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ACINETASTER KONIECKII, A NEW BRITTLE-STAR FROM THE MIDDLE DEVONIAN ARKONA SHALE

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Abstract.—A small brittle-star from the Middle Devonian Arkona Shale of western Ontario differs in so many features from those previously described in the order Stenurida that a new family, genus, and species is erected for it. *Acinetaster konieckii*, the new brittle-star, is characterized by five short, rapidly tapering arms and extensive interbrachial sectors of thin plating without marginals. The disk bears only papillose integument and has no conspicuous ossicles or spines. Each arm consists of ambulacrals, sublaterals, and laterals. The ambulacrals are arranged alternately; each is very thin except for a thick adradial ridge and a submedian ridge forming a T. Each sublateral, similarly very thin, has a submedian rodlike ridge articulated with the submedian ridges of the adjacent ambulacral and lateral by ball-and-socket type joints. The laterals are flat and subventral, those in the proximal part of the skeleton firmly associated with the plating of the interbrachial sector. The thick margin of each lateral, abutting against the adjoining plates of the series rather than imbricating with them, appears to have given the arm appreciable rigidity. The madreporite is aboral. The mouth opening is small, and the mouth-angle plates are rather short but thick and directed downward at an angle. This brittle-star is thought to have been a slow-moving scavenger or filter feeder.

INTRODUCTION

The Devonian Period has special significance in the evolutionary history of the brittle-stars, or Ophiuroidea. It was the time of their greatest diversity, and the only period in which all four orders are represented; the primitive order Stenurida became extinct in the Late Devonian and the advanced order Phrynophiurida first appeared in the Early Devonian.

The middle Paleozoic witnessed many changes in brittle-stars. The structure of the arm evolved by stages: the alignment of left and right ambulacrals, their fusion to form vertebrae, and the perfection of vertebral articulations into the distinctive types present in modern Ophiurida and Phrynophiurida. These changes in the form of ambulacrals, together with modifications of the mouth-angle plates, enabled the brittle-stars to enter into different ecologic niches, with new feeding habits, locomotion, and biting ability.

The burrowing brittle-stars typical of the early Paleozoic, feeding on detritus passed by the tube-feet from the protruding arm tips to the mouth, emerged from their protective sediment and during the middle Paleozoic evolved into agile swimming and climbing forms. Some seem to

have even become miniature predators, like their descendants among the Ophiurida, capable of biting and chewing with their enlarged and better articulated mouth-angle plates.

Along with these main directions of brittle-star evolution in the Devonian were many other experiments in locomotion, feeding, and arm structure. The brittle-star described here seems to have been one of the latter. Apparently incapable of rolling its arms upward to feed from a burrow, of rolling them downward to grasp and climb, or of flexing them quickly to swim, this animal probably kept its fairly rigid short arms extended permanently, perhaps lying flat upon the muddy sea floor or partly ensconced below its surface. There can be little doubt that it was a scavenger or filter feeder.

The specimen was found in the Arkona Shale by Joseph Koniecki, who generously presented it to our museum and for whom the species is named. Even though only the aboral side and the mouth-angle plates are known, this brittle-star is so distinctive that it warrants description.

OCCURRENCE

The specimen was found in place in the first shale pit from the new bridge on the south side of the Ausable River about four feet above river level during a period of normal rainfall, approximately one mile east of Arkona, West Williams Township, Middlesex County, Ontario.

SYSTEMATIC DESCRIPTION

Subclass OPHIUROIDEA Gray 1840

Order STENURIDA Spencer 1951

Suborder PROTURINA Spencer and Wright 1966

Remarks.—The new brittle-star described here, of which only the aboral side and mouth-angle plates are known, without doubt belongs to this order and suborder. Its alternating ambulacrals eliminate it from the orders Phrynophiurida and Ophiurida. Its very thin sublaterals, with rodlike thickening through the middle, are apparently articulated to the laterals, and the laterals themselves are subventral rather than curved around the arm; hence, both sets of plates are like those in such stenurids as *Eophiura*, *Rhopalocoma*, and *Ptilonaster*. Further, short stubby arms, such as occur in the new brittle-star, are characteristic of certain genera of the suborder Proturina, including *Stuertzaster*, *Stenaster*, and *Rhopalocoma*, whereas arms in genera of the order Oegophiurida are typically long, tapering to a thin, whip-like end.

