates same size as plates of inner columns. Perforated tubercles on most ambulacral and interambulacral plates.

*Type species.*—*Polytaxicidaris dyceri* Kier, new species.

*Discussion.*—This genus belongs to the family Archaeocidaridae. Jackson (1912, p. 206) placed three genera in the family: *Eocidaris*, *Archaeocidaris*, and *Lepidocidaris*. *Eocidaris* was based on isolated interambulacral plates and cannot be maintained as a usable genus (Mortensen, 1928, p. 58). *Polytaxicidaris* differs from *Archaeocidaris* in having more than four columns in each interambulacrum, and in having perforate tubercles on most of the ambulacral plates. It differs from *Lepidocidaris* in not having every third ambulacral plate higher and wider at the midzone than the others, in having perforate tubercles on most of the ambulacral plates, and in not having a high rounded area beyond the scrobicular ring on each interambulacral plate. Mortensen (1928, p. 58) did not consider *Lepidocidaris* as an archaeocidarid but placed it among the lepidocentrids because of the absence of a cortex layer on the spines in *Lepidocidaris*. However, the presence of a cortex layer cannot be considered a diagnostic feature of the archaeocidarids because most of the species of *Archaeocidaris*, based on well-preserved tests, do not have this layer as shown by the fine longitudinal striations, and lack of spinules on the spines. Both of these characters are considered by Mortensen (1935, p. 48) as evidence of a lack of cortex. He further distinguishes *Lepidocidaris* from this family by the enlargement of every third ambulacral plate at the midzone. However, the ambulacral plates are not always similar in other genera of the family as shown above in *Archaeocidaris immanis* (see text fig. 2) and in *Polytaxicidaris*. It therefore seems more reasonable to consider *Lepidocidaris* as an archaeocidarid.

Mortensen included *Nortonechinus* among the archaeocidarids, but

until the number of ambulacral columns is known in this genus, its reference to this family can only be tentative. *Polytaxicidaris* is easily distinguished by its interambulacral plates which are more regular in outline and bear a more pronounced primary tubercle, with the scrobicular tubercles occurring around the margin of the plate instead of being in a ring as in *Nortonechinus*.

The discovery of a species of Paleozoic echinoid having interambulacral plates similar to those found in *Archaeocidaris*, but belonging to a separate genus, makes unwise the erection of species of *Archaeocidaris* based on isolated interambulacral plates.

#### POLYTAXICIDARIS DYERI Kier, new species

Plates 4B, 5A; text figure 5

*Diagnosis*.—Having only one reasonably well-preserved specimen, diagnosis of species not possible.

*Material*.—There are six specimens, all preserved as impressions in a siltstone. The holotype is represented by two impressions, one of the oral surface, the best preserved of all the impressions; the other of the aboral surface showing part of both the inner and outer surface of the plates. Both the apical system and peristome are absent owing to the breaking through of the test of the lantern. The other specimens are not as well preserved and show only portions of the test. All the specific description is based on the holotype except for details of the spines from the paratypes.

*Shape*.—Not known, specimen flattened during or after burial.

*Ambulacra*.—Detailed structure not visible, narrow, approximately one-fifth width of interambulacra, straight with curved adradial margins reflecting curved margin of adambulacral plates, with approximately four pore pairs to each adjacent adambulacral plate. On oral surface, single regular series of small perforated tubercles running length of each half-ambulacrum between pore pairs and perradial suture, one-half as many tubercles as pore pairs. Because of poor preservation, not certain whether tubercle on every other ambulacral plate as in *Archaeocidaris* (text fig. 2) or on a compound plate with two pore pairs, as in Jurassic genus *Paracidaris* (illustrated in Mortensen, 1928, p. 478). On aboral surface, at midzone, tubercles as described above for oral surface, but nearer apical system apparently more tubercles, with one tubercle for each pore pair, poor preservation preventing certainty on this point.

*Interambulacra*.—Seven columns visible in all areas of holotype ex-

cept in one. In this area, although probably seven originally present, only six visible, as portion of test not preserved where seventh column would occur. Column 5 in middle of each interambulacrum with columns 6 and 7 on either side. Plates thin, imbricating slightly aborally, beveling over ambulacra, with well-developed, perforated primary tubercle near center of plate, slightly developed basal terrace, row of secondary tubercles around margin of each plate with approximately 25 on plate at midzone. Plates of inner columns hexagonal, wider than high except for initial plate of columns 5, 6, 7 where higher than wide, pentagonal, and usually without primary tubercle. Adambulacral plates pentagonal with curved adradial margin, approximately same size as plates of inner columns.

*Spines.*—Primary spines of interambulacral plates longitudinally finely striate, tapering, with well-developed milled ring. No complete spine, longest fragment 12 mm. long. Ambulacral spines smaller, longest 6 mm. long, with well-developed milled ring, slight taper. Secondary spines, formerly attached to scrobicular tubercles, small, less than 2 mm. long, details not discernible.

*Types.*—Museum of Comparative Zoology, Harvard: Holotype, 3354; figured paratype, 3353; unfigured paratype, 3352. New York State Museum, Albany: Paratypes, 11060-1.

*Horizon and locality.*—Mississippian (Osagean, Borden Group), Crawfordsville, Ind. Collector: C. B. Dyer.

### Family PALAEOCHINIDAE McCoy

#### Genus PALAEOCHINUS McCoy

#### PALAEOCHINUS TETRASTICHUS Kier, new species

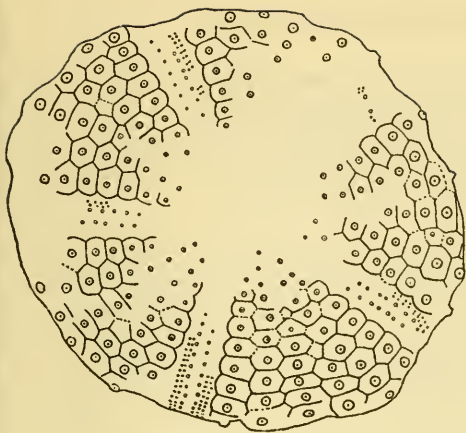
Plate 5B; text figures 6-10

*Diagnosis.*—Species characterized by four columns of similar plates in each interambulacrum, with five ambulacral plates to each adambulacral plate at midzone.

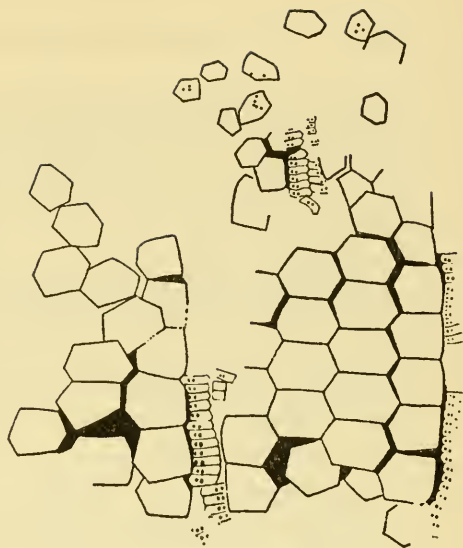
*Material.*—There are portions of five specimens present on a slab of irregularly bedded, argillaceous, bioclastic limestone. These specimens are flattened, with some plates shifted from their original position on the tests. Their plates are well preserved, still retaining their microstructure, and with the tubercles still present on their external surfaces.

*Shape.*—Vertically elongated as indicated by slight curvature of ambulacral margins throughout length.

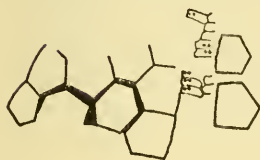
*Apical system.*—Three or possibly four genital plates on holotype,



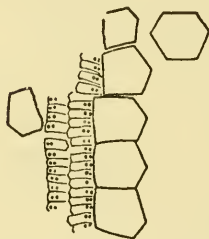
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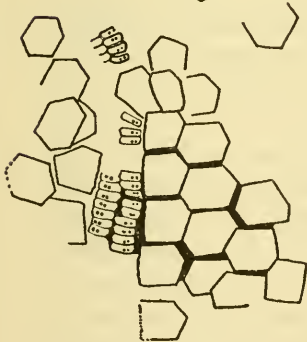
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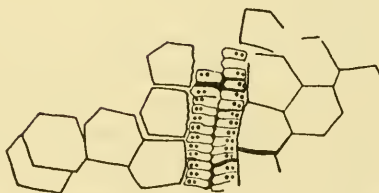
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FIGS. 5-10.—5, *Polytaxicidaris dyeri* Kier, new species: Aboral surface based on cast of holotype, Museum of Comparative Zoology, coll. 3354,  $\times 2$ . (See pl. 4B, fig. 4.)

