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Authors: Waters, Johnny A., and Ausich, William I.

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Gennaeocrinus tariatensis, a new Emsian (Devonian) monobathrid crinoid from the Tarvagatay Terrane of Mongolia

Johnny A. Waters[1] and William I. Ausich[2]

[1]Department of Geological and Environmental Sciences, Appalachian State University, Boone, North Carolina 28006, USA <watersja@appstate.edu>
[2]School of Earth Sciences, Ohio State University, Columbus, Ohio 43210, USA <ausich.1@osu.edu>

Abstract.—*Gennaeocrinus tariatensis* new species is an Emsian (Devonian) monobathrid crinoid described from the Tarvagatay Terrane of Mongolia and part of the Central Asian Orogenic Belt. The Tarvagatay Terrane is an arc terrane that accreted to the southern margin of the Siberian Craton. *Gennaeocrinus tariatensis* was collected from the Emsian Tariat Formation, a terrigenous sequence of conglomerates, sandstones, and siltstones. Associated faunas include brachiopods, molluscs, and rare tabulate corals. Although *Gennaeocrinus* is well known from the Emsian–Givetian of North America, this is the first occurrence of the genus outside Laurussia. Mongolia is a large country with many terranes having varied paleogeographic, sedimentological, and tectonic histories; but reports of Paleozoic echinoderms are rare. The crinoid occurrence from the Tariat Formation is from the same age as previously described Emsian crinoids from the Chuluum Formation but differs significantly in sedimentology, paleogeography, and paleolatitude.

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Introduction

The analysis of patterns of paleobiogeography depends on a global data set. Efforts to collect information on the age and location of disparate fossil species, such as the Paleobiology Database and the Geobiodiversity Database, among others, are critical in defining global patterns, but these depend on a robust primary literature describing occurrences of fossil taxa.

Reports of Paleozoic crinoids from Mongolia are infrequent, and many of the earliest papers described only stems (Stukalina, 1973, 1994, 1997; Tungalag, 1998). Webster and Ariunchimeg (2004) described a Lower Devonian (Emsian) fauna from Shine Jinst in southern Mongolia, including the first crinoid cups and thecae from Mongolia. They recognized five distinct taxa but named only *Cyathocrinites* because of poor preservation. Waters et al. (2021) described a Late Devonian (Famennian) echinoderm fauna of twelve crinoid genera and two blastoid genera from southwestern Mongolia. Recently, Carboniferous (Serpukhovian) crinoids have been collected from southwestern Mongolia, but they are too fragmentary for identification (Waters, personal observation, 2020).

In this paper, we describe the new periechocrinitid *Gennaeocrinus tariatensis* new species from the Emsian of Mongolia. *Gennaeocrinus* is well known from multiple species from the Devonian of North America and is questionable from western Europe. In terms of Devonian plate tectonics, it is well known from cratonic settings on east/southeast Laurentia and questionably known from similar settings on southwest Baltica and Iberia in the reconstructions of Domeier and Torsvik (2014). However, *G. tariatensis* was collected from a collage of small terranes and active island arc complexes in the Central Asian Orogenic Belt on the southeastern margin of Siberia. Thus, its tectonic, paleogeographic, sedimentological, and paleolatitudinal occurrence differs from all other species of the genus.

Geological setting

Mongolia is a very large country and occupies a primary position in the Central Asian Orogenic Belt (Fig. 1), the largest Paleozoic orogenic belt that evolved in a manner similar to the modern Indonesia and western Pacific. Mongolia comprises 44 terranes (Badarch et al., 2002), including cratonic, metamorphic, passive margin, island arc, forearc/backarc, accretionary complex, and ophiolitic terranes (Fig. 2).

