

Soft-bodied fossil preservation in the Cambrian Parahio Formation of Spiti

Cases of soft part preservation, now known widely in Cambrian rocks throughout the world¹, have resulted in a revolution in knowledge of early metazoan evolution. The famous Burgess Shale of British Columbia, Canada, has prompted the recognition of other important biotas elsewhere, such as at Chenjiang and Kaili in South China. Despite the extensive record of Cambrian sedimentary rocks in the Indian subcontinent, no preservation of soft or weakly biomineralized parts has been recognized to date.

The Parahio Valley of Spiti, Himachal Pradesh, India hosts the best-documented stratigraphic section of Cambrian rocks in the Indian subcontinent. Following its initial discovery and collection by Henry Hayden², a series of works have furthered our knowledge of the Cambrian Parahio Formation³⁻⁷. In his description of Hayden's fauna, Reed³ assigned a specimen on slab GSI9907 from Hayden's Bed 2 (Geological Survey of India (GSI) collection, Kolkata) to the archaeocyathid *Coscinocyathus* cf. *corbicula*. The slab also contains an indeterminate obolid brachiopod under the same specimen number⁸. It came from the *Oryctcephalus indicus* level, about 200 m above the base of the Parahio Formation

section in the valley⁷, is preserved in dark mudstone deposited in a deltaic marine setting⁶, and is from the base of Cambrian Stage 5, about 510 million years old⁷. This fossil is reconsidered herein, and illustrated photographically, as part of an ongoing synoptic review of Himalayan Cambrian fossils collected both previously and during recent fieldwork⁷⁻¹⁷. Locality details, including maps, are provided in the literature^{7,10,16}.

GSI9907 contains a fragment of an apparently originally circular or oval object, estimated to have been about 40 mm wide in life, with both a radial and concentric surficial ornament (Figure 1a). The original way up of the specimen is unknown. At the peripheral margin of the ornamented surface lines defining the radial ornament appear as two sets, with more firmly incised major lines regularly spaced about 2.5 mm apart, and less prominent minor lines spaced about 0.5 mm apart (Figure 1b). The angle between each major element is about 5°, suggesting that an originally circular animal had roughly 70 major elements. Less prominent concentric rings occur 0.5 mm or less apart. The warped topography of the surface defines several sinuous tubular structures, up to 1 mm wide,

that may radiate towards the centre of the structure. The tubes do not appear to extend beyond the margin of the ornamented surface. A flange, orientated normal to the ornamented surface extends from the middle portion of the specimen (at the approximately 11 o'clock position in Figure 1a). It widens towards the periphery and continues beyond the ornamented margin, and here is not interpreted to be part of the fossil. An obolid brachiopod is associated with the margin of the ornamented area⁸. Tectonic deformation is not clearly evident in GSI9907, but other fossils from the same horizon are notably sheared¹⁷.

Evidence of original skeletal material and radial rows of pores that would suggest affinity with plate-like archaeocyathids of similar gross morphology is lacking, and for these reasons archaeocyathid affinity is rejected herein. The regular spacing of the sharply defined radial ornament is hard to reconcile with a non-body fossil origin for the structure, such as a concretion or scratch circle¹⁸. It is likely that the tubular depressions are trace fossils, possibly those of an organism attracted to the associated carcass, but it is possible that they represent remnants of collapsed tubular soft tissues that were part of the individual¹⁹.

Among circular metazoans with malleable integument possible candidates include eldoniid metazoans and anthomedusoid scyphozoans, which are both of comparable size to that estimated for GSI9907 when complete. The most detailed evidence of affinity is provided by the major and minor radial elements in the ornament, and the densely concentrated concentric rings. The major radial elements resemble those seen in the peripheral parts of the sclerotized dorsal surface of flattened eldoniids²⁰. Dense concentric rings, interpreted as representing accretive growth, are also known in the dorsal surface of the animals. The inferred presence of 70 radial units defined by the major radial elements at the margin of this disk is broadly comparable to those seen in both *Eldonia ludwigi* and *Stellosomites eumorphus*²⁰. GSI9907 is too poorly preserved to be assigned systematically or to reveal other diagnostic features of the group, such as the curved