6-10, *Palaechinus tetrastichus* Kier, new species: 6, Holotype, U.S.N.M. 136454,  $\times 1.5$ . (See pl. 5B, fig. 3.) 7, Paratype, U.S.N.M. 136458,  $\times 1.5$ . 8, Paratype, U.S.N.M. 136457,  $\times 1.5$ . (See pl. 5B, fig. 3.) 9, Paratype, U.S.N.M. 136455,  $\times 1.5$ . (See pl. 5B, fig. 2.) 10, Paratype, U.S.N.M. 136456,  $\times 1.5$ . (See pl. 5B, fig. 3.)

two small, pentagonal, with three pores, third large with five pores, fourth may be genital plate, larger than other three, pentagonal with two pores on one margin of plate, no pores visible on other margin. Several smaller, angular, probably periproctal plates in same region with genital plates.

*Ambulacra*.—At midzone, 4 to 5 mm. wide, one-fourth width of interambulacra, with two columns of similar primary plates in each area. Five plates to each adambulacral plate at midzone, four near oral, aboral extremities. Plates pentagonal except where hexagonal opposite suture between two adjacent interambulacral plates. Pore pairs in peripodia, uniserial. Four to five secondary tubercles on each plate between pore pair and perradial suture.

*Interambulacra*.—At midzone, 18-19 mm. wide, four columns in each area. Plates of inner columns hexagonal, much wider than high; adambulacral plates pentagonal, slightly wider than high, notched along adradial suture for ambulacral plates, very slightly beveled under ambulacra. Sutures between interambulacral plates vertical with no indication of imbrication. Approximately 60 secondary tubercles on plate of inner column at midzone.

*Lantern*.—Not preserved.

*Spines*.—Several spines on tests and in matrix: narrow, longest 4 mm. long, vertically finely striated.

*Types*.—Holotype, U.S.N.M. 136454; paratypes, U.S.N.M. 136455-8.

*Horizon and locality*.—Mississippian (Madison formation, Lodgepole member) at type section of Lodgepole limestone, Little Chief Canyon, Fort Belknap Indian Reservation. Collector: R. M. Stainforth.

*Discussion*.—Three other species of *Palaechinus* are known with four columns of interambulacral plates in each area. *P. quadriserialis* Wright from the Lower Carboniferous of Ireland differs in having narrower adambulacral plates, and ambulacra with plates alternately enlarged at adradial margin. *P. globulus* Jackson from the Tournaisien of Belgium is easily distinguished by its spheroidal shape and in having smaller and narrower plates in the inner columns of the interambulacra, and in having eight ambulacral plates to each adambulacral plate as opposed to five in *P. tetrastichus*. *P. visetensis* Jackson from the Viséen of Belgium is easily distinguished by its extremely vertically elongated test with a spiral twist, and by its high interambulacral plates.



## Family ECHINOCYSTITIDAE Gregory

## Genus LEPIDECHINUS Hall

## LEPIDECHINUS COOPERI Kier, new species

Plate 6; text figures 11, 12

*Diagnosis.*—Species characterized by small size, similar ambulacral plates with four plates to each adambulacral plate, and five columns in each interambulacrum.

*Material.*—There are many specimens of this species, most of them occurring on slabs. All are flattened except for one slightly crushed test.

*Shape.*—Spherical to slightly higher than wide.

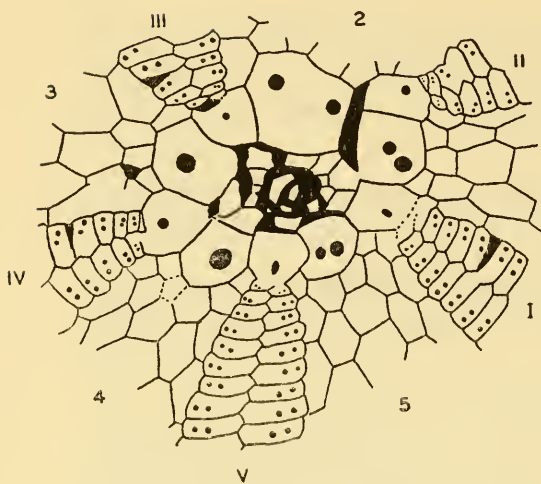
*Apical system.*—Well preserved in holotype (text fig. 11), portion in paratype U.S.N.M. 136460. Oculars large, pierced by one pore in oral portion of plate, insert except possibly ocular II in holotype being separated from periproct by genitals 1 and 2, separation resulting from displacement of plates during fossilization. Genital plates slightly larger than oculars except genital 2, much larger, approximately twice size of other genitals, not pierced by madreporic pores. Genitals 2, 5, 1 pierced by two pores each, genitals 3, 4 by one. Periproctal plates small, irregular in shape.

*Interambulacra.*—Five columns of thin imbricating plates in each area; adambulacral plates high, pentagonal; plates of inner columns approximately as wide as high, hexagonal. Plates imbricating aborally, laterally from center over ambulacra. Shape and occurrence of initial plates of columns exactly as shown by Jackson (1896) to be typical of most Paleozoic echinoids, with initial plate of column five (text fig. 12) pentagonal with apex of pentagon pointing orally; initial plate of column three hexagonal, although in some interambulacral areas heptagonal, followed by pentagonal initial plate of column four. Single plate in first row of each area.

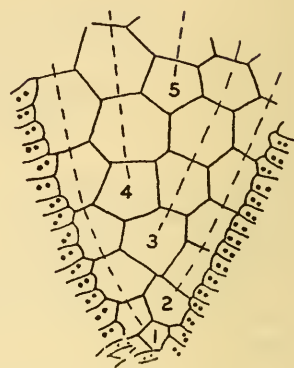
*Peristome.*—Small, surrounded by ambulacral plates with initial plate of interambulacrum separated from peristome.

*Lantern.*—Small, inclined, foramen magnum deep, braces block-shaped identical to those in *Lepidechinus iowensis* Jackson (1912, pl. 63, fig. 3). Portions of epiphyses and teeth visible, but shape not clear.

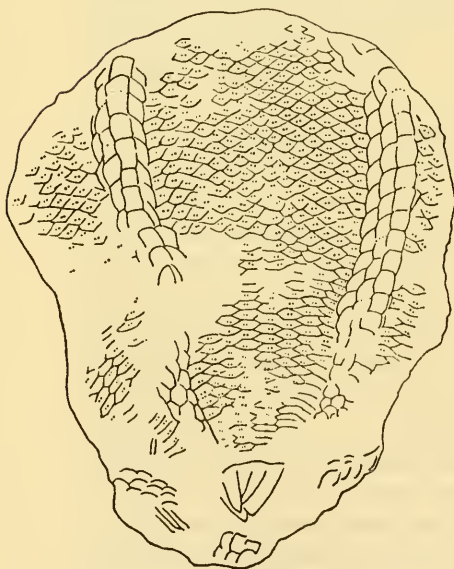
*Spines.*—Test covered with small, striated secondary spines with slightly dilated bases. Each ambulacral plate bearing one spine between pore pair and perradial suture. Approximately 15 spines on each interambulacral plate.



