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Redescription of the Cambrian edrioasteroid *Sprinkleoglobus spencensis* n. comb. (Wen et al., 2019) from the Spence Shale (Utah, USA)

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Article

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Abstract

The Cambrian edrioasteroid *"Totiglobus" spencensis* Wen et al., 2019 is redescribed on the basis of a new and exquisitely preserved specimen from the Cambrian Wuliuan of the Spence Shale Member, Langston Formation (Utah). This new occurrence is associated with soft-body preservation of several invertebrate groups and other shelly fossils. The description of "*T.*" *spencensis* was originally based on a single poorly preserved specimen. As a result, some of its features, such as curvature of the ambulacra and morphology of floor and cover plates, were misinterpreted or unavailable. The new material allows a new placement in *Sprinkleoglobus spencensis* n. comb. (Wen et al., 2019) on the basis of the general shape of the theca, attachment disc, and biserial flooring plates with podial pores and multiple cover plate series. The attachment disc of the new specimen lies in contact with a trilobite librigena, supporting evidence that this taxon is one of the earliest known examples of attachment to hard, mineralized substrata among Edrioasteroidea.

Non-technical Summary

Edrioasteroids are a group of extinct echinoderms that originated in the Cambrian during the early emergence of animal body plans. Fossils of this group look like modern starfish with five main rays (ambulacra) that converge in a central mouth. But this resemblance is only superficial. Edrioasteroids lived permanently attached to the sea floor or to hard substrates. Herein we redescribe the poorly known edrioasteroid *Sprinkleoglobus spencensis* n. comb. (Wen et al., 2019) on the basis of a new exquisitely preserved specimen from the Spence Shale Member, Langston Formation of Utah. This new specimen allows interpretation of its anatomy and will help us understand early echinoderm evolution.

Introduction

Edrioasteroids are a typical class of Paleozoic echinoderms with a discoidal to globular thecal shape and recumbent ambulacra (Bell, 1976). The phylogenetic significance of Cambrian edrioasteroid is currently debated (for example, concerning crinoid origin, see discussions by Ausich et al., 2015 and Guensburg et al, 2020). Accordingly, all new occurrences of Cambrian edrioasteroids are potentially relevant to our understanding of echinoderm phylogeny (Zamora et al., 2022).

Cambrian edrioasteroids have been reported from Stage 3 (late early Cambrian) to the Jiangshanian (middle late Cambrian) in Baltica, East Gondwana, West Gondwana, and Laurentia, with 15 named genera and 21 named species (Rahman and Zamora, 2024). Edrioasteroids are rare fossils in Cambrian deposits from Laurentia (North America) (see Table 1). The earliest occurrence includes isolated plates from the Poleta Formation, California, USA, dated as Cambrian Series 2 Stage 3 (late early Cambrian), which are also among the earliest known echinoderms (Sprinkle, 1973).

The recently described edrioasteroid "*Totiglobus*" *spencensis* Wen et al., 2019 was founded on a single specimen preserved in moldic condition (Fig. 1). The specimen was neither cast using recommended techniques for the study of specimens preserved as molds (Zamora et al., 2020), nor scanned using more sophisticated techniques, CT scanning for example (Rahman et al., 2010). Thus, many important features were misinterpreted or not observed, resulting in questionable assignment. Here we describe an exquisitely preserved specimen of "*Totiglobus*" *spencensis* from the Spence Shale Member of the Langston

Table 1. Occurrences of Cambrian edrioasteroids from Laurentia. Modified from Zamora et al. (2013b).