The crinoid described herein was collected from the Tariat Formation, which is part of the Tarvagatay Terrane of Badarch et al. (2002). The Tarvagatay Terrane occurs in the northern Hangay mountains. The Terrane consists of Precambrian basement overlain by lower Cambrian stromatolitic limestone and volcaniclastic rocks. Devonian and Mississippian conglomerate, sandstone, and siltstone containing marine fossils complete the sequence. Alekseeva (1993) described the Tariat Formation as a terrigenous sequence with 70 m of basal conglomerates overlain by 150 m of green sandstones, siltstones, and mudstones with abundant brachiopods and plant fossils in darker siltstones. An overlying terrigenous sequence contains 250 m dark-gray to greenish siltstones and sandstones also with abundant brachiopods. The Tariat Formation is unconformably overlain by lower Carboniferous conglomerates. The Tariat Formation is Emsian in age according to the presence of the strophomenoid

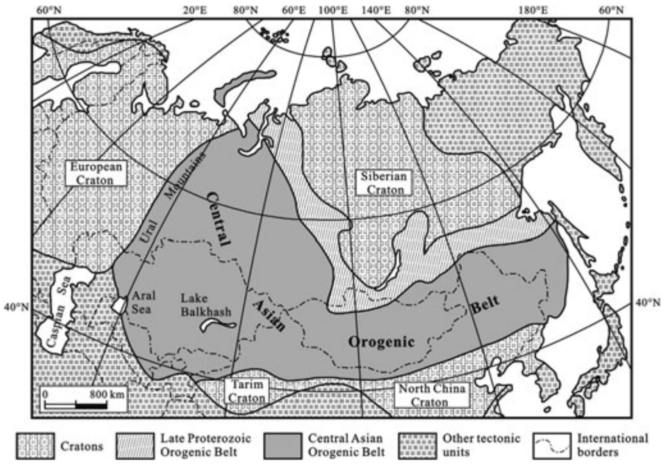

Figure 1. The Central Asian Orogenic Belt accretionary zone located between the European and Siberian cratons to the north and the Tarim and North China cratons to the south. Map after Ju and Hou (2014).

Maoristrophia kailensis Shishkina, 1990, a brachiopod that defines the Mongolian Chulun Horizon (Alekseeva, 1993). This horizon correlates with the Salairka Horizon in Siberia and the *Polygnathus kitabicus* Conodont Biozone in the basal Emsian (Yolkin et al., 2000).

Paleobiogeography

The tectono-stratigraphic compilations of Mongolia by Badarch et al. (2002) and Windley et al. (2007) recognized the Main Mongolian Lineament, which divides the country into an early Paleozoic domain in the north and a late Paleozoic domain in the south. The Tarvagatay Terrane is part of the Mongol–Okhotsk Belt north of the Main Mongolian Lineament. The Tariat Formation was deposited in a trench–accretionary wedge environment in the Mongol–Okhotsk Ocean to the south (in current orientation) of the Siberian Craton (Bussien et al., 2011).

Emsian paleobiogeography is based primarily on brachiopods and shows differentiation into the Rhenish–Bohemian Realm, the Appalachian Realm, and the high-latitude Malvinokaffric Realm. Some Devonian workers combine the Rhenish–Bohemian Realm into the Appalachian Realm. Brachiopods with a cosmopolitan distribution from the Mongol–Okhotsk fauna support the conclusions of Hou and Boucot (1990) that they are part of the Old World Realm even though geographic distances between the areas are quite large. Paleobiogeographic reconstructions by Torsvik and Cocks (2017) placed the Mongolian terranes, including the Tarvagatay Terrane, along the southern margin of the Siberian Craton at a latitude of approximately 50°N. The Old World Realm is primarily equatorial to mid-latitudes, and the Malvinokaffric Realm is located in the high latitudes of the Southern Hemisphere (Torsvik and Cocks, 2017).

Emsian faunas have a high degree of cosmopolitan distribution of taxa where adequate data are available. The Emsian marked the acme of a remarkable spread of reefs, the largest known and most latitudinally widespread reefs in the Phanerozoic according to Copper and Scotese (2003). Judging from the distribution of reefs, they concluded that the Middle Devonian (Emsian–Givetian) had a supergreenhouse climate. However, Joachimski et al. (2009), concluded that the Middle Devonian had sea surface temperatures closer to 23–25°C and was not a supergreenhouse climate according to oxygen isotopes in conodont apatite. Regardless of which temperature model is correct, Emsian sea levels were high, and geographically disparate faunas contained many similar, cosmopolitan genera.