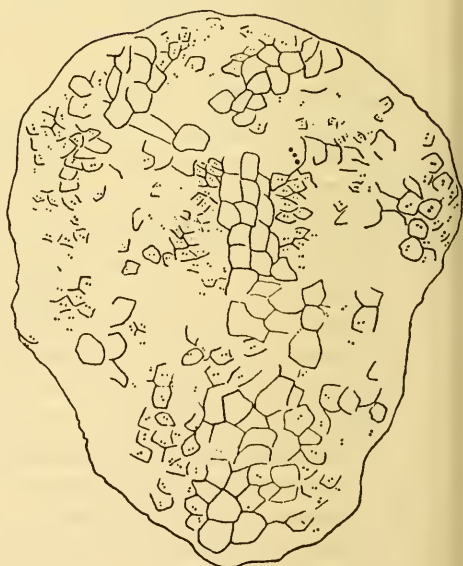
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FIGS. 11-14.—11, 12, *Lepidechinus cooperi* Kier, new species: 11, Apical system of holotype, U.S.N.M. 136458,  $\times 8$ . (See pl. 6, fig. 1.) 12, Oral interambulacrum of paratype, U.S.N.M. 136460,  $\times 6$ . (See pl. 6, fig. 4.)

13, 14, *Lepidesthes colletti* White: Both surfaces of specimen U.S.N.M. 136466,  $\times 2$ . (See pl. 8B, fig. 6.)

*Types*.—Holotype, U.S.N.M. 136458; paratypes, U.S.N.M. 136459-60.

*Horizon and locality*.—Mississippian (Kinderhookian—Gilmore City formation) quarries of Northwestern States Portland Cement Co. and Pennsylvania Dixie Cement Co., about 1 mile northwest of Gilmore City, Pocahontas County, Iowa. Collector: L. R. Laudon.

*Discussion*.—This species is easily distinguished from the other two species of *Lepidechinus* having five columns in each interambulacrum: *L. iowensis* Jackson from the Mississippian of Burlington, Iowa, and *L. belgicus* Jackson from the Viséen of Belgium. *L. iowensis* is much larger, has wider ambulacra, and its ambulacral plates are higher with every third plate in a column much larger than the other two. In *L. iowensis* there are seven ambulacral plates to an adambulacral plate, whereas there are only four in *L. cooperi*. Furthermore, in *L. iowensis* every third plate in a column is considerably larger. The known specimens of *L. belgicus* are so poorly preserved as to make comparison difficult; however, the ambulacra are much narrower in *L. belgicus* than in *L. cooperi*.

Genus **LEPIDESTHES** Meek and Worthen

**LEPIDESTHES ALTA** Kier, new species

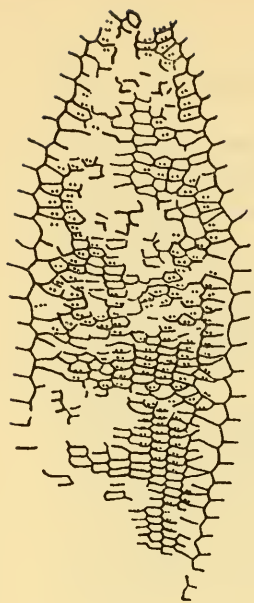
Plate 7; text figures 15-20

*Diagnosis*.—Species characterized by high test, 3 columns in interambulacrum at midzone, 10 to 12 in ambulacrum.

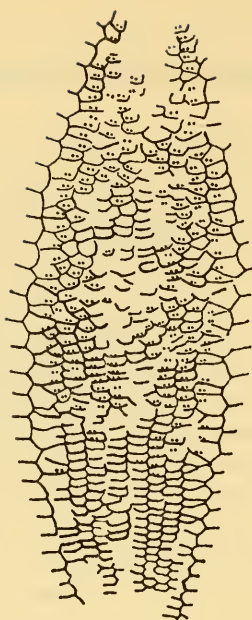
*Material*.—This species is based on one silicified specimen, which is for the most part an internal mold, except where the plates are still present in the oral portion of interambulacrum 5, its adjacent ambulacra, and most of the apical system and peristome. The silicification is coarse with the surface details of the plates not preserved. The test is not flattened vertically, but is slightly compressed through its width.

*Shape*.—Test highly inflated, higher than wide, height 80 mm., average width 60 mm. with greatest width aboral to midzone, narrowing orally. Apical system at apex of test; peristomal region only slightly concave.

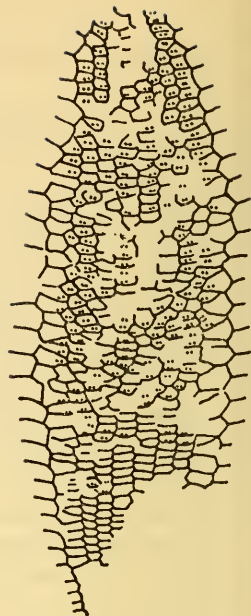
*Apical system*.—Partially preserved (pl. 7, fig. 5) with portions visible of genitals 1, 2, 4; oculars III, IV. Genital 2 approximately twice as large as other genitals, three pores visible, probably five or six originally, presence or absence of madreporic pores not possible to determine because of coarse silicification. Genitals 1, 4 with five, possibly six, genital pores. Oculars insert, nearly as wide as genitals, considerably lower, each with one pore near aboral margin.



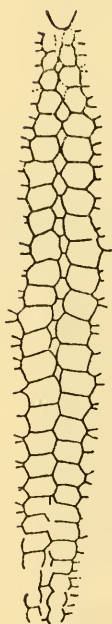
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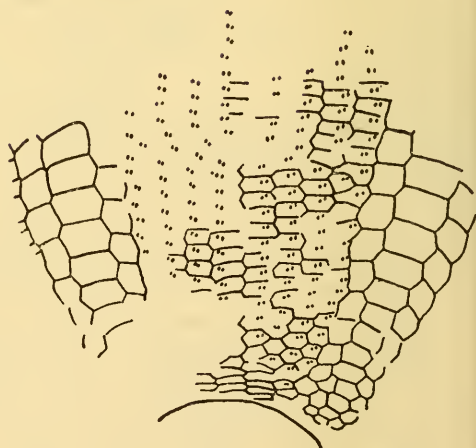
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FIGS. 15-20.—*Lepidesthes alta* Kier, new species: 15-19, Casts of interior surfaces of ambulacra I, II, III, and interambulacra 1, 2, respectively, of holotype, U.S.N.M. 80554,  $\times 1$ . (See pl. 7.) In these areas of holotype, plates absent, being represented by mold of interior surface of plates. Drawings of casts reversed in order to show plates in proper position as viewed from the exterior. 20, Exterior surface of portion of ambulacrum V and its adjacent interambulacra. In this portion of the holotype, the plates are still represented, therefore showing the arrangement of the plates at the exterior of the test,  $\times 1.5$ . (See pl. 7, figs. 2, 4.)

*Peristome*.—Very small, less than 10 mm. in diameter or one-sixth horizontal diameter of test. Bordering area composed of many columns of very low, wide ambulacral plates with at least three or four plates in each column. Interambulacra not reaching peristome, separated from it by ambulacral plates.

*Ambulacra*.—Average width at midzone 23 mm., nearly twice width of interambulacra. In most of ambulacra I, II, III, V (text figs. 15-17) plates preserved as internal molds, showing different shape, size than would be visible on exterior. On interior, plates of ambulacral columns adjacent to interambulacra larger than those of inner columns, but on exterior, of approximately same size. Exterior of plates preserved only in oral portion, plates low, width twice height, hexagonal with plates of columns adjacent to interambulacra narrower, pentagonal or hexagonal. In small portion of ambulacra IV showing exterior outline near midzone, plates narrower, width equal to height. Actual outline of isolated plate not known. Plates imbricating orally, laterally beveling under interambulacra, 60 to 80 plates in one column. No spinose processes evident on ambulacral plates as described by Cooper (1931, p. 537) in *Lepidesthes warrensis*. Pore pairs situated eccentric of center of plate on side nearest adjacent interambulacra, away from median line of ambulacra, with two inner columns of pores farther apart than others.

*Interambulacra*.—One-half width of ambulacra: 11 mm. at midzone. Three columns in each area except near peristome (text fig. 20) where four, in arrangement similar to that figured by Jackson (1912, pl. 67, fig. 8) in specimens of his *Lepidesthes wortheni*. Plates of median columns hexagonal, wider than high; adambulacral plates narrower, higher than wide, with rounded adradial border. Plates imbricating aborally, laterally over ambulacra, with plates of median columns beveling strongly over adjacent adambulacral plates, on interior appearing very narrow, in some cases not evident (text fig. 18).

*Type*.—Holotype, U.S.N.M. 80554.