Taxon	Series	Stage	Formation	Reference
Edrioasteroidea indet. A	2	3	Poleta Formation	Sprinkle, 1973
Yorkicystis haefneri, Zamora et al., 2022	2	4	Kinzers Formation	Zamora et al., 2022
Camptostroma roddyi, Ruedemann, 1933	2	4	Kinzers Formation	Ruedemann, 1933
new form B	?	?	Wheeler Shale	Guensburg and Sprinkle, personal observation, 2013
Totiglobus nimius	Maiolingian	Wuliuan	Chisholm Shale	Bell and Sprinkle, 1978
Sprinkleoglobus spencensis		Wuliuan	Langston Formation	Wen et al., 2019
Sprinkleoglobus lloydi	Maiolingian	Drumian	Marjum Formation	Sprinkle, 1985
Walcottidiscus typicalis, Bassler, 1935	Maiolingian	Drumian	Greater Phyllopod Bed	Bassler, 1935
new form C	Furongian	Jiangshanian	Conasauga Shale	Sprinkle, personal observation, 2013

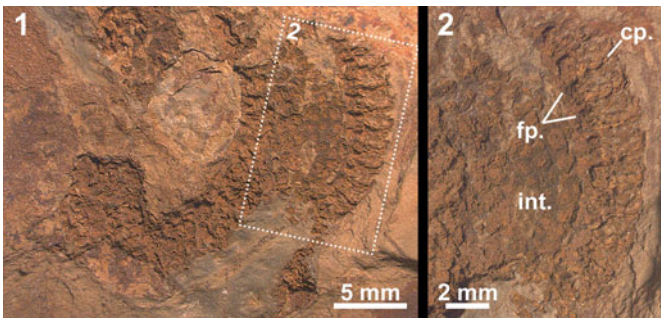

Figure 1. Holotype of *Sprinkleoglobus spencensis* (Wen et al., 2019) from the Spence Shale (Cambrian, Wuliuan Stage), Spence Gulch, Idaho. (**1**) Partial specimen preserving two ambulacra. (**2**) Detail of ambulacra showing floor plates (fp.) and cover plates (cp.). Interambulacra composed of tessellate plates (int.). Specimen number KUMIP 49294.

Formation (Miaolingian Series, Wuliuan Stage) of Utah (western United States). We review previous material described by Wen et al. (2019) and propose reassignment of the material to the recently described genus *Sprinkleoglobus* Zhao et al., 2022. *Sprinkleoglobus spencensis* n. comb. is among the earliest known direct evidence for attachment of edrioasteroids on hard substrates, a life mode later adopted among the great majority of Edrioasteroidea (Zamora et al., 2017; Wen et al., 2019). Early occurrence and expanded anatomical information of this new taxon establish an important standard for understanding edrioasteroid and stem group echinoderm phylogeny.

Locality and geologic setting

The collecting locality is known as High Creek Canyon in the Bear River Range north of Logan, Cache County, Utah. GPS coordinates are: 41°58′20.55″N, 111°42′03.93″W (Fig. 2). The single specimen was collected in situ, 2–3 meters below the top of the Spence Shale Member of the Langston Formation. The age, also indicated in Figure 1, corresponds to the *Glossopleura walcotti* Biozone, Wuliuan Stage, early middle Cambrian. Regionally, this is approximately coeval with the upper portion of the Pioche Shale farther to the southwest. The Spence Shale at High Creek is interpreted as having been deposited in a shelf environment deposited below storm wave base, shallower than localities further west and south (Kimmig et al., 2019).

Materials, preservation, associated fauna, and methods

The original single specimen of the edrioasteroid *Sprinkleoglobus spencensis* n. comb. was collected from the Spence Shale of Spence Gulch, Bear River Range, southeastern Idaho (Cambrian, Miaolingian Series, Wuliuan Stage) and appears attached to a hyolithid shell (Wen et al., 2019).

The new specimen described herein is largely articulated and complete. One ambulacrum lacks cover plates, exposing disheveled floor plates. Preservation of delicate structures and evidence of in situ attachment indicate rapid burial.

Two other specimens in private collections are known from the same locality but were unavailable for study (J. Savill, personal communication, 2023). One of these appears to be attached to a hyolithid.

The new specimen of *Sprinkleoglobus spencensis* n. comb. is part of a small associated cluster of other taxa (Fig. 3). It is attached to an interior librigena of the trilobite *Amacephalus idahoense* (Resser, 1939). Nearby is a pygidium of *Zacanthoides idahoensis* (Walcott, 1908), a small nearly complete *Gogia* sp., and not depicted in Figure 3, a vague trumpet-shaped fossil of unknown affinities.

