Estonian Journal of Earth Sciences
2023, **72**, 1, 50–53

https://doi.org/10.3176/earth.2023.76

www.eap.ee/earthsciences
Estonian Academy Publishers

SHORT COMMUNICATION

Received 8 April 2023
Accepted 18 May 2023
Available online 9 June 2023

Keywords:
Porifera, demosponge, Halichondrida, Beigong Biota, latest Ordovician, South China

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Citation:
Li, L. and Reitner, J. 2023. A remarkable new halichondrid demosponge, *Ptilospongia hemisphaeroidalis*, from the latest Ordovician Beigong Biota, South China. *Estonian Journal of Earth Sciences*, **72**(1), 50–53. https://doi.org/10.3176/earth.2023.76

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A remarkable new halichondrid demosponge, *Ptilospongia hemisphaeroidalis*, from the latest Ordovician Beigong Biota, South China

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ABSTRACT

A new halichondrid demosponge bubarid *Ptilospongia hemisphaeroidalis* gen. et sp. nov. is described from the latest Ordovician Beigong Biota in Jingxian County, Anhui Province, South China. The new taxon is well-preserved with a two-layer choanosomal skeleton structure (basal layer and erect monactines layer) and three different types of megascleres (styles, strongyles, strongyloxeas), providing an excellent insight into a bubarid affinity and indicating a previously unknown group. It probably represents the earliest known fossil record of bubarids, providing a more reliable calibration point currently available for taxonomic and molecular phylogenetic studies.

Introduction

The Late Ordovician mass extinction is the earliest among the Big Five in Phanerozoic (Sepkoski 1996). It severely damaged the ecological structure and had a devastating influence on the marine ecosystem, resulting in a catastrophic decline in biodiversity, with at least 85% of species going extinct during this crisis (Sheehan 2001). Significantly, recent studies indicate that diverse and abundant sponges flourished rapidly during and after the second pulse of the Late Ordovician mass extinction, and dominated the benthic community of the marine ecosystem (Li et al. 2015, 2019, 2023; Botting et al. 2017, 2018a, 2018b). One of the well-known representatives is the Beigong Biota, an unusual deep-water sponge assemblage spanning the interval of the end-Ordovician mass extinction from the black siliceous mudstone of the Kaochiapien Formation (Upper Ordovician–Llandovery) at Beigong of Jingxian County, southern Anhui Province, South China (Li et al. 2015). This sponge assemblage is of latest Ordovician (late Hirnantian) to earliest Silurian (early Rhuddanian) age, extending across the Ordovician–Silurian boundary. As a whole, the Beigong Biota contains abundant and diverse fauna of siliceous sponges. More importantly, most of them are perfectly preserved with a nearly complete sponge skeleton. In addition, not only the Burgess Shale-type taxa, but also the taxa that resemble modern sponges were discovered in this biota. Notably, there is a considerable number of taxa in the biota, representing numerous missing links in the multiple Phanerozoic sponge lineages (Li et al. 2019, 2023). Thus, further studies on this unusual biota could potentially reveal a more complete picture of the evolution of Phanerozoic sponges.

In this paper, we describe a new demosponge found in the Beigong Biota, showing probably encrusting habit and a two-layer structure of choanosomal skeleton, which are unique to the family Bubaridae Topsent, 1894. The smooth diactines without any ornaments in the basal skeleton and a megasclere assemblage of three different types (styles, strongyles, strongyloxeas) indicate a previously unknown taxon in Bubaridae, allowing us to describe a new genus and a new species in this family.

Material

The present new material is collected from a continuous sequence across the Ordovician–Silurian boundary at the Beigong section of Jingxian County, southern Anhui Province, South China (Fig. 1). The type species is from horizon SF14 of the lowermost Kaochiapien Formation, associated with graptolites such as *Neodiplograptus shanchongensis*, *Normalograptus angustus*, *N.* sp. aff. *indivisus*, *N. laciniosus*, *N.*? *lungmaensis*, *N. normalis*, *N.* cf. *ugurensis*, etc., which are typical taxa in the *Metabolograptus persculptus* Biozone, indicating the latest Ordovician (late Hirnantian) age (Li et al. 2015). The specimen is deposited at the Nanjing Institute of Geology and Palaeontology, Nanjing, China, and indicated by their accession numbers.

