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A New Species of Bothriocidarid (Echinoidea) from the Cincinnati Maquoketa Group of Iowa

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A new species of echinoid, *Bothriocidarid maquoketensis*, has been discovered in the Cincinnati (Upper Ordovician) Fort Atkinson Formation, Maquoketa Group, of northeastern Iowa. The new species is characterized by

two widely spaced primary perforate tubercles on opposite sides of the peripodia and by numerous paired interambulacral plates. This occurrence extends the geographic and stratigraphic range of *Bothriocidarid* in North America.

INDEX DESCRIPTORS: Echinoidea, *Bothriocidarid maquoketensis*, Maquoketa Group, Upper Ordovician, Iowa.

The bothriocidarid echinoids are a primitive family of sea urchins known only from Ordovician rocks of Europe and North America. At present the family consists of three distinctive genera — *Bothriocidarid*, *Neobothriocidarid*, and a new genus to be described by Kier (in press) from the Bromide Formation of Oklahoma. The three genera are similar in that they are characterized by a small, rigid test that is composed of thick, nonimbricated plates. In addition, they all possess podial pores that open externally in distinct peripodia surrounded by a rim on which one or more perforate spine tubercles are developed. They differ markedly with respect to the position of the radial water vessels (internal or within the ambulacral plates), arrangement of ambulacra, position and shape of podial pores, and the development of interambulacra.

The fossil record of the bothriocidarid echinoids is scant, and well-preserved specimens are rare. Two fairly well-preserved specimens representing a new species, *Bothriocidarid maquoketensis*, have been found in the Cincinnati (Upper Ordovician) Fort Atkinson Formation, Maquoketa Group, of northeastern Iowa. The occurrence extends the geographic and stratigraphic range of *Bothriocidarid* in North America.

On the basis of conodont faunas (Sweet et al., 1959), the Fort Atkinson Formation is considered to be late Edenian in age. If so, it is likely that *B. maquoketensis* n. sp. is approximately equivalent in age to *B. parvus* Mannil (1962) and *B. globulus* Eichwald (1860), both from the Upper Ordovician Vormsi F1b strata of Estonia.

SYSTEMATIC PALEONTOLOGY

Class ECHINOIDEA Leske

Subclass PERISCHOECHINOIDEA M'Coy

Order BOTHRIOCIDAROIDA Zittel

Family BOTHRIOCIDARIDAE Klem

Genus BOTHRIOCIDARIS Eichwald

Type species. — *Bothriocidarid globulus* Eichwald, 1860, p. 654.

Diagnosis. — Bothriocidaridae with ambulacra arranged in two columns that terminate adorally in a single nonporiferous plate and apically in a single radial (ocular), one of which is a madreporite; one pore pair per ambulacral plate, pores diverging toward interior; interambulacra in a single column or with paired plates, interambulacra not reaching the peristome; lantern and spines present.

Remarks. — Most species of *Bothriocidarid* are characterized by single-columned interambulacra and thus differ from modern echinoids, which possess two columns of interambulacral plates, and

from most other Paleozoic species which have numerous plates either arranged in several columns or irregularly arranged. It is evident from the material described here, however, that the interambulacral columns in *Bothriocidarid* may consist in part of paired plates. Although the paired plates are suggestive of double-columned interambulacra, the lack of interradial genital plates and the position of origin of the interambulacra suggest that *B. maquoketensis* n. sp. is nothing more than a divergent species of *Bothriocidarid*.

Bothriocidarid maquoketensis

Pl. 1, fig. 1-8; text fig. 1

Diagnosis. — A species of *Bothriocidarid* characterized by two widely spaced perforate tubercles, one on either side of the peripodium; interambulacra that consist of numerous paired plates that tend to alternate with a single plate near the ambitus; one to three perforate tubercles on the interambulacral plates.