*Horizon and locality*.—Mississippian (Meramecian—base of St. Louis or Warsaw limestone), Highland Rim, west of Nashville, Tenn.

*Discussion*.—This specimen is remarkable as it preserves the original shape of the echinoid. All previously described specimens of *Lepidesthes* have been flattened. Because of its high test, this echinoid must have had some difficulty maintaining an upright position, and it is probable that its tube feet were extremely long, extending from ambulacral plates well up on the test, to reach the sea floor and steady the animal. Presumably it lived in quiet water, as is true of modern echinoids of similar shape (Mortensen, 1935, p. 49).

Of all the species of *Lepidesthes*, this one resembles most *L. wortheni* from the Keokuk group at Crawfordsville, Ind. Both species have three columns of interambulacral plates at the midzone with four near the peristome. *L. alta* differs in having wider interambulacra, and ambulacra with 10 to 12 columns at the midzone as opposed to 8 in *L. wortheni*. Finally, the oral ambulacral plates are lower in *L. wortheni*.

**LEPIDESTHES GRANDIS** Kier, new species

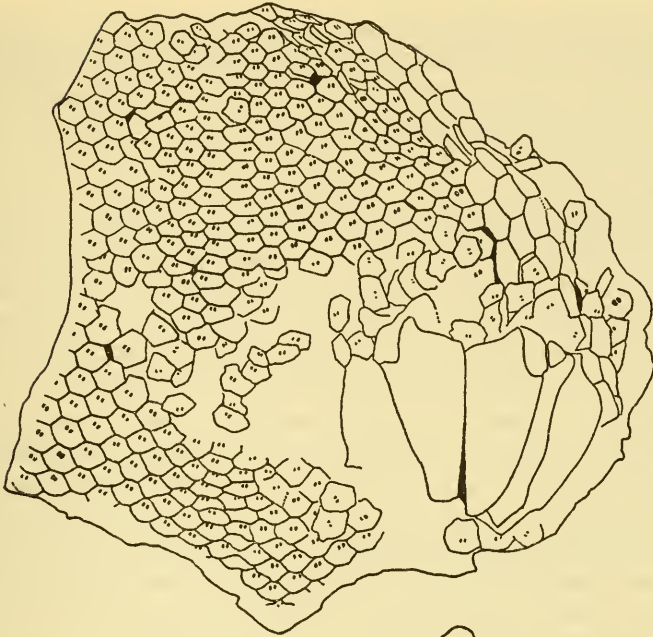
Plate 8A; text figures 21, 22

*Diagnosis*.—Species characterized by large size, 20 columns in each ambulacrum, four in each interambulacrum.

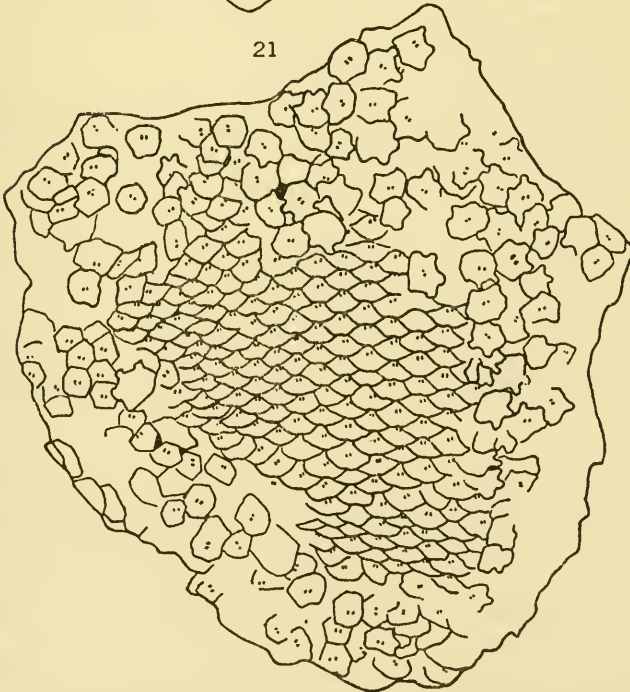
*Material*.—There are four flattened fragments. The holotype, the largest, is 90 mm. wide, 85 mm. high, 20 mm. thick, with one surface showing the midzone portion of two ambulacra, one interambulacrum, and a portion of the lantern; the other surface showing the oral portion of an ambulacrum. The other fragments are small, showing portions of the ambulacra, and interambulacra. In all the fragments, the plates are very well preserved with the tubercles, peripodia, and spines present. The aboral portion of the test and the apical system are not preserved.

*Shape*.—Not known. Test extremely large with an approximated horizontal diameter over 130 mm.

*Ambulacra*.—Extremely wide, approximately 65 mm. at midzone, five times width of interambulacra; 20 columns at midzone. Plates imbricating orally, with greatest imbrication in oral portion of test, laterally beveling under interambulacra. At midzone, plates hexagonal, wider than high, plates of median columns lower, wider than other plates. Pore pairs in peripodia in upper middle of exposed portion of plates except in median columns where occurring on side of plate away from median suture. Pores oblique to surface with pore pairs on under surface located more orally than pore pairs on upper surface. Edges of plates notched and grooved (see pl. 8A, fig. 3) resulting in interlocking of plates when in original position; imbrication slight. Oral of midzone, plates gradually lose hexagonal shape becoming irregular in outline, with exposed portion of plates considerably wider than high, with curved contacts with adjacent plates. Plates oral of midzone (see pl. 8A, fig. 4) approximately twice as thick as midzone plates, pore pairs located in center of exposed portion of plate immediately below adjacent aboral plate, pores not as oblique as in midzone plates. Imbrication very great with less than one-half area of plate exposed



21



22

FIGS. 21-22.—*Lepidesthes grandis* Kier, new species: 21, One side of holotype, U.S.N.M. 136461, showing most of width of portion of an ambulacrum at the midzone and a portion of an adjacent interambulacrum,  $\times 1$ . (See pl. 8, fig. 1.) 22, Other side of holotype showing portion of ambulacrum oral to midzone,  $\times 1$ .

to surface, with low angle from horizontal of edge or sutural portion of plates. In many plates aboral portion bilobed (see pl. 8A, fig. 5) with lobes extending on either side of pore pairs on under surface of adjacent aboral plates. Paratype U.S.N.M. 136464 with many low, lathlike plates probably from peristome.

*Interambulacra*.—At midzone four columns of hexagonal, higher than wide plates imbricating aborally, laterally over ambulacra. Plates notched, grooved, interlocking when in original position. In paratype U.S.N.M. No. 136462, oral portions of interambulacrum visible with plates more imbricate, more rounded than at midzone. Several poreless plates lying near this interambulacrum possibly representing fifth column but due to shifting of plates not possible to be certain.

*Lantern*.—One pyramid, two half-pyramids, portion of two epiphyses, one brace present on holotype. Lantern large with pyramid 25 mm. high, 22 mm. wide. Foramen magnum shallow, with sides of wide-angled pyramid corrugated for attachment of interpyramidal muscles. Epiphyses cap half-pyramids, extremely wide extending high above upper limits of outline of half-pyramid but not joined, widest epiphyses ever described in Paleozoic echinoid. Outer surface of each epiphysis corrugated where plate joins half-pyramid. Tip of brace exposed between two adjacent epiphyses.

*Spines*.—Longitudinally deeply striated, expanded bases, tapering, with approximate maximum length of 5 mm. Secondary tubercles on most of surface of interambulacral and ambulacral plates.

*Types*.—Holotype, U.S.N.M. 136461; paratypes, U.S.N.M. 136462-4.

*Horizon and locality*.—Pennsylvanian (Strawn group, Millsap Lake formation). Found in wash on old Evans farm,  $\frac{3}{4}$  mile south of Dennis, Hood County, Tex. Collector: Mrs. J. H. Renfro.

*Discussion*.—Having 20 columns in each ambulacrum immediately distinguishes this echinoid from any other known species of *Lepidesthes*. Previously the maximum number of columns known in an ambulacrum of *Lepidesthes* was 16. The great size of its test further distinguishes *L. grandis* from all other species of this genus. The only other echinoid having as many columns in each ambulacrum is *Meekechinus elegans* Jackson, with 20 columns. In *Meekechinus*, however, primary tubercles occur on both the interambulacral and ambulacral plates. These tubercles are the distinguishing feature between *Meekechinus* and *Lepidesthes*.