Other echinoderms occur in the same stratum as that yielding *Sprinkleoglobus spencensis* n. comb., including a common but undescribed species of the eocrinoid *Gogia* and ctenocystoids. A few specimens of a common but undescribed *Gogia* are also attached to bioclastic debris by small holdfasts (Zamora et al., 2013a). Several other Lagerstätte occur in the Spence Shale and are rich in arthropods (Kimmig et al., 2019) and diverse echinoderms, including three species of *Gogia*, the eocrinoid *Lyracystis reesei* Sprinkle and Collins, 2006, the ctenocystoid *Ctenocystis utahensis* Robinson and Sprinkle, 1969, and the stylophoran *Ponticulocarpus robisoni*, Sumrall and Sprinkle, 1999 (Sprinkle and Collins, 2006; Kimmig et al., 2019; Wen et al., 2019; P. Jamison, personal communication, 2024).

The single specimen described was received partly prepared. Additional preparation with fine needles removed more matrix. Detailed coated and uncoated images are multi-focus, stacked montages taken at the Field Museum with a Leica DMS 300 digital microscope and accompanying software. Locality images were provided by the first author.

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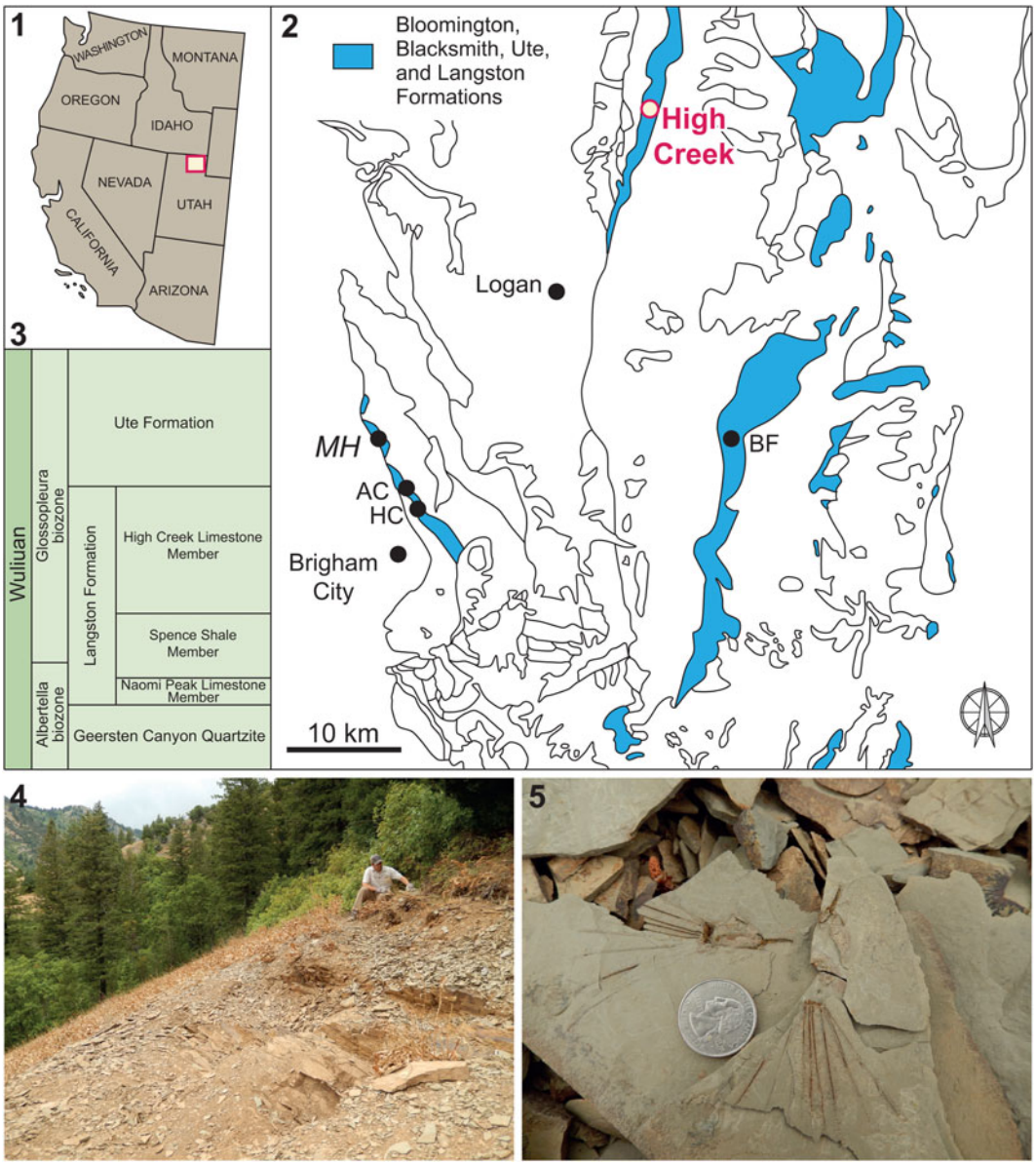