Taxonomy

Phylum PORIFERA Grant, 1836
Class DEMOSPONGIAE Sollas, 1885
Order HALICHONDRIDA Gray, 1867
Family BUBARIDAE Topsent, 1894
Genus *PTILOSPONGIA* gen. nov.

Type species. *Ptilospongia hemisphaeroidalis* gen. et sp. nov.

Etymology. From Greek *ptilo*, plume; referring to the tracts of soft-looking and feathery spicules of this sponge.

Diagnosis. Encrusting, hemispherical sponge with hispid surface. Ectosomal skeleton is absent. Choanosomal skeleton is mainly composed of bundles of long styles projecting perpendicularly to substrata with heads embedded in a basal layer of strongyles. Megascleres are long and smooth styles, strongyles and strongyloxeas.

Remarks. The new taxon found in the Beigong Biota probably shows encrusting habit and a two-layer structure. The basal layer is characterized by normal-appearing diactines and the perpendicular layer is formed of bundles of monactines with the bases embedded in the basal skeleton. This remarkable structure is in accordance with the diagnostic characters of the family Bubaridae Topsent, 1894.

At present, all the genera included in Bubaridae are modern ones, no fossil species have ever been found (Van Soest 2001; Alvarez and Van Soest 2002; Finks et al. 2004; Morrow and Cárdenas 2015). Significantly, modern sponges are classified mainly based on larval type, reproduction, megascleres and microscleres. It is clear that the first two characteristics are not applicable to fossil sponges. Therefore, the type of megascleres and microscleres as well as their arrangements in the sponge body become the key criteria of classification. Unfortunately, microscleres are rarely discovered, particularly in siliciclastics of the lower Palaeozoic, because of their tiny size and the fact that the main component (opaline silica) dissolved easily in seawater (Land 1976; Zhang

