SNSB Bayerische Staatssammlung für Paläontologie und Geologie

■ München, 31.12.2020

■ Manuscript:
received:
05.10.2019
revision:
accepted, 28.12.2020
available online, 30.12.2020

■ ISSN 0373-9627

■ ISBN 978-3-946705-08-6

Short Communication

Neobothriocidaris (Echinoidea) from the Late Ordovician Bromide Formation, Oklahoma, USA

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Zitteliana 94, 165–168

Key words: fossil Echinoidea; stem group echinoids; Bothriocidaridae; Ordovician; Oklahoma; USA
Schlüsselwörter: fossile Echinoidea; Stammgruppen-Echiniden; Bothriocidaridae; Ordovizium; Oklahoma; USA

Echinoids (sea urchins) are common as fossils in Mesozoic and Cenozoic sediments (Smith 1984; Kroh 2020); however, the fossil record of these echinoderms harks back to the late Middle Ordovician (Darriwilian; Pisera 1994, Lefebvre et al. 2013). The vast majority of Ordovician and Silurian echinoids belong to the bothriocidarids (stratigraphical range: Darriwilian to Ludlow; e.g. Franzén 1979; Männil 1983; Pisera 1994; Kutscher & Reich 2004; Lefebvre et al. 2013), which are the oldest members (Pisera 1994) and range amongst the most basal stem group echinoids (e.g. Smith & Savill 2001). They show a unique morphology (e.g. Männil 1962) characterised by a primitive lantern, thick and distinct, tessellated ambulacral and interambulacral plates arranged in varying numbers of columns, and small spines (e.g. Paul 1967; Kolata 1975; Kier 1982; Guensburg 1984; Smith & Savill 2001).

The early diversification of the echinoids in Baltica and Laurentia remains poorly understood (cf. review in Lefebvre et al. 2013; Reich 2014); there is, however, a diverse early sea urchin fauna from Laurentia (Sprinkle & Guensburg 2004) that includes members of all three currently recognised bothriocidarid genera, i.e. *Bothriocidaris* von Eichwald, 1860, *Neobothriocidaris* Paul, 1967, and *Unibothriocidaris* Kier, 1982.

An important rock deposit providing insights into the early fossil history of echinoids is the early Late Ordovician (Sandbian) Bromide Formation of south-central Oklahoma, USA, that contains an abundant and very diverse echinoderm fauna (Sprinkle 1982, and papers therein), including several different species of echinoids (Kier 1982).

In addition to more than 50 ambulacral and interambulacral plates of *Bothriocidaris kolatai* Kier, *Unibothriocidaris bromidensis* Kier, and *Bromidechinus rimaporus*, a single ambulacral plate attributable to the genus *Neobothriocidaris* was discovered during the systematic screening of micropalaeontological sieve residues from this site. Because Ordovician evidence of echinoids is exceedingly rare worldwide, this fossil, perhaps of a new species, deserves special attention and is described in detail here.

Systematic palaeontology

The terminology used in the description (Fig. 1G, H) is modified from that used by Paul (1967) and Smith (1980, 1984).

The bulk samples were first dried, and fossils were then isolated using hot water or sodium carbonate (Wissing et al. 1999). After wet-sieving (>10.0, 5.0, 0.5, 0.1, 0.063, 0.03 mm), residues were dehydrated, and meso- and microfossils were studied under a stereo microscope. The fossil described in this study was first analysed and photographed with a digital light microscope (Keyence VHX 5000), and subsequently mounted onto an SEM stub and sputter-coated with Au for SEM analysis and documentation using the desktop scanning electron microscope Phenom XL. The specimen is deposited at the SNSB – Bayerische Staatssammlung für Paläontologie und Geologie, Munich, Germany.