Figure 2. Locality information. (**1**) Map of western United States with indication of the area exposing the Langston Formation. (**2**) Enlargement of the red rectangular area in (**1**). (**3**) Simplified stratigraphy of the Langston Formation. (**4**) Quarry rich in echinoderms in the Langston Formation at High Creek locality, Utah. (**5**) Moldic preservation of undescribed eocrinoid from the productive horizon. (**1–3**) From Kimmig et al. (2019).

Repositories and institutional abbreviations. The specimen reported in this study is deposited at the Field Museum, Chicago, USA (PE 93415). The holotype of the same species is deposited in the University of Kansas Museum of Invertebrate Paleontology, with part numbered as KUMIP 49294A and counterpart as KUMIP 492941B.

Systematic paleontology

Classification and terminology. The classification and morphologic terminology follow Bell (1976). A–E are used to designate the five ambulacra in pentaradially symmetric echinoderms, with the anterior part indicated by ambulacrum A and the posterior part by interambulacrum CD. The type specimen is exposed in anterior view only. Certain aspects of the morphology in the new species appear to be unique (see the following), further complicating interpretation.

Phylum **Echinodermata** Bruguière, 1791 (ex Klein, 1734)
Class **Edrioasteroidea** Billings, 1858
Order **?Edrioasterida** Bell, 1976

Remarks. On the basis of new observations "*T.*" *spencensis* is transferred to the new genus *Sprinkleoglobus* (see the following). The genus *Sprinkleoglobus* was tentatively included in the order Edrioasterida by Zhao et al., 2022 on the basis of the presence of biserial podial pore-bearing flooring plates. Details of the arrangement of the oral plates and flooring plate interiors, which would add to the diagnosis, are lacking at this time.

Genus ***Sprinkleoglobus***

Type species. Totiglobus? *lloydi* Sprinkle, 1985 under original designation.