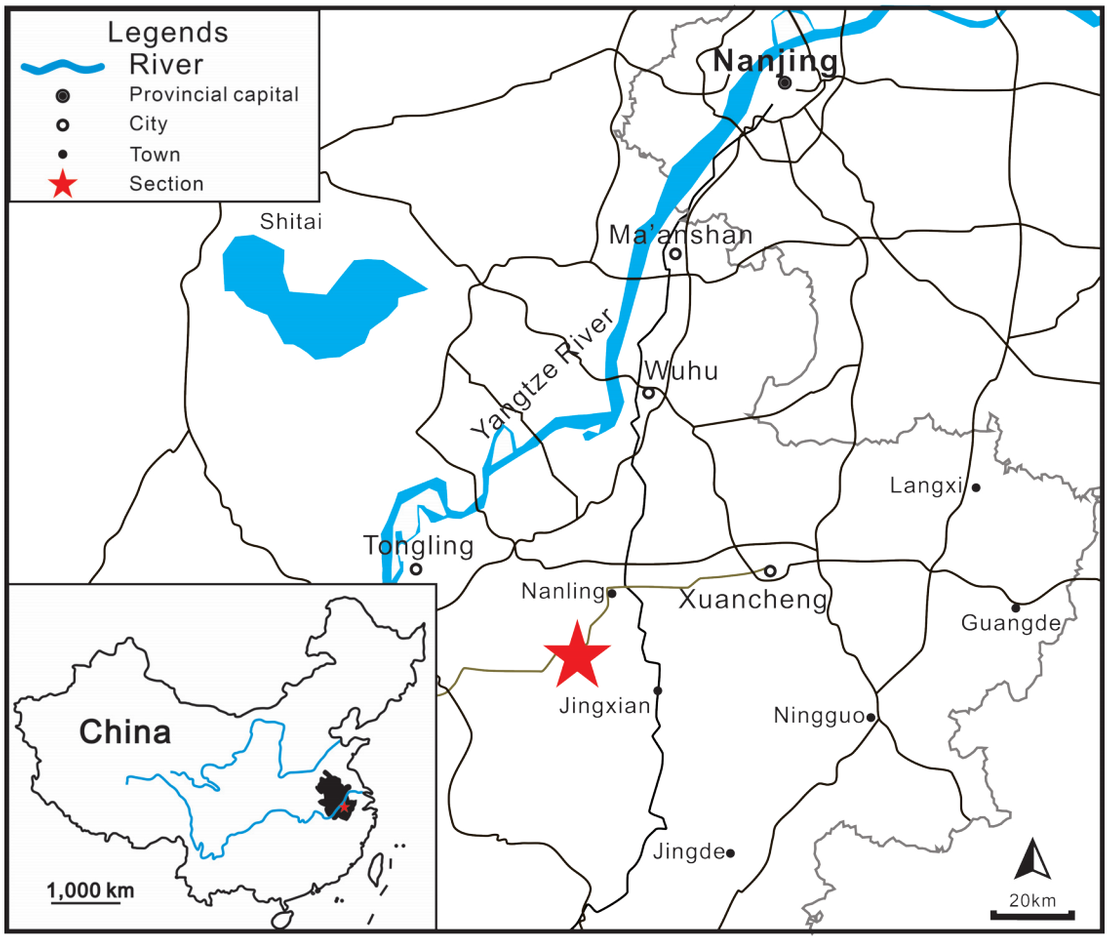

Fig. 1. Map showing the location of the Beigong section in Jingxian County, Anhui Province. The black irregular area with the red star is the location of Anhui Province. The red star indicates the position of the studied section.