The aboral location of the madreporite in the Arkona specimen is atypical; in most brittle-stars in which it is known, this plate is either marginal or on the oral surface of the interbrachial sector. In addition, the disk is provided with only very tiny ossicles, giving it a papillose texture, whereas in other stenurids, such as *Rhopalocoma*, it bears numerous stellate or rayed ossicles with central prominent articulated spines and is strengthened at the interbrachial edge by a row of thick marginal plates.

Although the sublaterals of the new brittle-star appear to have possessed ball-and-socket type articulations with both the ambulacrals and laterals, the close junctions between the latter plates

would seemingly preclude the downward enrollment to protect the ambulacral groove in the manner postulated for *Eophiura* by Spencer (1940, p. 508).

The collapsed nature of the disk in this, the only specimen of its kind, makes interpretation of its original form difficult. I doubt that it was ever distended as much as was postulated for *Stuertzaster* by Spencer (1940, p. 510) and by Spencer and Wright (1966, p. U80, fig. 68, 1a).

Because the Arkona brittle-star has numerous differences from previously described stenurids, it is made the type of a new family.

ACINETASTERIDAE n. fam.

Type genus—Acinetaster n. gen.

Diagnosis.—Brittle-star of the order Stenurida with five short, rapidly tapering arms and extensive interbrachial sectors without thickened marginal plates. Laterals subventral, broad and extended, abutting instead of imbricating, separated from ambulacrals by sublateral plates, rather firmly associated with thin plating of interbrachial sector. Sublaterals with submedian ridge articulating with ridges of ambulacrals and laterals. Disk not clearly set off from interbrachial sectors or arms, its integument papillose but without large ossicles or spines. Madreporite aboral. Mouth small; mouth-angle plates high but fairly short.

Remarks.—The relationship of this to other families in the order Stenurida is indicated in the following key:

Key to Families in the Order Stenurida

1. Ambulacral basins for tube-feet shallow; radial water-vessel located in open ambulacral groove, a shallow trough along median of oral surface of arm ..... Suborder PROTURINA ... 2
   Ambulacral basins for tube-feet fairly well developed and clearly defined; radial water-vessel enclosed by thick adradial ridges of ambulacrals ..... Suborder PAROPHIURINA ... 6
2. Laterals embracing sides of arms to form side-shields 3
   Laterals subventral, rather flat 4
3. Arms of only medium length, tapering; mouth-angle plates deeply excavated for first buccal tentacles; no skeletal elements in disk .. Phragmactinidae (U. Ord.)
   Arms very long and narrow, little if any taper; mouth-angle plates not deeply excavated; aboral skeleton of stout rayed ossicles ..... Bdellacomidae (U. Sil.-L. Dev.)
4. Sublateral plates elongate, not well articulated with ambulacrals and laterals ..... Pradesuridae (L. Ord.-L. Dev.)
   Sublateral plates wide, with strong submedian ridge well articulated with both ambulacrals and laterals by ball-and-socket joints 5
5. Disk and interbrachial sectors with rayed ossicles bearing prominent spines; edge of interbrachial sector well defined, may be rimmed with thick, spine-bearing marginal plates; laterals apparently capable of wide swing ..... Rhopalocomidae (U. Sil.-U. Dev.)
   Disk with papillose integument, without prominent ossicles or spines; interbrachial sectors thinly plated, without marginal plates; laterals closely joined in series and to interbrachial plating, and thus limited in swing ..... Acinetasteridae (M. Dev.)

6. Ambulacrals opposite; interbrachial areas reduced; buccal slit shallow if present ..... Stenasteridae (M. Ord.-U. Ord.)
   Ambulacrals alternating; interbrachial sectors extensive, bearing scales; buccal slit prominent and deep 7
7. Sublateral series prominent, well articulated with both ambulacrals and laterals; arm ends blunt; ambulacrals with simple rodlike adradial ridges ..... Eophiuridae (L. Ord.)
   Sublaterals not present; arm ends tapering; ambulacrals with incipient boot-shaped ridges ..... Palaeuridae (L. Ord.-L. Dev.)

ACINETASTER n. gen.

Type species.—*Acinetaster konieckii* n. sp.