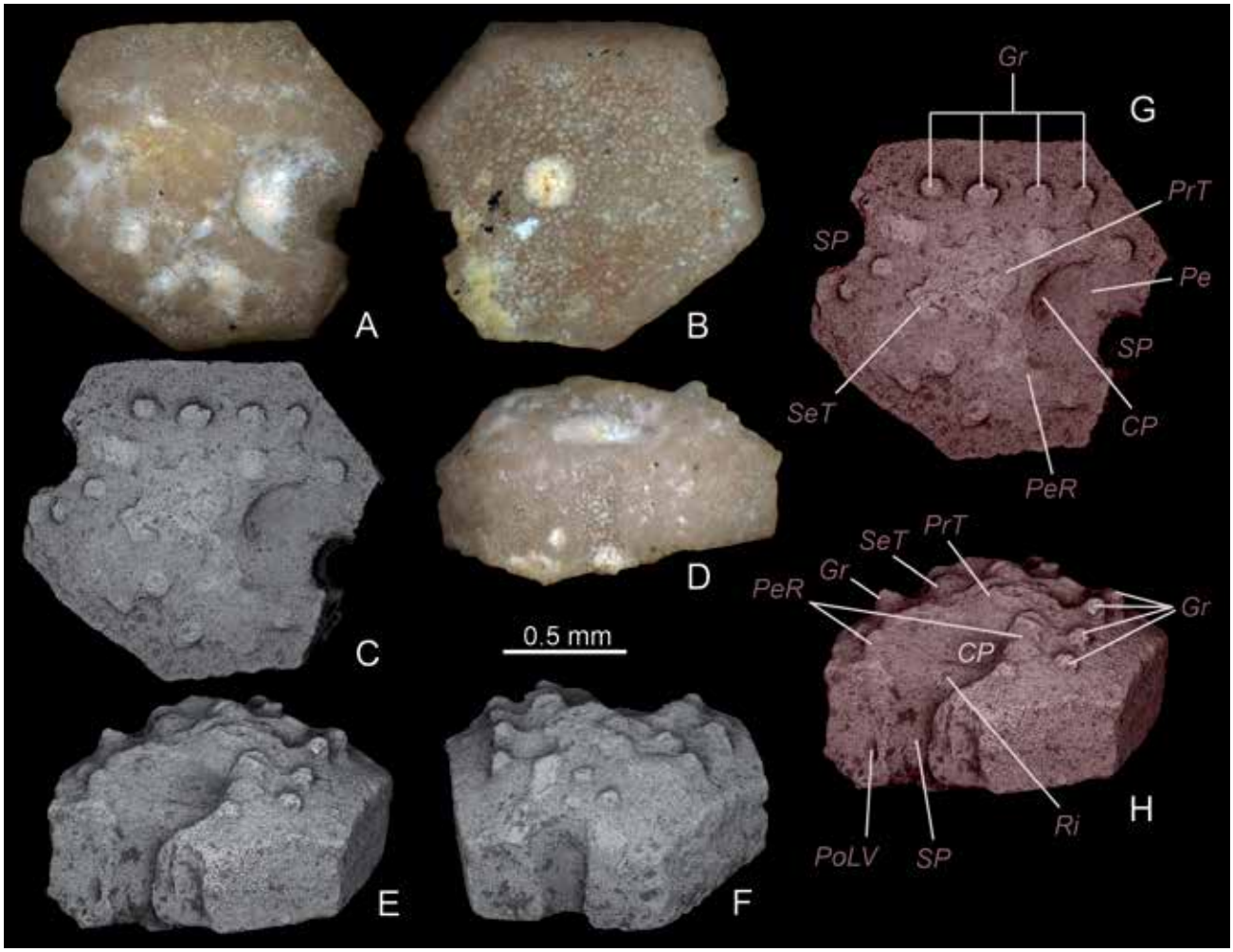

Figure 1: Coronal plate of *Neobothriocidaris* sp. nov. (SNSB-BSPG 2017 XIX 100) from the Sandbian Bromide Formation, Dunn quarry, Criner Hills, Oklahoma. **(A, C)** outer view; **(B)** inner view; **(D, E, F)** oblique outer view; **(G, H)** outer and oblique views, showing morphological terms used in this study.
LM (A, B, D), and SEM (C, E, F, G, H) images.
Abbreviations: *CP*—central pore; *Gr*—granules; *Pe*—peripodium; *PeR*—peripodial rim; *PrT*—primary tubercle; *PoLV*—pore of the internal water vascular system; *Ri*—ridge; *SeT*—secondary tubercle; *SP*—sutural pore.