Materials and methods

The holotype of *Gennaeocrinus tariatensis* n. sp. was collected from an outcrop of the Tariat Formation at 48°12′23″N, 100°1′49″E (measured by GPS) in Arkhangai Aimag, Tariat Somon, Mongolia (Fig. 3). The specimen was a mold preserved in a greenish–gray fossiliferous siltstone. Descriptions of the specimen are based on a latex cast prepared at the Paleontological Center of the Mongolian Academy of Science and photographed with ammonium chloride sublimate.

Repository and institutional abbreviation.—The latex cast of the holotype is reposited in the collections of the Mongolian University of Science and Technology (MUST) research collections in Ulaanbaatar, Mongolia.

Systematic paleontology

The superfamilial classification used here follows Cole (2017), Wright (2017), and Wright et al. (2017); family-level classifications follow Moore and Teichert (1978). Morphologic terminology follows Ubaghs (1978) and Ausich et al. (2020). The plating of interrays is given by the number of plates in each range from proximalmost plate to the last range before the tegmen. In the posterior interray, the primanal is indicated by "P," and the first interradial plate in regular interrays is indicated by "1."

Subclass Camerata Wachsmuth and Springer, 1885
Infraclass Eucamerata Cole, 2017
Order Monobathrida Moore and Laudon, 1943
Family Periechocrinidae Bronn, 1849
Genus *Gennaeocrinus* Wachsmuth and Springer, 1881

Type species.—*Actinocrinus kentuckiensis* Shumard, 1868, by original designation.

Other species.—*G. carinatus* Wood, 1901; *G. carinatus crassicostatus* Goldring, 1923; *G. chilmanae* Kesling, 1968; *G. chilmanae* Kesling, 1968; *G. cornigerus* (Lyon and Casseday, 1859); *G. decorus* Goldring, 1923; *G. dulukae* Kesling, 1969; *G. eucharis* (Hall, 1862); *G. facetus* Rowley, 1903; *G.*? *germanicus* Schmidt, 1941; *G. goldringae* Ehlers, 1925; *G. maxwelli* Johnson and Lane, 1969; *G. mourantae* Goldring, 1934; *G. nyssa* (Hall, 1862); *G. perculiaris* Goldring, 1923; *G. percarinatus* Goldring, 1935; *G. romingeri* Kesling, 1964; *G. sculptus* Rowley, 1903; *G. seversoni* Laudon, 1973; *G. similis* Goldring, 1935; *G. simulans* Rowley, 1904; and *G. variabilis* Kesling and Smith, 1962.

Occurrence.—Previously, this genus was known from the Emsian to Givetian in North America, with questionable