Derivatio nominis.—The name of this genus is derived from the Greek *akinetos* ("rigid, fixed") and *aster* ("star, starfish"), referring to the apparent lateral immobility of the arms.

Remarks.—Inasmuch as only one species is known to have the characteristics of this brittle-star, the variations within the family remain unknown. Hence, *Acinetaster* is diagnosed only as a representative of its now monogeneric family.

ACINETASTER KONIECKII n. sp.

Pl. 1, figs. 1–3; Pl. 2, figs. 1–8

Derivatio nominis.—This species is named in honor of Joseph Koniecki, a long-time member of the Friends of the University of Michigan Museum of Paleontology, Inc., who found the type and only specimen and presented it to our museum.

Description.—Only aboral surface of disk and arms and oral surface of mouth area known. Form stellate, without distinct boundary between disk and arms; extensive areas between the five short arms occupied by thin interbrachial sectors.

Arms tapering rapidly, their ends narrowly rounded; each arm extended about 12.5 mm from center of mouth. Disk now collapsed, probably originally protrusible to a limited degree. Disk lacking thick stellate ossicles or spines, its central area papillose and its interbrachial extensions thinly plated and only very faintly ornamented. Mouth opening very small.

Ambulacrals alternating. Each with an adradial rodlike ridge set close against the ambulacral row of the opposite side of the arm. Submedian ridge of each ambulacral extending laterally from the adradial ridge to form a short-stemmed T, its distal end concave to articulate with the submedian ridge of the sublateral plate; remainder of ambulacral plate evidently very thin, only traces of it preserved. Original form of ambulacral apparently subquadrate. Oral side of ambulacrals not exposed.

Sublaterals articulated with ambulacrals adradially and with laterals abradially, probably by ball-and-socket joints. Submedian ridge of each sublateral prominent; its adradial end narrowly rounded to fit into a concavity of the outer end of the submedian ridge of the ambulacral, and its abradial end concave to fit the inner end of a ridge of the lateral. Remainder of sublateral plate very thin, only traces of it preserved; plate originally apparently subquadrate.

Laterals distinctly subventral, sloping outward from the sublateral row and not tending to form side-shields. Each lateral with a thick outer margin and a submedian ridge, together forming a T; submedian ridge articulating with concavity of similar ridge of the sublateral. Remainder of lateral plate very thin, with only traces preserved. Adoral and aboral ends of thick outer margin abutting against the ends of adjoining laterals with no detectable imbrication. In

proximal half of arm, thick outer margins of laterals so closely associated with integument and thin plating of the interbrachial sector as to obscure exact boundaries between them.

Interbrachial sectors with thin plating gradually merging into papillose integument of central part of disk and aboral sides of proximal arm areas. Distal edge of each sector extremely thin, not marked by any thick marginal plates, lobate, evidently with a lobe on each side of an arm and a rather sharp indentation at the middle of the interbrachial edge. Slot-like structure in the papillose area of the disk, aligned radially with the indentation of the interbrachial sector, proximal but not connected to it; structure may be true slot through edge of disk or (more likely) a sharp interradial depression of the disk.

Mouth-angle plates close-set, forming a small circlet; diameter of circlet formed by inner edges of mouth-angle plates (without tori) only about 1 mm. As preserved, each mouth-angle plate turned downward. In normal orientation, each mouth-angle plate fairly thick and stout, but short, its proximal end rimmed around an elongate roughened depression. No tori preserved, but evidently originally present and fitted into depressions at proximal ends of mouth-angle plates.

Madreporite aboral, a small subcircular plate about 1 mm in diameter, situated in left part of an interradius, not near margin of disk. Surface of madreporite with shallow sculpture but without visible perforations.

Comparison with previously described brittle-stars.—The presence of well-developed series of sublaterals is recorded in only a few genera of the Stenurida, including *Bdellacoma*, *Eophiura*, *Phragmactis*, *Ptilonaster*, *Rhopalocoma*, and *Stuertzaster*. Even fewer of these exhibit sublaterals which articulate with both ambulacrals and laterals by ball-and-socket joints: *Eophiura* Jaekel 1903 (Lower Ordovician of Czechoslovakia), *Rhopalocoma* Salter 1857 (Upper Silurian of England), and *Ptilonaster* Hall 1868 (Upper Devonian of New York). It is to these three genera that *Acinetaster* need be compared.