Material. — Two specimens, both free from the matrix, were available for study. The holotype (SUI 42700) is a nearly complete specimen that for the most part has retained its original spherical shape. The test is 9 mm in diameter and is composed of approximately 135 plates. The paratype (SUI 42701) is a somewhat distorted specimen that was probably about 16 mm in diameter. Some of the plates are disarticulated and were pushed to the interior or lost during preservation. Both specimens have been abraded and most of the surface detail has been destroyed. The pores and some sutures are filled with clear calcite cement. Both specimens are in the repository at the University of Iowa, Iowa City, Iowa.

Description. — The plates of the apical system in the holotype are intact except for one radial that is displaced slightly below the surface of the test and one or two disarticulated plates at the center. In this specimen the apical system consists of five relatively large, thick, contiguous radial plates (text fig. 1B). The radials are slightly wider than high. One radial possesses a single, small, round pore situated half way between the center of the plate and the interradial suture. The four other radials do not appear to have pores or slits. Surface features have been abraded from all radials except one, which possess two elevated perforate tubercles. Eight or nine smaller plates are located within the circlet of radials; the five largest plates are in the interradial position and three or four smaller plates are located at the center of the apical system.

The apical system in the paratype is mostly disarticulated; only two radials are intact. One of the radials clearly possesses two widely spaced pores. There are two closely spaced perforate tubercles on the other radial. In addition, when viewed under xylol there is an anastomose network of dark calcite, not seen on any other plate, near the base of the two tubercles, but it is not clear whether this structure passes through the plate to the interior as would be expected if it were the madreporite (text fig. 1C). If this is the madreporite, it is possible that the two pores on the remaining radial plate are genital pores.

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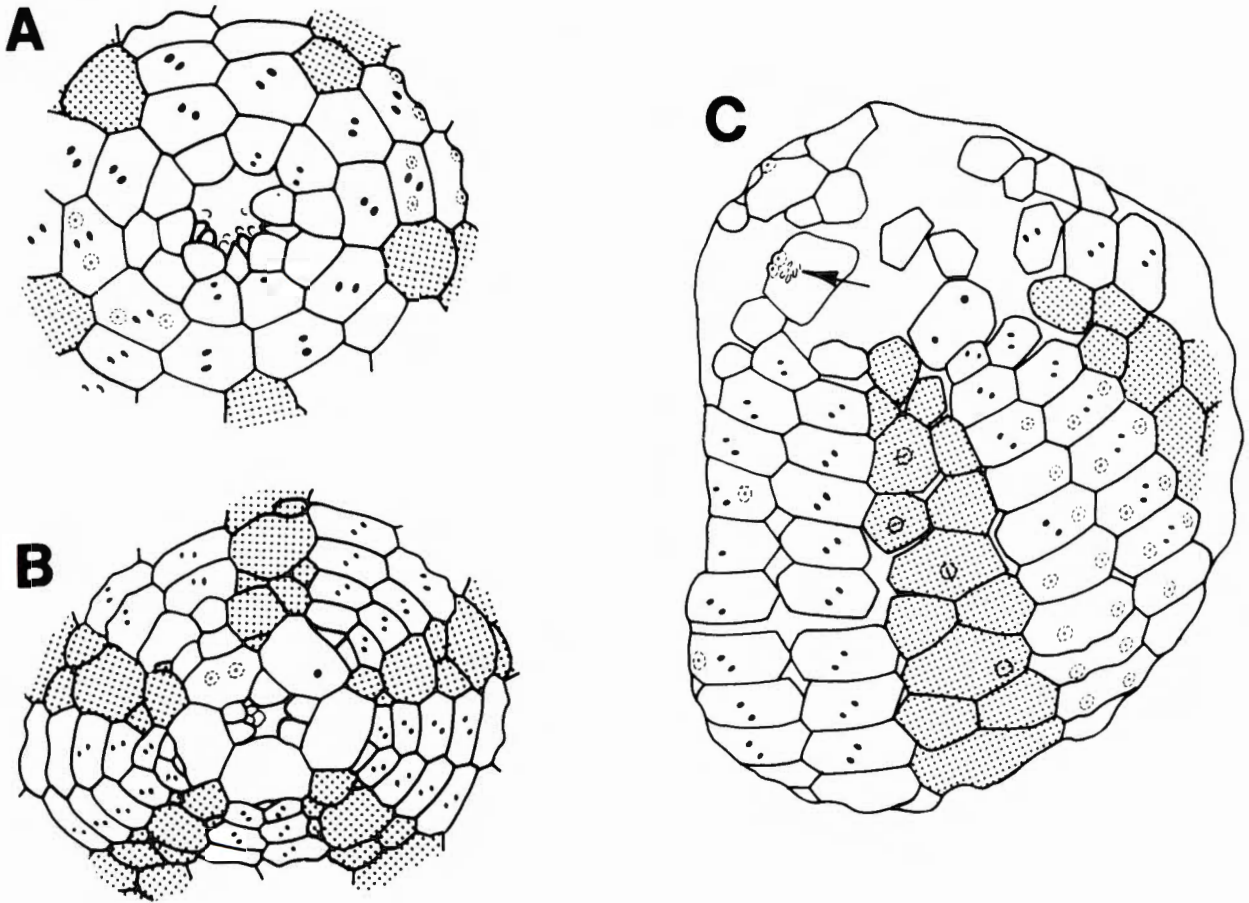