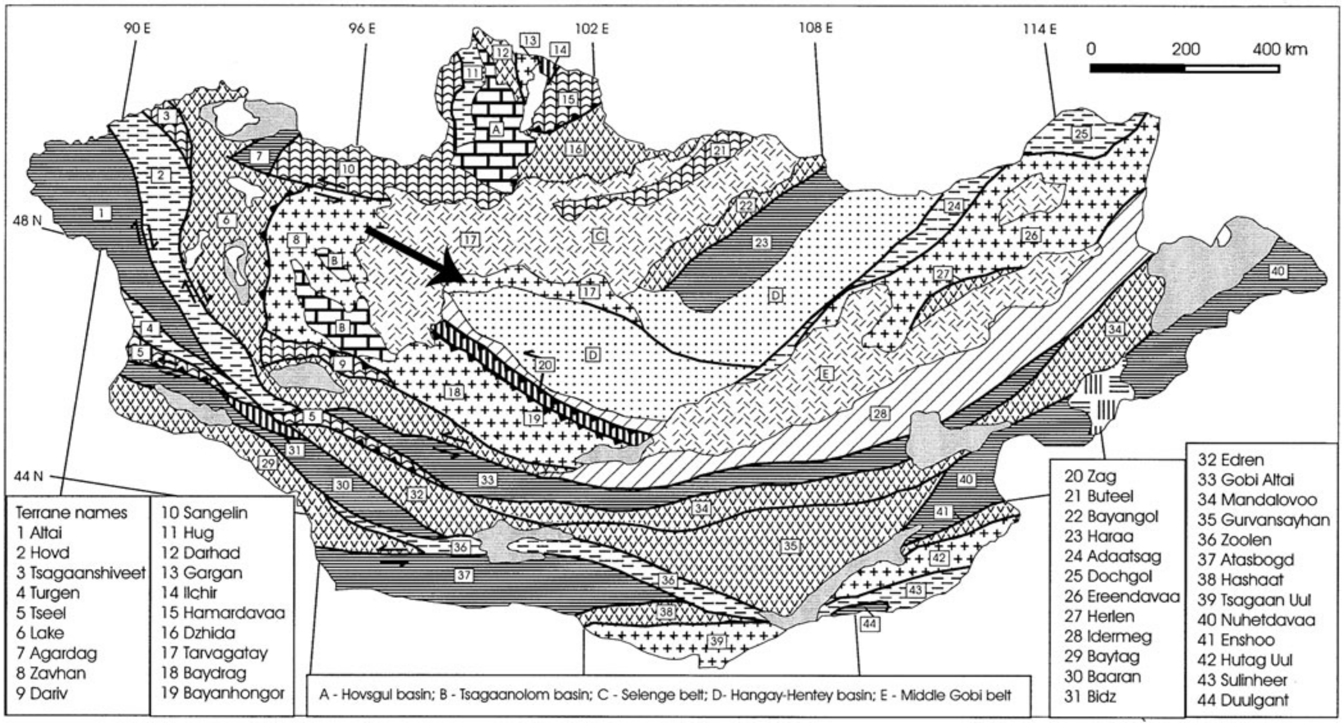

Figure 2. Map of the 44 tectonic terranes of Mongolia (after Badarch et al., 2002). The crinoid locality, indicated by the arrow, is located on the Tarvagatay Terrane, an arc terrane that accreted to the southern margin of the Siberian Craton.

Figure 3. Field photo of outcrops of the Tariat Formation located in the Arkhangai Aimag, Tariat Somon, Mongolia. The Tariat is an Emsian fossiliferous unit composed primarily of conglomerates, sandstones, and siltstones. The arrow points to the crinoid locality.

occurrences in Germany and Spain. The specimen described herein is from the Emsian of Mongolia.

Remarks.—Wachsmuth and Springer (1881, p. 160) proposed *Gennaeocrinus* "for a little group of crinoids from the Upper Devonian, which cannot be satisfactorily referred to any established genus." They noted differences in the plating of the anal area and the number and arrangement of both anal and interradial plates. As presently understood, *Gennaeocrinus* is a common periechocrinid crinoid from the Lower and Middle Devonian of North America with questionable occurrences in Germany and Spain (Ausich and Kammer, 2008; Webster and Webster, 2014), but this Devonian genus has a high morphological disparity with, for example, aboral cup shapes varying from very low cone or bowl shape to medium globe shape and a wide range in aboral plate sculpturing, presence or absence of a basal ridge and a basal concavity, plating arrangements in all interrays, the number of fixed secundibrachials, and number of free arms. A comprehensive review of *Gennaeocrinus* is needed, but this is beyond the scope of the present study.