Both *Eophiura* and *Acinetaster* have short arms with rounded ends and extensive interbrachial sectors without marginal plates. In *Eophiura*, according to Spencer (1940, p. 508), "there is good evidence that the joints allowed movements to bring the outer lateralia as cover plates over the groove . . . " The movements in *Acinetaster* appear to have been much more restricted. In addition, *Eophiura* has very wide and deep buccal slits, whereas such slits do not seem possible in the new brittle-star. The madreporite, which is reported to be oral in *Eophiura*, is definitely aboral in *Acinetaster*. Thus, the new Middle Devonian form has appreciable differences from the Lower Ordovician *Eophiura*.

Rhopalocoma resembles *Acinetaster* in having short stubby arms, large interbrachial sectors, and small buccal slits. It differs in having stout, spine-bearing marginals rimming the interbrachial sectors and stellate or rayed spine-bearing ossicles on the disk. According to Spencer (1940, p. 512), the ossicles of the disk are "quite thick" and show some radial alignment in *Rhopalocoma*.

Ptilonaster princeps Hall, the type and only species of the genus, is large. Hall (1870, p. 334) recorded that the ten rays or arms in this Upper Devonian brittle-star were each at least 4½ inches (114 mm) in length, whereas the five rays in *Acinetaster* are each only about 12½ mm, or only slightly more than 1/10th as long. In addition, the arms of *P. princeps* are narrow, being only about 1/10th the length in their widest portion; those in *Acinetaster* are nearly 1/5th the length in the corresponding position. The rigidity of the arms may have been similar in the two brittle-stars, however; Hall (1870, p.334) reported, "Rays composed of an ambulacral, adambulacral [sublateral], and marginal [lateral] series, which are united by their edges, and apparently not imbricating." In addition, the disk in *Ptilonaster* is provided with spicules, the mouth-angle plates are elongate, and the madreporite is situated near the edge of the disk (Spencer and Wright, 1966, p. U81). Spencer stated (1940, p. 513) that the spicules in the disk of

Ptilonaster were provided with pointed spines, and thus differentiated it from *Rhopalocoma*, which has club-shaped spines.

Functional morphology and paleoecology.—The thick margins of the laterals are subventral and flat, abutting the edges of adjoining laterals rather than imbricating with them. This arrangement suggests that the arm had very little lateral movement. This interpretation is strengthened by the close association, practically fusion, of the edges of the laterals with the thin plating of the interbrachial sector.

The well-developed articulations of sublaterals with both the ambulacrals and the laterals may have allowed the latter plates to be turned downward to a limited degree, but it seems very doubtful that they could effectively enroll inward to protect the ambulacral grooves or to provide a deep channel for the tube-feet, as Spencer (1940, p. 538) postulated for *Eophiura*.

The whole aspect of the arm structure indicates fairly severe restriction of motion. *Acinetaster konieckii* probably was slow-moving, depending more upon its tube-feet than upon arm wriggling for locomotion.

The short, rapidly tapering arms are arched very little and merge into the extensive, very thick, flat, interbrachial sectors. Thus, this brittle-star lay flattened upon the sea floor or perhaps partly embedded in the muddy sediment. Even the central part of the disk may not have protruded or expanded much above the general level of the arms; the collapse of the disk as preserved does not show appreciable distortion.

The narrow circlet of mouth-angle plates seems to preclude the existence of long buccal slits, if any, so that the mouth could expand and contract only a little in biting and/or chewing. On the other hand, the short, stout mouth-angle plates appear to have been provided with large tori. As the specimen is preserved, the mouth-angle plates are directed downward, and this may indeed have been their normal position in feeding. Thus, the tori, or teeth, may have slanted downward to be more efficient in digging and scraping than in crushing; with limited radial expansion, they could not have been used in biting prey of appreciable size.

The aboral location of the madreporite is unusual in brittle-stars. It may have been an adaptation developed by a line of brittle-stars living with their oral surfaces closely appressed against the sediment or shallowly buried in it.