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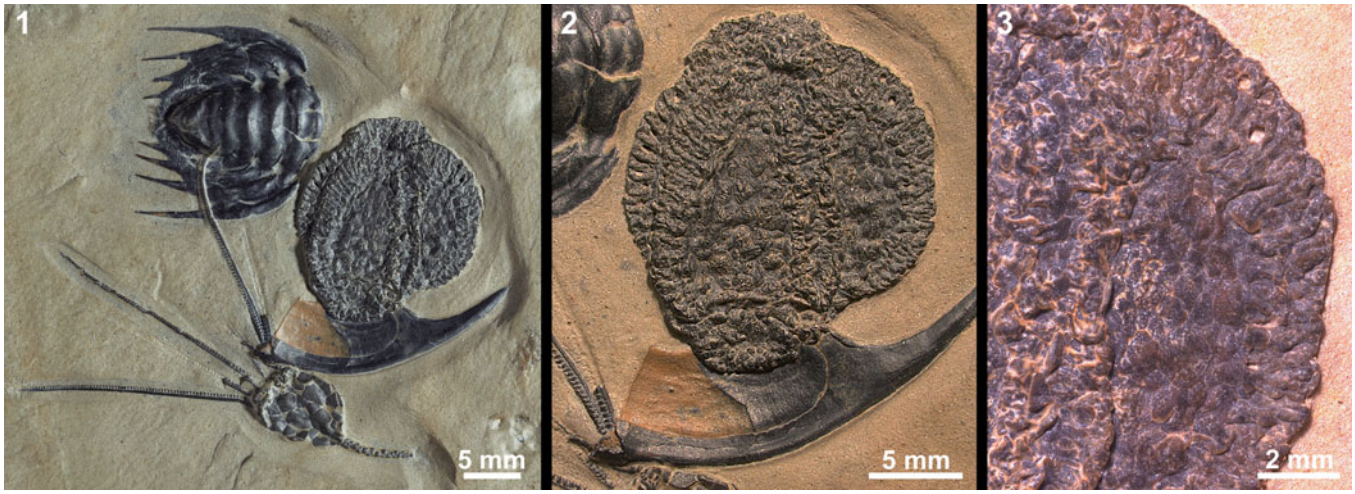

Figure 3. New specimen of *Sprinkleoglobus spencensis* n. comb. (uncoated images) from the Cambrian Wuliuan of the Spence Shale Member, Langston Formation (Utah). (**1**) Associated assemblage, including attached to *Amacephalus idahoense* (Resser, 1939) librigena, nearby complete eocrinoid *Gogia* sp., and pygidium of *Zacanthoides idahoensis* (Walcott, 1908). (**2**) Entire specimen and attachment close up. (**3**) Detail of right-hand ambulacrum.

Included species. *Sprinkleoglobus lloydi* (Sprinkle, 1985), *S. extenuatus* Zhao et al., 2022, and *S. spencensis* n. comb.

Diagnosis. An edrioasterid with globoid to pear-shaped theca, with small aboral attachment structure, much narrower than theca, composed of tiny plates. Ambulacra long and wide, nearly reaching the holdfast, with large biserial flooring plates and multiserial cover plates. Interambulacral plates slightly tumid (after Zhao et al., 2022).

Remarks. The genus *Sprinkleoglobus* was created to accommodate *Sprinkleoglobus lloydi* (Sprinkle, 1985) and *S. extenuatus* Zhao et al., 2022. The latter species is of particular interest in that it is among the earliest known edrioasteroids. The former species was originally described on the basis of a single specimen from the Marjum Formation (Cambrian, Miaolingian Series) of Utah and first included with doubts in the genus *Totiglobus* Bell and Sprinkle, 1978. Description of the latter was based on two specimens from the Chengjiang biota of Yunnan Province, China. With a third occurrence of the genus, some characters of the anatomy are now understood in greater detail (see the following). The general thecal shape and ambulacral development of *Sprinkleoglobus spencensis* n. comb. resemble *S. extenuatus*, and thus it is included with that genus.

Sprinkleoglobus spencensis n. comb.
Figures 1, 3–5

2019 *Totiglobus spencensis* (Wen et al., 2019), fig. 2

Type specimen. Holotype is a largely disarticulated specimen preserved as a natural mold (KUMIP 49294A and counterpart KUMIP 492941B). New referred specimen is complete, flattened (PE 93415).

Diagnosis (emend.). Species of *Sprinkleoglobus* characterized by wide oral area, large interambulacral plates, strongly ornamented cover plates, and fully calcified small discoidal holdfast.

Occurrence. Spence Shale Member of the Langston Formation (Wuliuan Stage, early Miaolingian Series, Cambrian).