The generic assignment of this new Mongolian species would be questionable, except that it belongs to a group of *Gennaeocrinus* species that includes *G. kentuckiensis* (Shumard, 1868), the type species of the genus. Although this new specimen is a partial calyx, its morphology is distinct from other species and is considered a new species. The *Gennaeocrinus* species grouping to which *G. tariatensis* n. sp. belongs includes *G. comptus* Rowley, 1903, *G. kentuckiensis* (type species), *G. maxwelli*, *G. percarinatus*, *G. romingeri*, and *G. sculptus*. These seven species all have a calyx shape of low cone/bowl to very low cone/bowl, multiple radiating ridges connecting to like ridges on adjoining calyx plates, basal concavity absent, and posterior interray plating P-3- (where known). As delineated in the following, species diagnostic characters for this group of species include calyx shape, presence or absence of an arcuate ridge on the radial plates, presence or absence of a central node on calyx plates where radiating ridges coalesce, presence or absence and character, if present, of a rim around the base of the calyx, presence or absence of prominent ray ridges, proximal regular interray plating, presence or absence of an anitaxial ridge, presence or absence or spinose tegmen plates, and number of free arms per ray.

Gennaeocrinus tariatensis new species
Figure 4

Holotype.—The holotype and only known specimen is IV.JW.2013.1-5 reposited in the collections of the Paleontological Center of the Mongolian Academy of Sciences, Ulaanbaatar, Mongolia.

Diagnosis.—Low to very low bowl calyx shape, multiple stellate ridges connecting to like ridges on adjoining plates throughout the calyx, arcuate ridge on radial plates absent, central node on calyx plates absent, basal ridge around base of calyx absent, prominent ray ridges absent, regular interray plating 1-3, anitaxial ridge absent or very weak, nature of tegmen plates and free arms per ray unknown.

Occurrence.—Tariat Formation (Emsian), Arkhangai Aimag, Tariat Somon, Mongolia.

Description.—Calyx low to flat bowl shaped, arms probably grouped; calyx plate sculpturing multiple radiating ridges from plate centers and connecting with like ridges on adjacent plates; central nodes are not formed where ridges coalesce at plate centers. Basal circlet flat cone shaped, a small percentage of overall calyx height, column cicatrix occupying most of basal circlet, individual sutures between basal plates not clearly preserved. Radial circlet projects outward, presumably slightly visible in lateral view, a small percentage of overall calyx height, radial plates presumably five, hexagonal or heptagonal, approximately as wide as high, in lateral contact except in the CD interray.

Regular interrays do not interrupt radial plate circlet, in contact with tegmen. First interradial plate hexagonal, higher than wide, approximately the same size as radial plates and first primibrachial plates; second range with two plates, more distal plating not preserved, but more than two plates. Interradial regions connect to tegmen.

Primanal higher than wide, probably hexagonal, positioned between the C and D radial plates, CD interray much wider that regular interrays, plating P-3-6-?.

First primibrachial fixed, hexagonal wider than high, smaller than radial plates and approximately the same size as the first interradial plate in regular interrays and the second primibrachial; second primibrachial axillary, presumably pentagonal or heptagonal; fixed secundibrachials present.

Tegmen and free arms unknown. Proximal column circular, but other aspects unknown.

Etymology.—A species of *Gennaeocrinus* from the Tariat Formation (Emsian).

Remarks.—*Gennaeocrinus tariatensis* n. sp. is represented by one specimen, which is an incomplete calyx with breaks in plating in places. Normally such a specimen would be insufficient as the foundation of a new species. However, as previously noted, this specimen can be confidently placed in *Gennaeocrinus,* and its morphology is unique among species of *Gennaeocrinus*. The following characters distinguish *Gennaeocrinus tariatensis* within the grouping of similar species: a low to very low bowl calyx shape; arcuate ridge on radial plates absent; central node on calyx plates absent; sharp ridge around base of calyx absent; ray ridges absent, proximal normal interray plating 1-2-; absent or weak anitaxial ridge; tegmen unknown; character of tegmen plates and number of free arms per ray unknown. By contrast, *G. comptus* has a very low cone calyx shape; arcuate ridge on radial plates present; central node on calyx plates absent, discontinuous, sharp ridge around base of calyx; prominent ray ridges; proximal normal interray plating 1-3?-; prominent anitaxial ridge; one central spine on tegmen; six arms per ray. *G. kentuckiensis* (type species) has a low bowl shape; arcuate ridge on radial plates absent; central node on calyx plates; continuous, low ridge around base of calyx; prominent ray ridges; proximal normal interray plating 1-2- or 1-3?-; weak anitaxial ridge; spines on tegmen plates; and eight arms per ray. *G. percarinatus* has a