Figure 1. *Bothriocidarid maquoketensis* n. sp., oral (A) and aboral (B) views of holotype SUI 42700, approx. x 9. The interambulacra and obvious primary tubercles are stippled. See Plate 1, figures 7 and 8.

(C) aboral view of paratype SUI 42701 showing paired interambulacra plates. Position of anastomose network of dark calcite shown at arrow. The interambulacra and the obvious primary tubercles are stippled, approx. x 5. See Plate 1, figure 2.

The ambulacra consist of two columns of perforate plates with 12 to 14 plates per column in the smaller specimen (holotype SUI 42700) and 13 to 14 in the larger specimen (paratype SUI 42701). The plates are irregularly hexagonal except for the last formed plates at the apical end, which range from trigonal to pentagonal in outline. A plate at the ambitus in the paratype is 3.2 mm wide, 1.5 mm high, and 0.9 mm thick. The width-to-height ratio of ambulacral plates is greater in the larger specimen than in the smaller specimen.

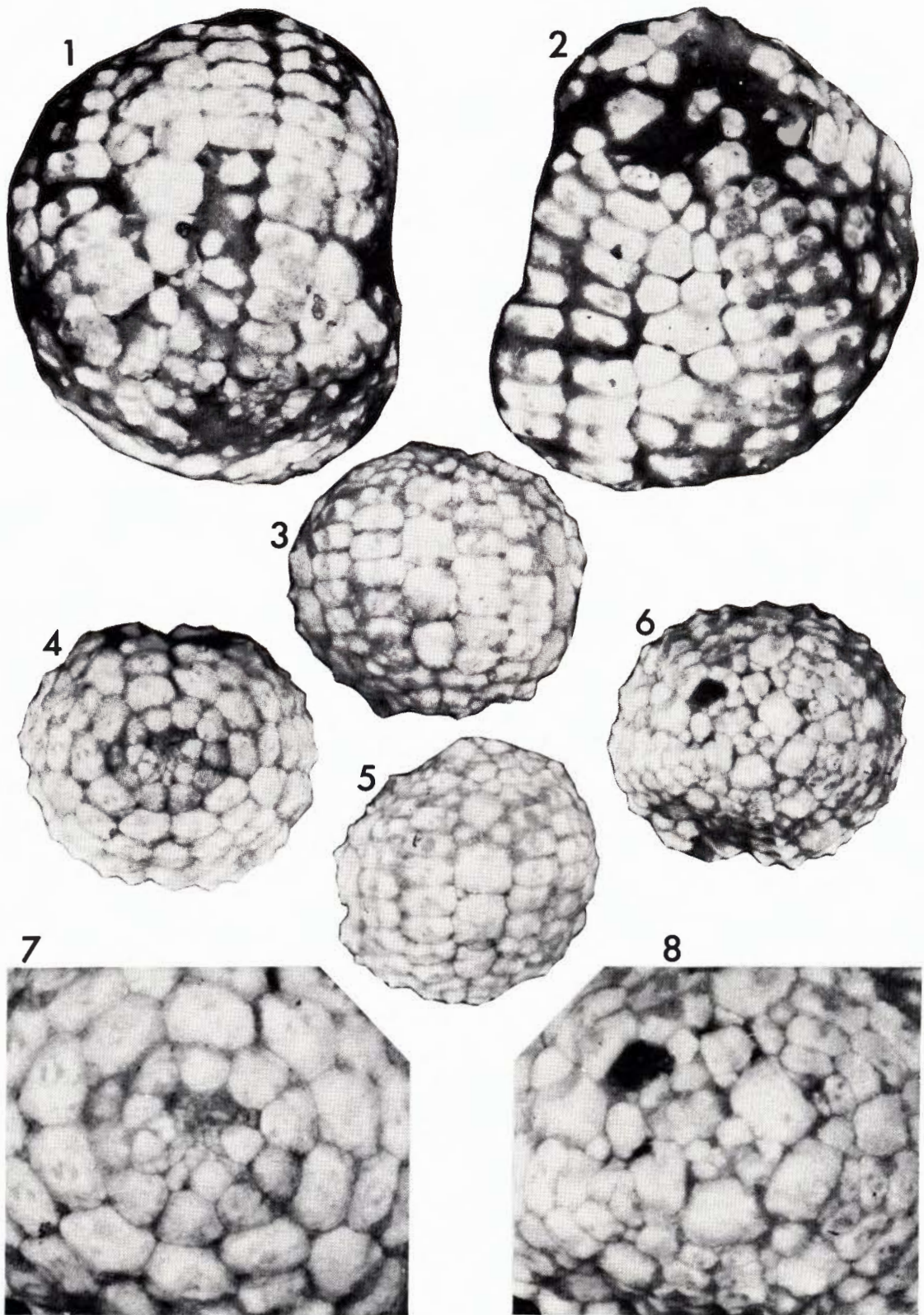
The peripodia are round, have a rim that is only slightly raised above the plate surface, and are generally located at the center of the plate. The pore pairs are arranged obliquely, one above the other, at an angle of about 65° to the long axis of the plate. The outer pore of a pore pair is more adapical than the inner pore. Small, irregularly shaped calcareous spicules of the tube feet are still attached to some peripodia on the paratype. Most ambulacral plates have two elevated, perforate tubercles, located on opposite sides of the peripodia. The peripodia and the tubercles generally lie on the long axis of the plate. Tubercles at the ambitus of the paratype are commonly 0.5 mm in diameter. Small nodes and pustules also occur on the ambulacral plates.