Description. Referred specimen flattened theca preserved in lateral view, original shape globoid, adoral surface strongly convex with a wide oral area. Five wide ambulacra are inferred from three exposed examples; ambulacra raised above interambulacra. Ambulacra approximately half the width of each interambulacrum; approximately 18 mm long and 15 mm wide as preserved; with slight distal taper, ending in broad rounded terminations near the holdfast. Each ambulacrum composed of flooring and cover plates. Flooring plates biserial, much wider than long (see discussion that follows); adradial ends thin, paddle-shaped, smooth, forming wide floor of the adradial ambulacrum, abradial ends thicker, exposed surfaces each with V-shaped coarse ridge. Podial pores rimmed, large, ovate. Cover-plate pattern difficult to interpret; holotype and referred specimen indicate large highly ornamented rectangular abradial elements with much smaller adradial elements bordering the perradial suture; abradial elements with ridges in continuity with exposed floor-plate ornament; ridges extend adradially where they continue to near the perradial suture; arrangement of adradial cover plates uncertain.

Interambulacra composed of large, slightly tumid, reticulate, tessellate plates; transitioning distally to low conical plates; approximately 60 in fully exposed anterior interambulacrum, larger elements with smaller intercalated elements; reticulate ornamentation appears to become more prominent distally.

Aboral part of the theca terminating in a holdfast, consisting of numerous small rounded thick plates forming a basal attachment disk; disc approximately 30% of thecal diameter as preserved.

Remarks. Flattening, recrystallization, coarse irregular ornament in ambulacra/oral region, and potentially irregular plate arrangement all contribute to difficulties in morphological interpretation of the new available specimen. Further, the important posterior side of the specimen is unexposed, obscuring observation of main apertures (periproct, gonopore, and hydropore). Original diagnosis by Wen et al. (2019) misinterpreted important features such as the curvature of ambulacra, which is the result of flattening of the dome-shaped theca with straight ambulacra (see

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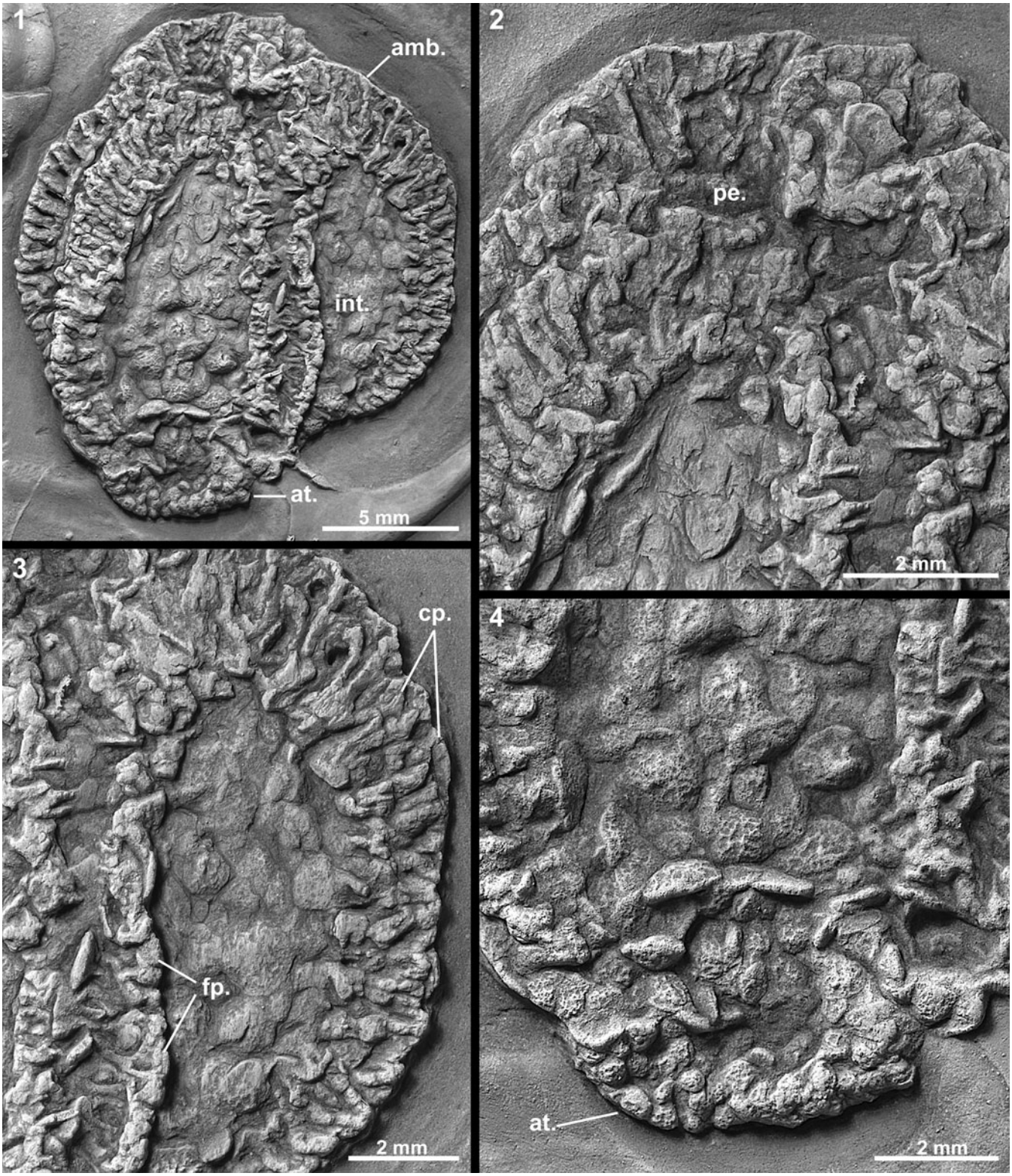