Class Echinoidea Leske, 1778
Stem group Echinoidea
Order Bothriocidaroida Zittel, 1879
Family Bothriocidaridae Klem, 1904

Genus *Neobothriocidaris* Paul, 1967

Neobothriocidaris sp. nov.
Fig. 1

Material: One ambulacral plate, SNSB-BSPG 2017 XIX 100.

Occurrence: Early Late Ordovician (Sandbian), Bromide Formation: Pooleville Member; Dunn quarry (34°06‘23.43 N, 097°10‘53.14 W), Criner Hills, Carter County, Oklahoma, USA.

Associated fossils: Light brown- to creme-coloured biomicrites with abundant bryozoans, brachiopods, and echinoderms, including crinoids, rhombiferans, diploporans, asteroids, ophiuroids, cyclocystoids, edrioasteroids, echinoids, and holothurians (based on partially articulated and disarticulated material; MR, own observations; material reposited at the SNSB-BSPG, under accession number 2017 XIX).

Description: This single perforate plate is referred to *Neobothriocidaris*. The irregularly hexagonal, somewhat thickened plate is characterised by one subcentral and two sutural pores (Fig. 1A, C) and, due to the latter, positioned mid-chevra and not adjacent to an interambulacrum. The ridge on the peripodium defining the (peripodial) sutural pore is faintly visible (Fig. 1E). A medium-sized, flat primary tubercle is positioned subcentrally (Fig. 1C, E) in contact to the peripodial rim, with apparently two secondary tubercles adjacent to it. The peripodial rim is built up on both sides by 3–4 domed and interconnected

granules (Fig. 1E). The other surface of the plate bears 9–10 domed granules, which are higher than the tubercles (Fig. 1C-E). The plate is 1.3 mm high and 1.4 mm wide.

Comparison: This ambulacral plate undoubtedly comes from a new species from the genus *Neobothriocidaris*. It shares with other species of that genus the presence of the internal lateral water vessels (Fig. 1D, E). The plate morphologically most closely resembles plates seen in *Neobothriocidaris peculiaris* Paul, 1967 from the Katian of Scotland and Norway (Paul 1967, Bockelie & Briskeby 1980) and *Neobothriocidaris* sp. Kolata, 1975 (Sandbian of Illinois), in particular by having one primary and a minimum of two secondary tubercles; however, in our *Neobothriocidaris* sp. nov. the peripodial rim is not distinctly raised and ridge-like, but rather composed of interconnected granules. In addition, the new *Neobothriocidaris* is distinguished from *Neobothriocidaris minor* Paul, 1967 (Katian of Scotland and the Baltic area; cf. Schallreuter 1989) by the greater number of granules on the outer surface, and from *Neobothriocidaris* sp. Pisera, 1994 (Darriwilian of Poland) and *Neobothriocidaris templetoni* Kolata, 1975 (Katian of Illinois) by their additional tubercles. As only a single plate is presently available of this echinoid, we deem it meaningless to erect a new taxon and describe the fossil in open nomenclature as *Neobothriocidaris* sp. nov.

It has been previously demonstrated that disarticulated fossil plates and ossicles of Echinoidea are diagnostically valuable, and hence can be useful in reconstructing echinoderm communities and palaeobiodiversity. The newly discovered *Neobothriocidaris* specimen is the first reported occurrence of this echinoid genus from the early Late Ordovician Bromide Formation of Oklahoma, USA.

Acknowledgements

The fossil was collected by the second author in 2013, while he was part of a group of NHM palaeontologists from London conducting fieldwork in Oklahoma. MR is indebted to, i.a., Timothy A. M. Ewin, Consuelo Sendino, Paul D. Taylor (all Natural History Museum, London) for the invitation to join the field party and fruitful discussions, and to James Sprinkle (University of Texas at Austin) for guiding us in the field. Jeffrey R. Thompson (University College London) is thanked for being supportive in discussing echinoderm systematics and phylogeny. Finally, we thank Michael Krings (SNSB-BSPG, Munich) and Tanja R. Stegemann (Naturkundemuseum Ostbayern, Regensburg) for carefully reading and correcting the manuscript.

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