The interambulacra consist of numerous paired plates. The column is a single plate wide adorally, but consists of increasingly more paired plates apically. The paired plates commonly alternate with a single, large, wide plate along the length of the column. At the apical end of the

column the interambulacra terminate in a single plate at the interray suture outside of the circlet of oculars. The ambulacral columns converge adorally and separate the interambulacra from the peristome; the proximal interambulacral plate is situated between the second and third plates of adjacent ambulacral columns.

The interambulacral plates are pentagonal to heptagonal in outline and range from 11 to 16 per column in the paratype and from 8 to 13 in the holotype. At the ambitus in the holotype the plates are higher than wide, but are approximately equidimensional where a column is two plates wide. In the paratype the interambulacral plates are generally wider than high and they are larger than adjacent ambulacral plates. A plate at the ambitus in the paratype is 4 mm wide and 2 mm high. One to three elevated, perforate tubercles occur on plates along the midzone in both the holotype and paratype.

In the holotype some of the basicoronal plates are disassociated, but it is clear that there were 10 imperforate plates — 5 relatively large radial plates alternating with 5 smaller interradiial plates (text fig. 1A). These plates are surrounded by 10 contiguous primordial ambulacral plates. The radial plates are essentially pentagonal and the adoral edge is broadly rounded. The height and width of the radials are approximately the same. The interradiials are slender and elongate and are approximately half the size of the radials. The interradiials are partially concealed by the stout radials. The basicoronal plates surround several



undifferentiated peristomial plates.