*Morphological notes*.—The imbrication of the plates in *Lepidesthes* has always been considered as evidence of former flexibility of the



test. While flexibility accompanies imbrication in the Echinothuridae and no doubt in some Paleozoic echinoids, it apparently did not occur in this species of *Lepidesthes*, as it is obvious that no sliding could have occurred along the sutures between the plates. The ambulacral and interambulacral plates at the midzone of the test are notched and grooved along their edges preventing any movement. In the oral portion of the test the ambulacral plates could not have shifted without cutting off the tube feet of an adjacent plate. The imbrication served not for flexibility but rather for strength, with the elimination of a vertical suture. Where the angle of the sutural portion of a plate is low, the sutural area is great with a strong bond resulting between the plates, but where the suture is vertical the thickness of the suture can be no greater than the thickness of the plate. For example, a plate with an edge having an angle of 30 degrees to the horizontal will have twice the sutural area of a plate with a vertical suture. Furthermore, the vertical suture is more susceptible to fracture as it is parallel to the force of a blow upon the surface of the test, whereas the oblique suture is at an angle to the blow with part of the force being transmitted through the plate rather than along the plate surface.

#### LEPIDESTHES COLLETTI White

Plate 8B; text figures 13, 14

*Lepidesthes colletti* White, 1878. Proc. Acad. Nat. Sci. Philadelphia, p. 33.

In the U. S. National Museum is an echinoid from the Warsaw limestone at Boonville, Mo., which can be referred to this species. White's holotype, long missing, is now at the U. S. National Museum (135221) (Trumbull, in press) and was available for comparison. The Boonville specimen is similar in all respects to the holotype.

*Figured specimen*.—U.S.N.M. 136466.

*Horizon and locality*.—Mississippian (Meramecian—Warsaw limestone), Boonville, Mo.

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## EXPLANATION OF PLATES

## PLATE 1

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|---|------|
| <i>Archaeocidaris inmanis</i> Kier, new species.....  | 3    |
| Aboral view, $\times 1$ , holotype, U.S.N.M. 90763. Specimen photographed under glycerine with that portion of specimen showing only matrix later air brushed out by Lawrence B. Isham, scientific illustrator. Pennsylvanian (Dewey limestone), NE $\frac{1}{4}$ sec. 33, T. 23 N., R. 12 E., Washington County, Okla. Portion of interambulacrum visible in upper right-hand portion of photograph depicted on text figure 1. |      |

## PLATE 2

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|--|---|
| <i>Archaeocidaris inmanis</i> Kier, new species.....   | 3 |
| 1, 2, Side views, $\times 1$ ; 3, oral view, $\times \frac{1}{2}$ ; 4, enlarged view of portion of ambulacrum visible in lower part of figures 1 and 3 of this plate, with drawing of same region on text figure 2, $\times 3$ , holotype, U.S.N.M. 90763. Photographed under glycerine. |   |

## PLATE 3

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A. <i>Archaeocidaris immanis</i> Kier, new species.....	3
1, View of fracture surface across interambulacral plates showing absence of basal terrace, $\times 1$ . Photographed under glycerine. 2, View of ambulacral plate showing well-developed flange for perradial overlap, $\times 8$ , holotype, U.S.N.M. 90763.	
B. <i>Archaeocidaris agassizi</i> Hall.....	7
3, View showing ambulacral plates in place; 4, view showing isolated ambulacral plates after their removal from area shown in figure 3. Note that perradial flange is not visible where plates in original position (fig. 3) but visible where plates separated, $\times 6$ , figured specimen, U.S.N.M. S3825. Mississippian (Lower Burlington), Burlington, Iowa.	
C. <i>Archaeocidaris aliquantula</i> Kier, new species.....	7
5, Oral view, $\times 4$ , holotype, U.S.N.M. 136451; 6, view of interambulacral plates showing coarse radial plications extending from basal terrace to margin of each plate, $\times 4$ , paratype, U.S.N.M. 136452; 7, view of ambulacral, interambulacral, plates, and primary and secondary spines, $\times 4$ , paratype, U.S.N.M. 136453. Mississippian (Kinderhookian), Gilmore City formation, Gilmore City, Iowa.	

## PLATE 4

A. <i>Archaeocidaris blairi</i> (Miller).....	8
1, Aboral view; 2, oral view. $\times 2$ , U.S.N.M. S3828. Photographed under glycerine. Mississippian (Warsaw), Boonville, Mo. Drawing of specimen on text figures 3, 4.	
B. <i>Polytaxicidaris dyeri</i> Kier, new species.....	11
3, View of oral surface; 4, cast of oral surface; 5, view of aboral surface, $\times 2$ , holotype, Museum of Comparative Zoology, Harvard, 3354. Mississippian (Osagean), Borden Group, Crawfordsville, Ind. Drawing of figure 4 on text figure 5.	

## PLATE 5

A. <i>Polytaxicidaris dyeri</i> Kier, new species.....	11
1, View of paratype, $\times 2$ , Museum of Comparative Zoology, Harvard, 3353. Mississippian (Osagean), Borden Group, Crawfordsville, Ind.	
B. <i>Palaechinus tetrastichus</i> Kier, new species.....	12
2, View of paratype, $\times 1$ , U.S.N.M. 136455; 3, view of slab containing holotype, U.S.N.M. 136454, the large specimen, and two paratypes, U.S.N.M. 136456 (upper right) and U.S.N.M. 136457 (lower left), $\times 1$ . Mississippian, Madison formation, Lodgepole member, at type section of Lodgepole limestone, Little Chief Canyon, Fort Belknap Indian Reservation. Drawings of specimens on text figures 6, 8, 9, 10.	

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system of this specimen on text figure 11. 2, Oral view of lantern,  $\times 4$ , paratype, U.S.N.M. 136459; 3, aboral view; 4, view of portion of oral side,  $\times 4$ , paratype, U.S.N.M. 136460. Drawing of oral portion of interambulacrum of this specimen on text figure 12. Photographed under glycerine. Mississippian (Kinderhookian), Gilmore City formation, Gilmore City Iowa.,

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- Lepidesthes alta* Kier, new species..... 17  
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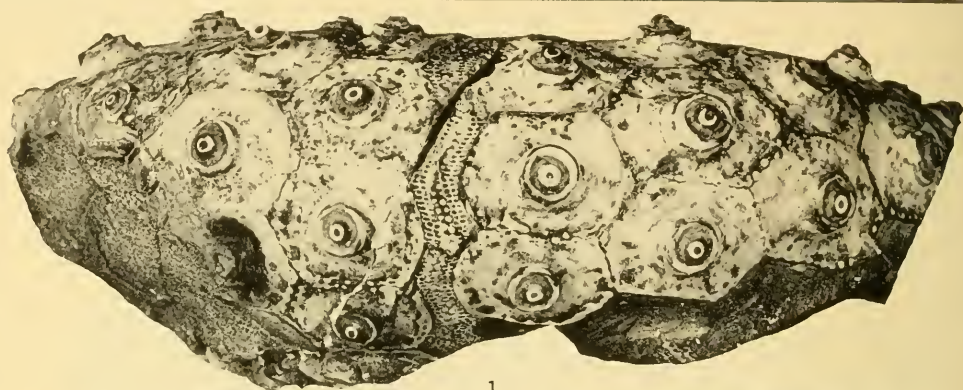
## PLATE 8

- A. *Lepidesthes grandis* Kier, new species..... 20  
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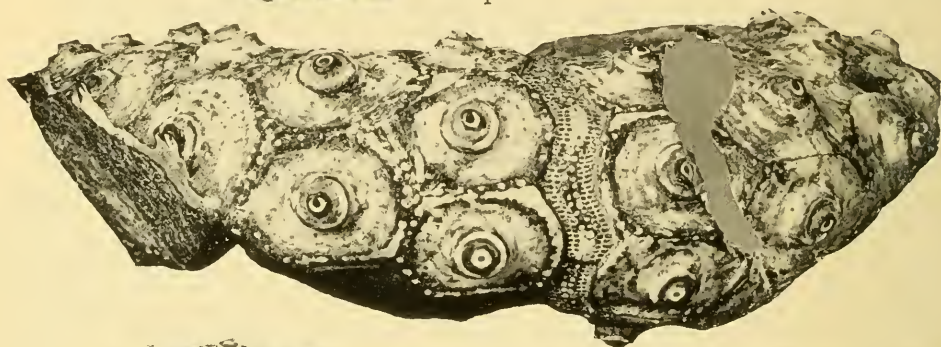