Figure 4. Morphology of *Sprinkleoglobus spencensis* n. comb. from the Cambrian Wuliuan of the Spence Shale Member, Langston Formation (Utah). Holotype PE 93415 (coated with ammonium chloride). (**1**) Entire specimen. (**2–4**) Detail of oral region (**2**), right-hand side (**3**), and holdfast (**4**). amb. = ambulacra; at. = attachment structure; cp. = cover plates; fp. = flooring plates; int. = interambulacral; pe. = peristome.

Zamora et al., 2022 for comparison). Fine ambulacral anatomy was available in the original specimen (Fig. 1) but not reported in the description. New specimen and new observations of the original material indicate that *Sprinkleoglobus spencensis* n. comb. expresses a biserial floor plating and highly ornamented cover plates that diminish in size toward the perradial suture.

Both the type species of *Sprinkleoglobus*, *S. lloydi*, and *S. extenuates*, are characterized by short ambulacra extending down

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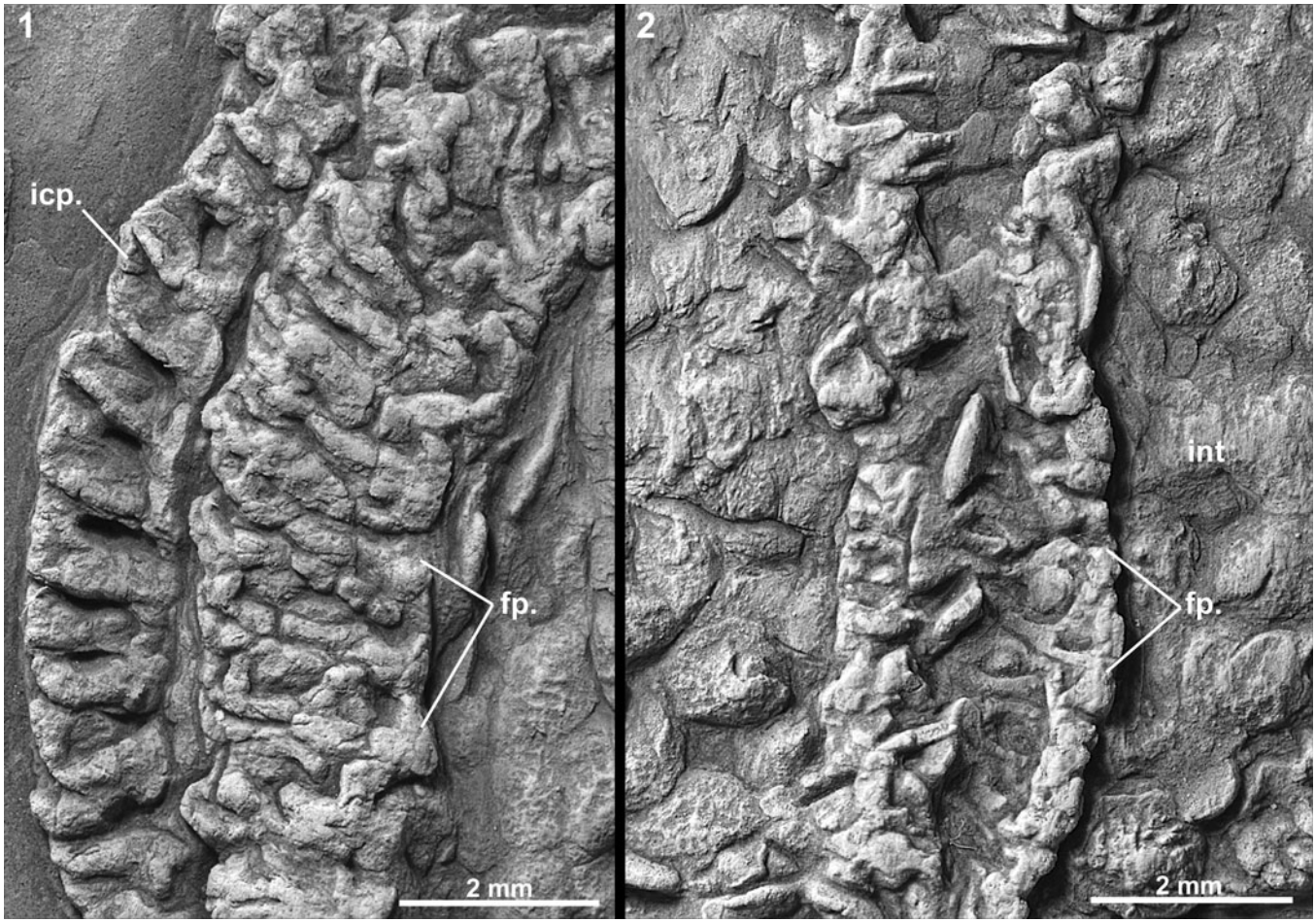

Figure 5. Ambulacral detail (coated with ammonium chloride) of *Sprinkleoglobus spencensis* n. comb. from the Cambrian Wuliuan of the Spence Shale Member, Langston Formation (Utah). (**1**) Left-hand ambulacra with coarse cover plate ornament. (**2**) Central ambulacrum with floor plates. fp. = flooring plates; icp. = internal part of cover plates; int = interambulacra.