The basicoronal area is not well preserved in the paratype, but elements that are present appear to be very similar to those of the holotype.

Several slender spines from 2 to 3 mm long are embedded in the matrix on the surface of the paratype.

Remarks. — Species concepts in *Bothriocidaris* are based largely on the number and distribution of perforate spine tubercles, and on the shape and elevation of the peripodial rim. Seven species are presently known from the Middle and Upper Ordovician of Europe and North America, including *Bothriocidaris maquoketensis* n. sp. and a species to be described by Keir (in press) from the Bromide Formation of Oklahoma.

B. maquoketensis differs from *B. parvus* Mannil (1962) and *B. globulus* Eichwald (1860) both from the Upper Ordovician (Vormsi F_{1b}) of Estonia and the Bromide species in having only two perforate primary tubercles on the peripodia rather than three or more. The new species is similar to *B. pahleni* Schmidt (1864) from the Middle Ordovician (Johvi, D₁) and *B. eichwaldi* Mannil (1962) from the Upper Ordovician (Pirgu Stage, F_{1c}) of Estonia in having only two perforate tubercles on the peripodia; however, in the latter two species the tubercles are much closer to each other, the peripodial rim is higher, and the interambulacra lack perforate primary tubercles. *B. maquoketensis* is probably most closely related to *B. solemi* Kolata (1975) from the Champlainian (Middle Ordovician) Grand Detour Formation, Platteville Group, near Dixon, Illinois. *B. solemi* also is characterized by two primary perforate tubercles on the peripodia and by primary tubercles on the interambulacra, but it differs from *B. maquoketensis* in having closer peripodial tubercles and numerous secondary perforate tubercles on the ambulacra and interambulacra. None of the other species are known to have paired interambulacral plates as does the new species.

Ontogenetic changes in morphology are evident in the two specimens of *B. maquoketensis*. One of the most noticeable changes is the increase in number of interambulacral plates per column, from 8 to 13 in the smaller (diameter of test 9 mm) to 11 to 16 in the larger (diameter of test 16 mm). The corresponding increase in the number of ambulacral plates, however, is only from 12 to 14 to 13 and 14. New interambulacral plates appear to have originated along the adradial suture between the oculars and the fourth ambulacral plate. The number of paired interambulacral plates increase apically, apparently as a result of the increasing size of the test and corresponding increase in width of the interambulacra.

Occurrence. — Both specimens were collected by Glenn Crossman of Riceville, Iowa, in road fill near exposures of the Fort Atkinson Formation. The associated fossils, including the brachiopods *Lepidocyclus laddi* Wang, *Austinella whitfieldi* (Winchell) and *Hypsipytycha hybrida* Wang, and the lithology (argillaceous, fine grained, buff dolomite) strongly suggest that both echinoids came from the Cincinnati (Upper Ordovician) Fort Atkinson Formation (bed no. 8 of Parker et al., 1959) of the Maquoketa Group. The holotype (SUI 42700) was found southeast of Fort Atkinson, Winneshiek Co., Iowa (NW NW NE Sec. 17, T. 96 N., R. 9 W., Decorah Quad.). The paratype (SUI 42701) was found southwest of Eldorado, Fayette Co., Iowa (SW SW Sec. 18, T. 95 N., R. 8 W., Decorah Quad.).

Name. — The specific name refers to the Maquoketa Group, in which the species occurs.

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Plate 1

- 1-8. *Bothriocidaris maquoketensis* n. sp.; Fort Atkinson Formation, Maquoketa Group, northeastern Iowa: specimens photographed under xylol. 1, 2. Paratype SUI 42701, oral and aboral views, respectively, x 4. 3-8. Holotype SUI 42700, 3 and 5 are side views showing paired interambulacral plates, 4 and 6 are oral and aboral views, respectively, x 5. 7, 8, closeups of oral and aboral surfaces, x 11.