ARCHAEOCIDARIS IMMANIS KIER, NEW SPECIES

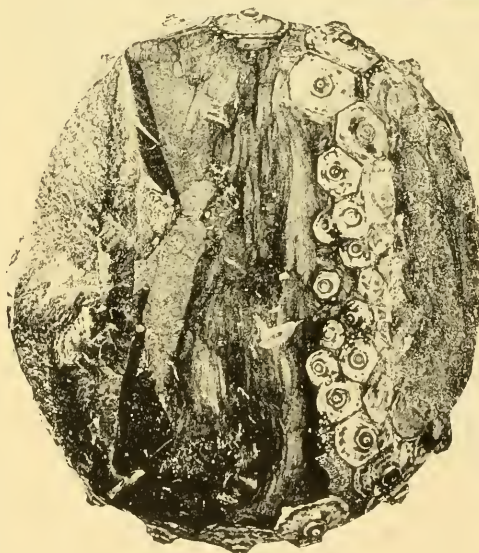
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1



2



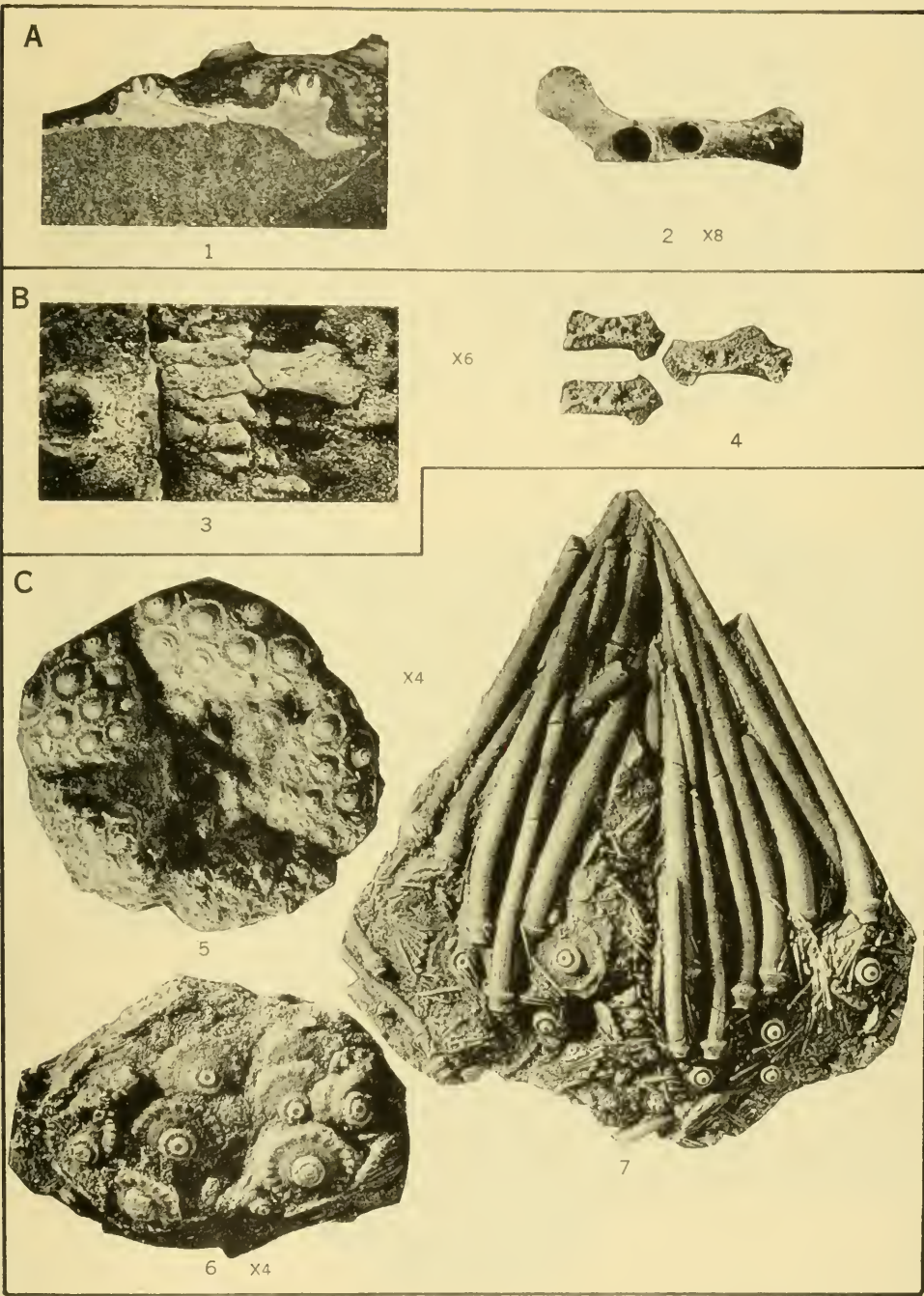
3  $\times \frac{1}{2}$



4  $\times 3$

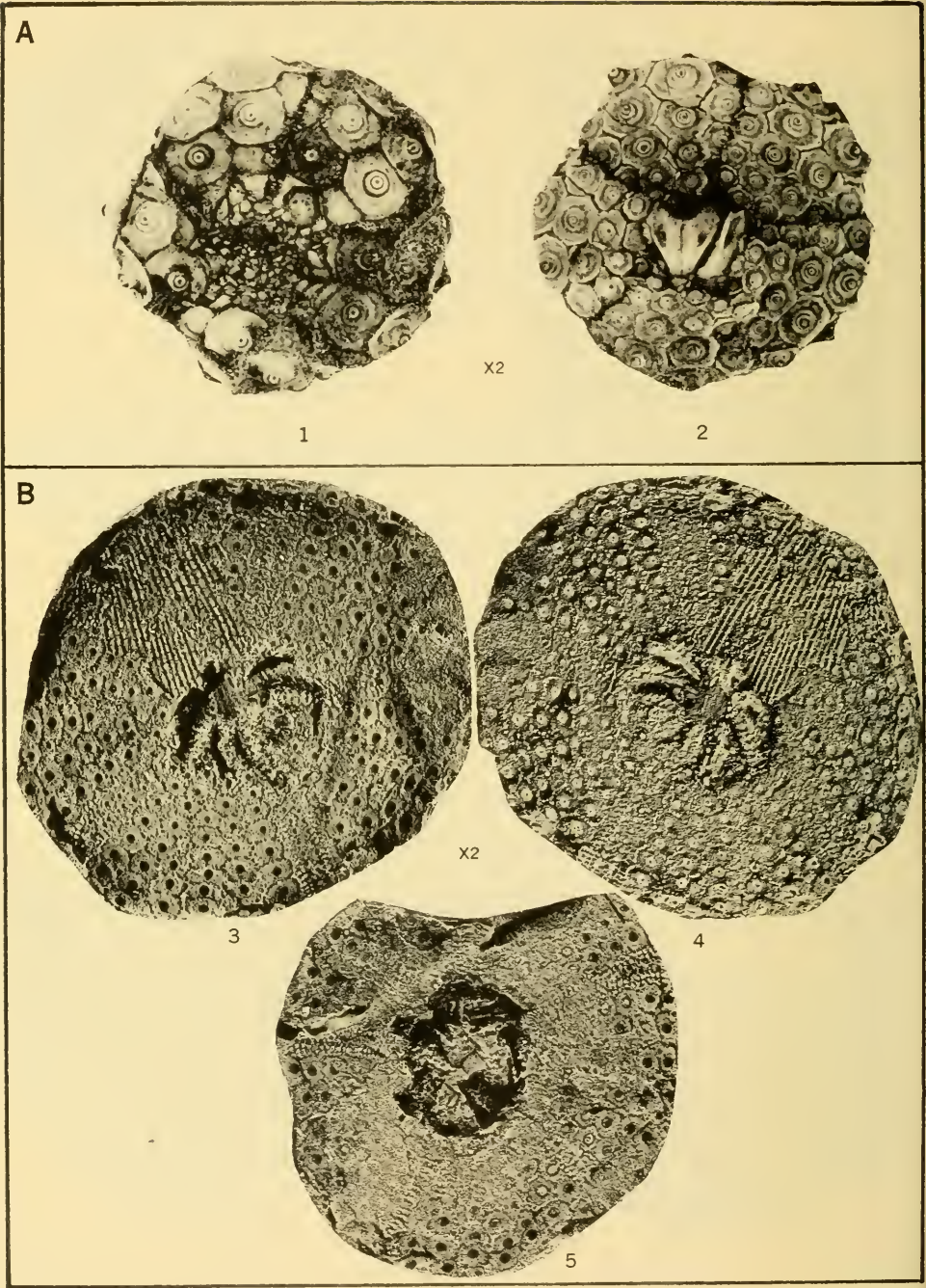
*ARCHAEOCIDARIS IMMANIS* KIER, NEW SPECIES

(See explanation at end of text.)