It would be scientifically valuable to have a specimen of *Acinetaster konieckii* which exhibited not only the oral side of the arms but also the true shape of the disk. If the disk did actually have radial slits, giving it a resemblance to the test of a key-hole urchin, then *Acinetaster* would be a most unusual brittle-star. In that case, one might speculate that deep indentations of the interbrachial sectors were isolated in the course of evolution, leaving vents for circulation of water used in filter feeding.

Considering all morphologic features of the species, I conclude that it was either a scavenger, moving slowly on or through surface sediment in its search for small dead organisms or organic detritus, or a filter feeder, using its mouth-angle plates and tori for anchorage to the bottom while sorting through particles with its tube-feet on the slightly elevated arm tips.

Holotype.—UMMP 64833.

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EXPLANATION OF PLATE 1

Acinetaster konieckii n. sp.

FIG. 1 — Aboral view of holotype and only specimen, UMMP 64833. Madreporite situated in interradius at the left, adjacent to elongate area bereft of plating and close against the side of sublaterals of the arm. The elongate slits in the other two preserved interradii, in the corresponding positions of the broken section adjacent to the madreporite, may be slots through the interbrachial sector (unique for brittle-stars) or merely products of post mortem distortion of the disk. Fragile nature of the interbrachial plating indicated by fractures and cracks. × 10.

FIG. 2 — Madreporite and adjacent plates, from interradius at the left in Pl. 1, fig. 1. × 20.

FIG. 3 — Aboral view of arm and part of interbrachial sector at right in Pl. 1, fig. 1. The papillose ornamentation of the integument and the alternation of the ambulacrals can be seen. × 20.


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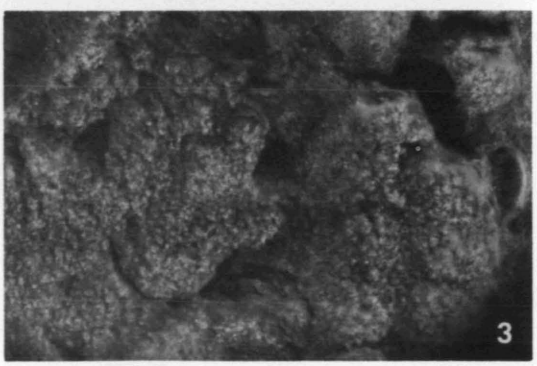
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EXPLANATION OF PLATE 2

Acinetaster konieckii n. sp.
All figures × 20

FIGS. 1–3 — Oral views of mouth area, showing proximal surfaces of mouth-angle plates. As preserved, the plates are turned downward, perhaps retaining their living orientation and indicating that the unpreserved tori were used in digging or scraping.

FIG. 4 — Abutting laterals from the arm at the right in Pl. 1, fig. 1. Absence of imbrication seems to indicate little flexibility or movement possible in the arm.

FIG. 5 — Ambulacrals, sublaterals, and laterals of the arm at the right in Pl. 1, fig. 1. The cracks at the left are interpreted as post mortem tension cracks through the thin plating of the interbrachial sector.

FIG. 6 — Ambulacrals, sublaterals, and laterals of the distal half of the middle arm in Pl. 1, fig. 1. The shape of the sublaterals in particular varies according to the presence of integument and preservation of the thin plate itself.

FIG. 7 — Ambulacrals, sublaterals, and laterals of arm shown as the middle one in Pl. 1, fig. 1. Note the apparent fusion of laterals with the thin interbrachial plating suggesting very restricted lateral mobility of the arm.

FIG. 8 — Distal tip of arm shown as middle arm in Pl. 1, fig. 1. Very small and crowded ambulacrals are present in this part of the arm, but high magnification with the specimen submersed in water shows that even the small ambulacrals maintain their alternation.


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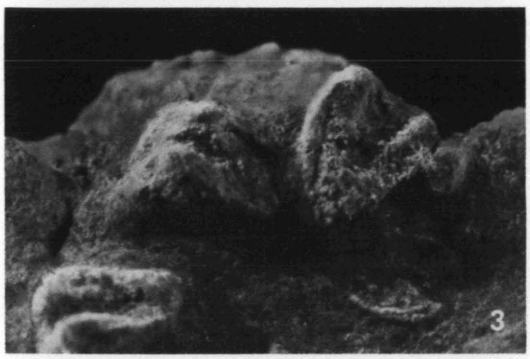
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