approximately 50% of the bud-shaped theca, in contrast to the long ambulacra extending nearly to the holdfast globoid theca in *S. spencensis*. Interambulacral and distal thecal plates of *S. lloydi* and *S. extenuatus* are smaller and more numerous than those of *S. spencensis*. The holdfast of *S. spencensis* is more completely exposed, apparently more heavily calcified, than other species of *Sprinkleoglobus*. The new species is also highly ornamented, but that character is difficult to compare due to poor preservation of the other two species.

Concluding remarks

The species of edrioasteroid "*Totiglobus*" *spencensis* Wen et al., 2019 is transferred to the genus *Sprinkleoglobus* on the basis of a new, well-preserved, complete referred specimen and comparison with the fragmentary holotype. It furnishes new information concerning a relatively poorly known genus, but there is much more to be learned, including oral region and posterior interray plating. In one important aspect, the holotype and referred specimens complement each other with regard to interpretation of the cover-plate configuration (see the preceding). Biserial ambulacral floor-plate morphology resembles those of *S. lloydi*, *Totiglobus nimius* Bell and Sprinkle, 1978 and *Stromatocystites* Pompecki, 1896. There is still much to be determined in this taxon to furnish sufficient data for an informed phylogenetic analysis. *S. spencensis* provides important information regarding attachment strategies among edrioasteroids. This study also emphasizes the risk of describing new species of Cambrian echinoderms on the basis of a few poorly preserved specimens.

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Competing interests. The authors declare none.

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