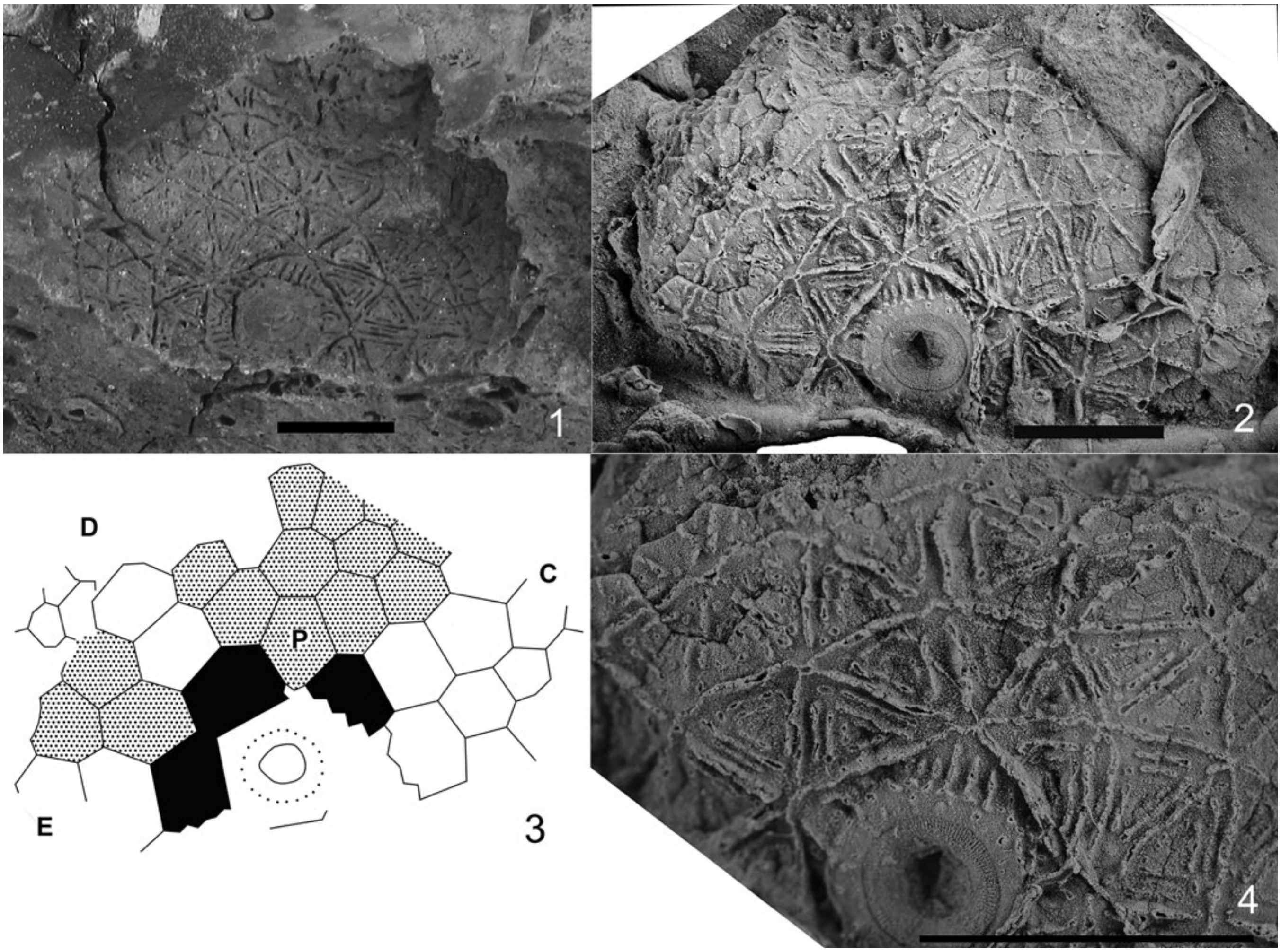

Figure 4. *Gennaeocrinus tariatensis* n. sp. (**1**) Photograph of the holotype of *Gennaeocrinus tariatensis* preserved as a mold in a greenish-gray siltstone. (**2**) Latex cast of the holotype showing prominent ornament of radiating ridges that cross plate boundaries. (**3**) Plate diagram of *Gennaeocrinus tariatensis* prepared by W.I.A. (**4**) Enlargement of the latex cast of *Gennaeocrinus tariatensis* showing subtle plate boundaries largely obscured by strong radiating ridges. Scale bars = 1 cm.

low(?) bowl calyx shape; presence or absence of arcuate ridge on radial plates unknown; central node on calyx plates; sharp ridge around base of calyx discontinuous, small, sharp; prominent ray ridges; proximal normal interray plating 1-2-; weak anitaxial ridge; tegmen unknown; and number of free arms unknown. *G. romingeri* has a very low bowl shape; arcuate ridge on radial plates absent; central node on calyx plates; sharp ridge around base of calyx absent; prominent ray ridges; proximal normal interray plating 1-2-; weak anitaxial ridge; tegmen unknown; and four free arms per ray. *G. sculptus* has a low bowl shape; arcuate ridge on radial plates absent; central node on calyx plates; sharp, continuous ridge around base of calyx unknown; prominent ray ridges; proximal normal interray plating 1-2-; anitaxial ridge absent; tegmen spines absent; six free arms per ray. *G. maxwelli* is a very poorly preserved, silicified specimen, and characters other than recognizing its presence within this grouping of species cannot be discerned with confidence.

Discussion