ARCHAEOCIDARIS IMMANIS KIER, NEW SPECIES; ARCHAEOCIDARIS AGASSIZI HALL; AND ARCHAEOCIDARIS ALIQUANTULA KIER, NEW SPECIES

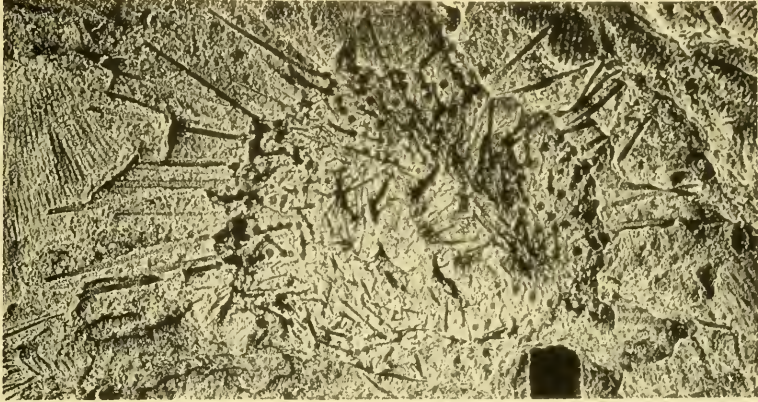
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ARCHAEOCIDARIS BLAIRI (MILLER) AND POLYTAGICIDARIS DYERI KIER, NEW SPECIES  
(See explanation at end of text.)

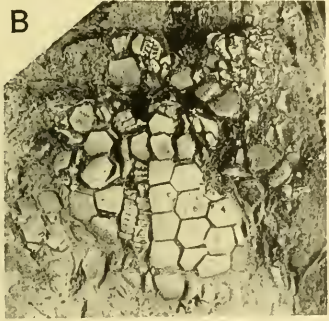


A

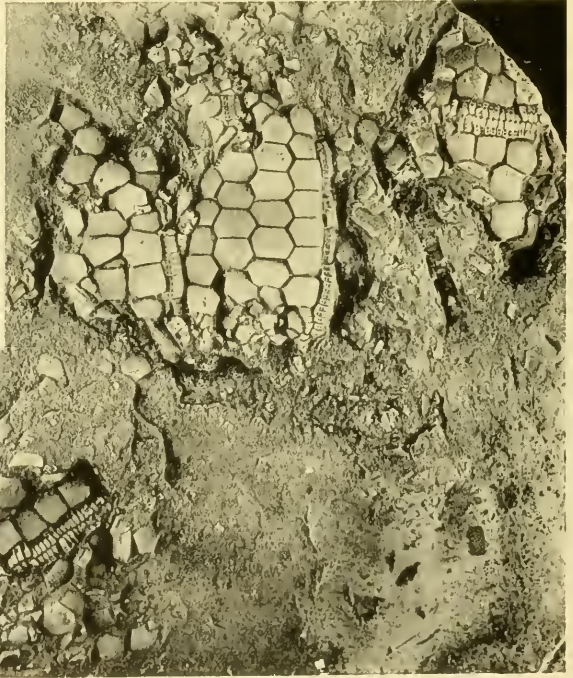


1 X2

B



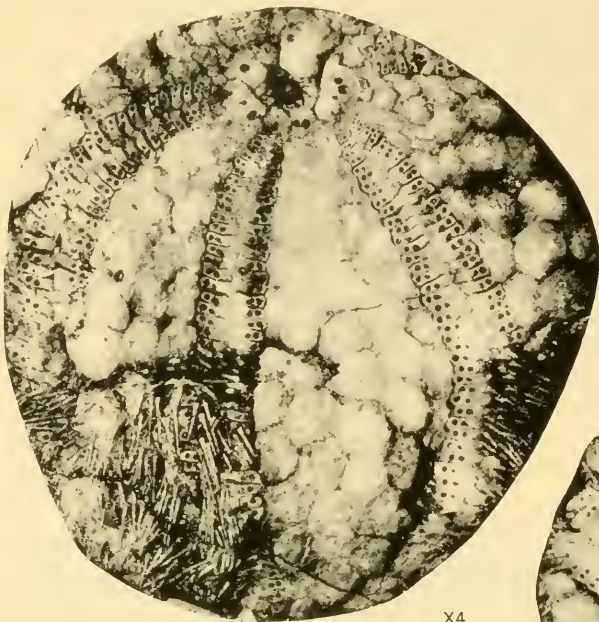
2



3

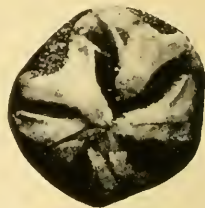
POLYTAXICIDARIS DYERI KIER, NEW SPECIES, AND PALAEOCHINUS TETRASTICHUS KIER, NEW SPECIES

(See explanation at end of text.)