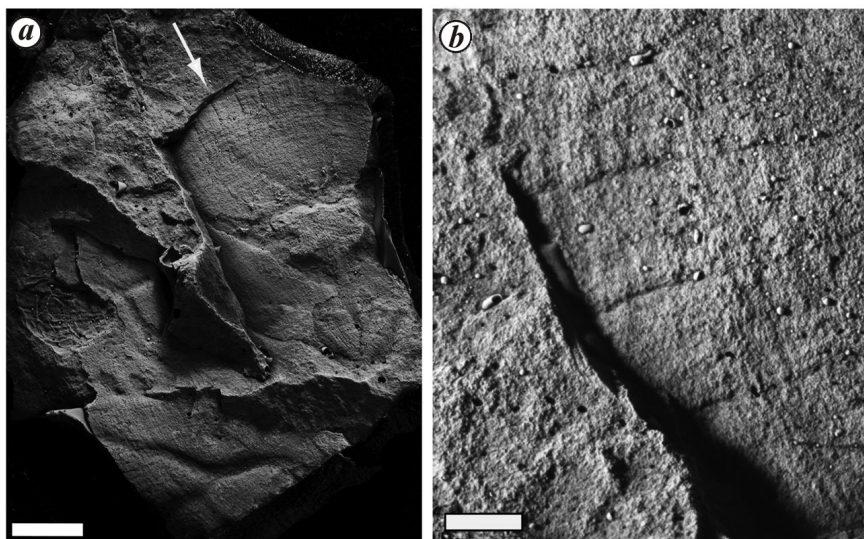


Figure 1. Polyurethane replica of eldoniid integument, Cincinnati Museum Center IP 71574, of specimen GSI9907. **a**, Malleable integument with both radial and concentric ornament, tubular structures, and the counterpart of an obolid brachiopod; white arrow points to area enlarged in **(b)** (scale bar = 5 mm). **b**, Details of the margin of the same specimen showing regular spacing of the major and minor radial ribs and the concentric ribs (scale bar = 1 mm).

gut and tentacular mouth, but a specimen is known with associated tubes somewhat akin to those seen in the Himalayan specimen (ref. 20, figure 6e). The association with the obolid brachiopod is also interesting, as bivalved epibionts attached in a similar position are well known in eldoniids²⁰.

An alternative is anthomedusoid affinity, comparable to the pneumatocyst of the living *Velella velella*, a pelagic hydrozoan colony commonly known as the 'by-the-wind sailor'. Such animals also have a radial and concentric ornament. The case for this assignment would be stronger if the flange could be shown to be homologous with the velellid sail; but in GSI9907 this structure is likely an artifact. Also, velellid concentric rings are widely spaced and boldly defined, marking the gas-filled chambers of the pneumatocyst²¹, whereas in GSI9907 the concentric rings are weakly defined and closely spaced. For these reasons an eldoniid affinity is more strongly supported. This interpretation is consistent with known eldoniid occurrence in Cambrian rocks, whereas putative velellids from rocks of lower Palaeozoic age²² have been discounted¹⁸. Velellids are pelagic organisms, with floating aided by the pneumatocyst. Differences of opinion exist as to whether eldoniids were pelagic^{20,23} or benthic²⁴. Other fauna also from Hayden's Bed 2 are benthic. If pelagic, GSI9907 likely represents a sunken carcass.

Even though mudstones of the Parahio Formation are deformed, this specimen shows that exceptional preservation of soft tissue did occur on occasion and could survive to the present. Further finds in these rocks will permit testing of the ideas proposed herein, although the intense fracture and steep topography of

these mudstones may limit the chances of a large area of bedding plane surface being exposed. GSI9907 hosts the first recognized metazoan soft-tissue structure from the Cambrian of the Indian subcontinent.

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ACKNOWLEDGEMENTS. I thank officers of the Geological Survey of India for access to their collections; R. R. Gaines (Pomona College) and S. R. Jensen (Universidad de Extremadura) for discussions, and the anonymous reviewer for useful comments. My Himalayan work has been supported by grant NERC GT8/F/89/GS/7, and National Science Foundation grants EAR-9980426 and EAR-1124303.

Received 17 June 2015; revised accepted 20 October 2015

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