Gennaeocrinus is a monobathrid crinoid that is well known from the Emsian and Givetian of North America with possible occurrences from Germany and Spain. By contrast, *G. tariatensis* n. sp. is the first species of the genus found in the Central Asian Orogenic Belt (CAOB). It was collected from Emsian terrigenous sediments on a convergent margin terrane in the Mongol–Okhotsk Belt, which accreted onto the Siberian Craton. In terms of paleolatitude, previously known species of *Gennaeocrinus* have an equatorial distribution, but *Gennaeocrinus tariatensis* occurs at 50°N. The occurrence of *Gennaeocrinus tariatensis* significantly increases the paleogeographic range of *Gennaeocrinus*, but information is still lacking to hypothesize on patterns of migration. The occurrence of *Gennaeocrinus* in the Mongol–Okhotsk fauna is not completely unexpected as Emsian brachiopods have a high degree of cosmopolitanism and significant similarity between taxa in the Old World Realm and the Mongol–Okhotsk fauna (Hou and Boucot, 1990).

Webster and Arunichimeg (2004) described an Emsian crinoid fauna from the Chuluun Formation in the Shine Jinst area of Mongolia. In contrast to the terrigenous nature of the Tariat Formation, the Chuluun Formation is dominated by carbonates with mound- and reef-forming stromatoporoids and corals in addition to crinoidal grainstones. This locality is south of the Main Mongolian Lineament and is located on either the Mandavooloo or Gobi Altai Terrane. In contrast to assertions by Webster and Arunichimeg (2004) that the Chuluun crinoids were the most northerly known Emsian crinoid fauna, recent paleogeographic reconstructions (Torsvik and Cocks, 2017) of the CAOB place the Mandavooloo and Gobi Altai Terranes at a latitude of 25–30°N. *Gennaeocrinus tariatensis* is the most northerly known Emsian crinoid, with a paleolatitude of approximately 50°N.

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