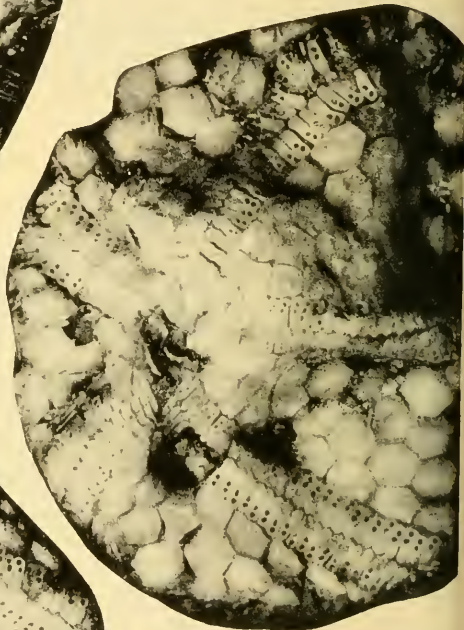


1

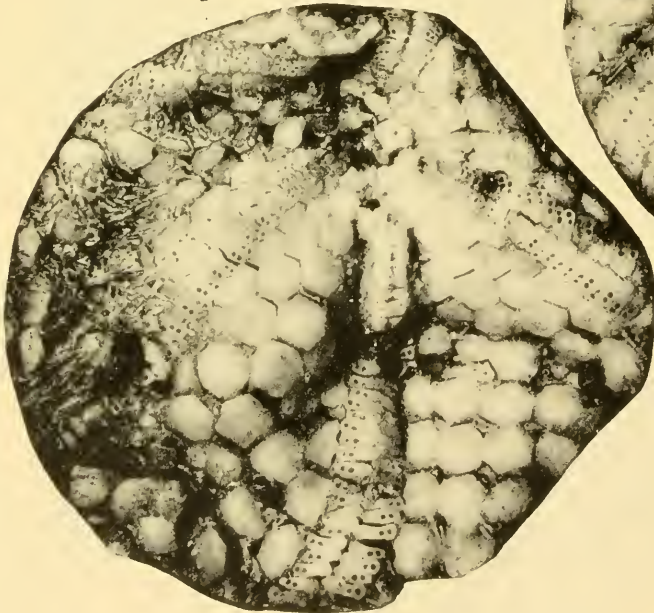
X4



2 X4



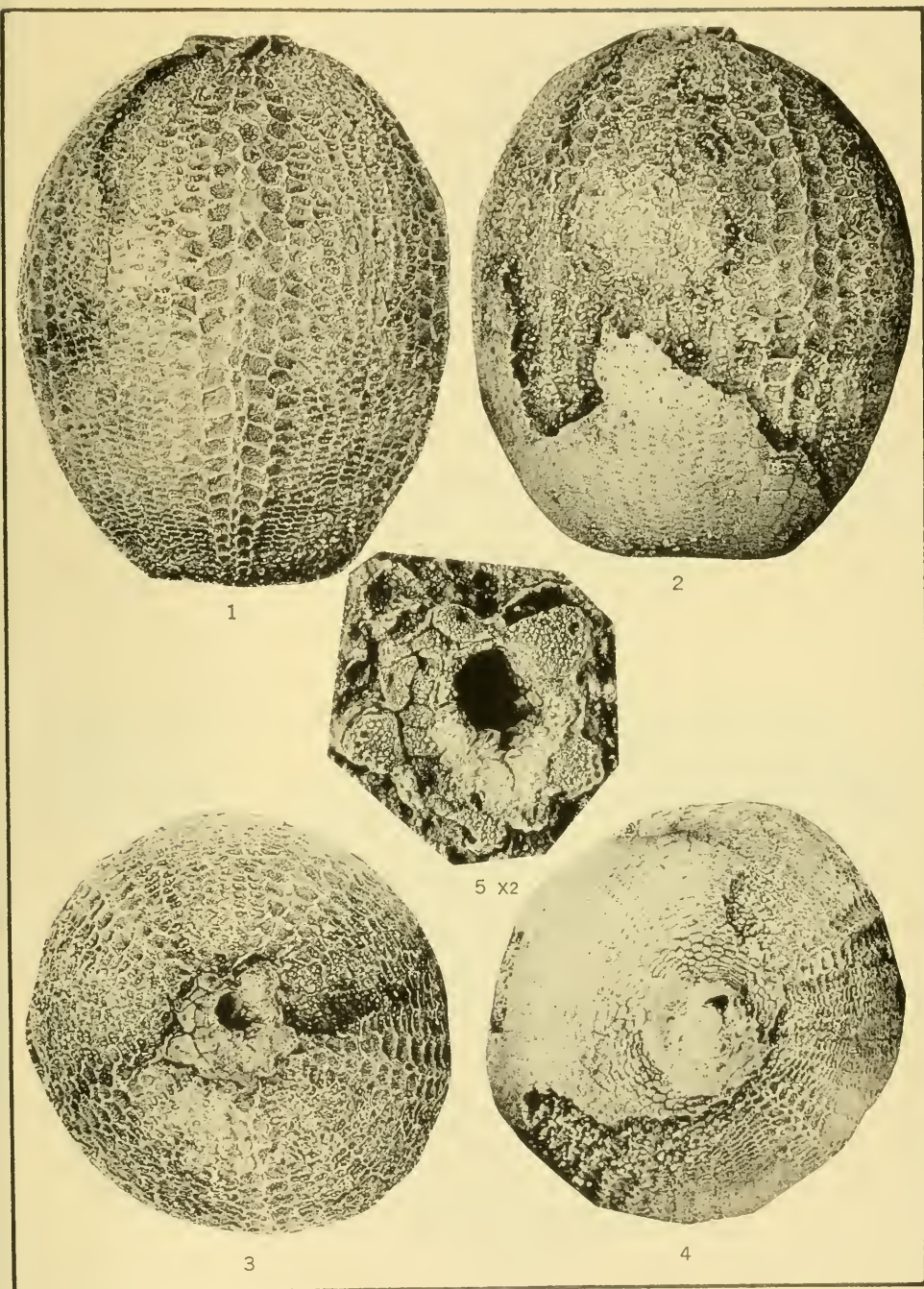
4



3

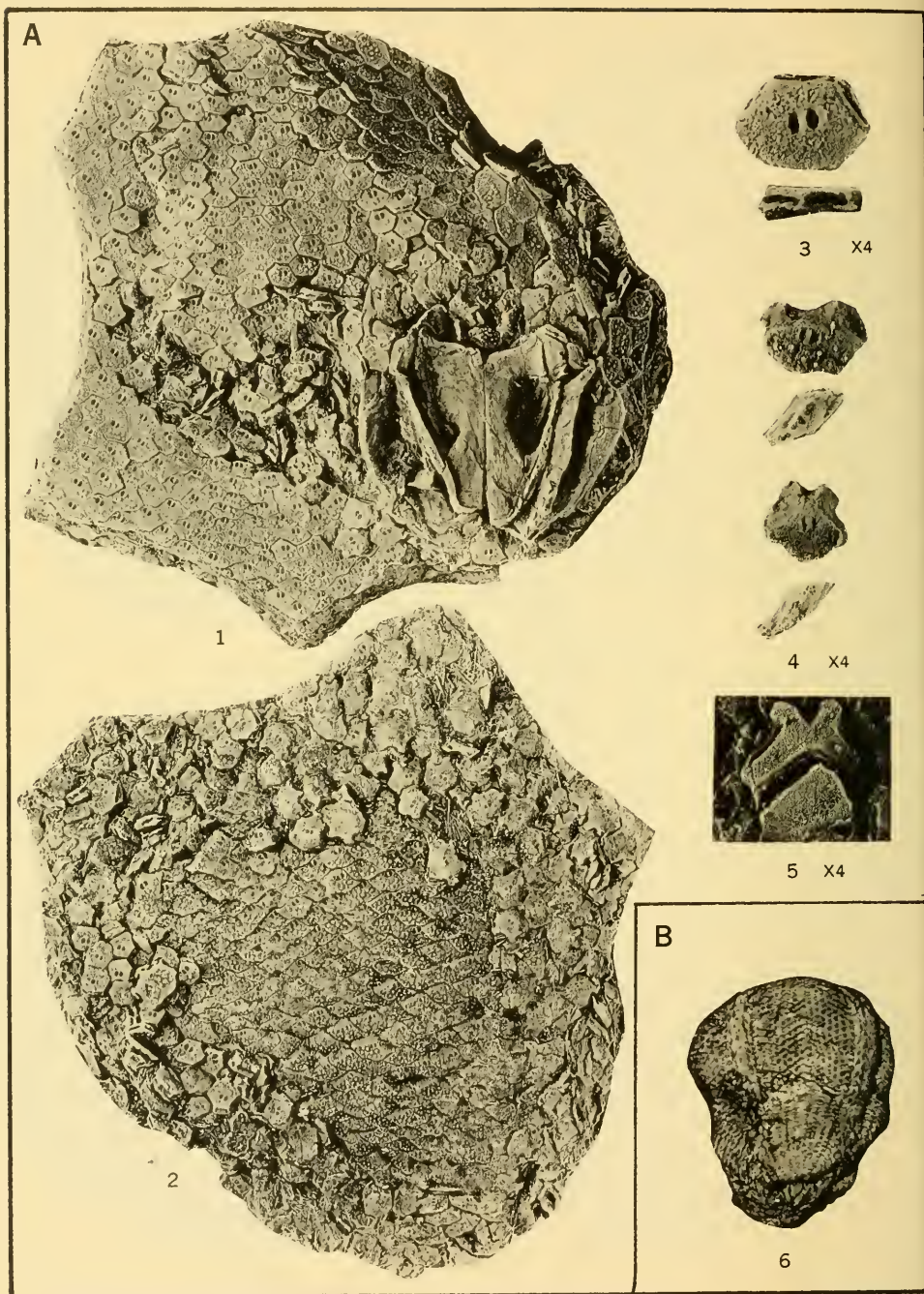
LEPIDECHINUS COOPERI KIER, NEW SPECIES

(See explanation at end of text.)



*LEPIDESTHES ALTA* KIER, NEW SPECIES

(See explanation at end of text.)



LEPIDESTHES GRANDIS KIER, NEW SPECIES, AND LEPIDESTHES COLLETTI WHITE  
(See explanation at end of text.)