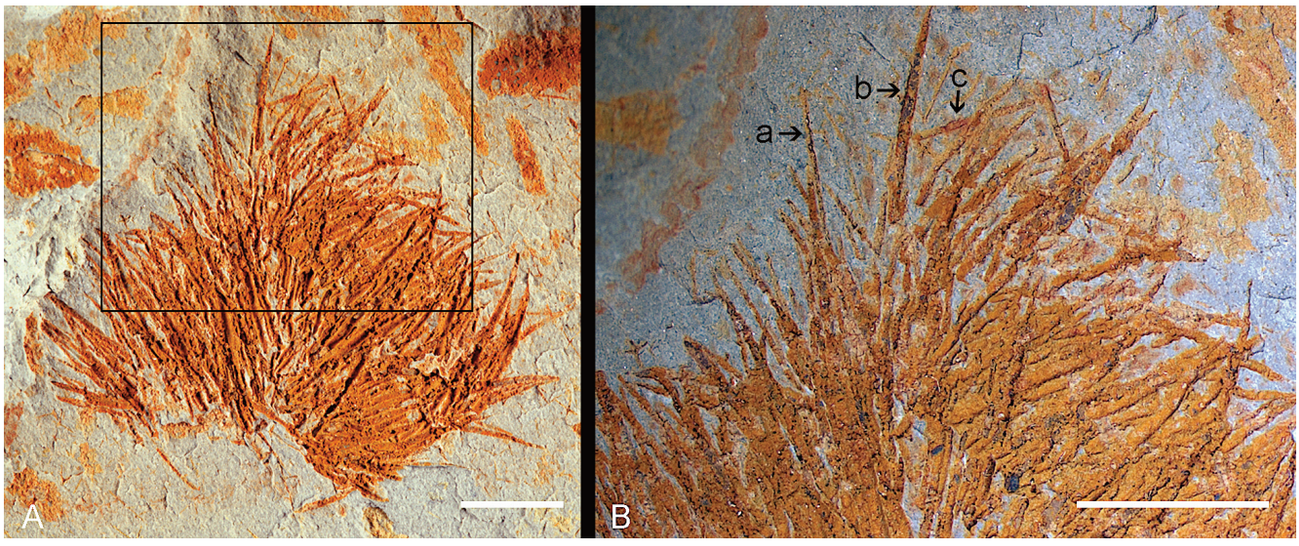

Fig. 2. *Ptilospongia hemisphaeroidalis* gen. et sp. nov., holotype SF14-35. **A** – overall view of the complete and lateral compressed specimen; **B** – magnified view of the box area in A, the arrows show different types of megascleres: a – strongyloxea, b – style, c – strongyle. Scale bars = 5 mm.

and Pratt 2000). In the absence of microscleres, we can only differentiate varieties of fossil sponges according to the type and arrangement of megascleres.

Although microscleres cannot be identified in the new genus, the megascleres (styles, strongyles, strongyloxeas) and the two-layer choanosomal skeleton structure (basal layer and erect monactines layer) strongly suggest a bubarid affinity. Therefore, it seems reasonable to assign this new taxon to Bubaridae. However, there are no previously described taxa of Bubaridae showing close similarity in spicule morphology of basal skeleton with the new taxon described here, which probably represents a previously unknown group.

Ptilospongia hemisphaeroidalis gen. et sp. nov.
Figure 2

Types. SF14-35, one complete and well-preserved compressed specimen with iron hydroxide spicule replacements.

Diagnosis. As for genus.

Etymology. From Greek *hemi-*, half; *sphaeroidalis*, spherical, referring to the hemispherical shape of the sponge body. Gender feminine.

Age/Occurrence. *Metabolograptus persculptus* Biozone, Kaochiapien Formation, Jingxian County, Anhui Province, China.

Description. Small, hemispherical sponge with hispid surface giving a pompon-like appearance, up to 11.5 mm tall and 15.2 mm wide in the compressed specimen. The apex is located at the longitudinal axis of the sponge body, which is formed by megascleres in an upwardly plumose arrangement, prominently protruding from the surface. The maximum diameter is approximately in the lower third of the body height, narrowing upwards and downwards, with a diameter of about 5.2 mm near the bottom. Although the base is unrecognizable in the present specimen, the width of the sponge body decreasing toward the bottom probably indicates a rounded or encrusting base to facilitate the fixation of the sponge (Fig. 2A).

There is no evidence of a distinct ectosomal skeleton, and it is therefore presumed to be absent.

Choanosomal skeleton differentiates into two layers, the basal layer is formed of relatively slender normal-appearing strongyles, and perpendicular to this layer long and stout styles with heads embedded in the basal skeleton, few strongyles and strongyloxeas are also present, scattering sporadically in the space between the stout styles (Fig. 2B). The most distinctive megascleres are stout styles, about 2.02–3.93 mm long, with a uniform thickness of around 0.13–0.25 mm from the base to three quarters of the spicule length, and then tapering smoothly to a sharp tip. Generally, the styles are smooth and straight, only slightly curved near the quarter of the tip. Compared to the styles, the strongyles are much slenderer, about 1.92–2.22 mm and 0.1–0.12 mm in diameter. Strongyloxeas are even slenderer but longer, up to 2.82 mm long and 0.08–0.09 mm in diameter. Strongyles and strongyloxeas are both straight, without curved tips. Microscleres are unrecognizable or absent.

Remarks. The new species bears superficial similarities to modern representatives of Bubaridae. However, there are some significant and prominent differences between the new species and modern sponges, mainly in terms of the spicule morphology and type of both basal and perpendicular layers.

Among the species of the four valid genera in the family Bubaridae (Alvarez and Van Soest 2002), *Bubaris vermiculata* (Bowerbank 1866) shows close similarities with the new species described herein as to the type of megascleres – both of which have three types of megascleres (styles, strongyles and strongyloxeas), with mainly styles projecting perpendicularly to substrata. However, unlike *B. vermiculata*, which is characterized by sinuous or vermicular diactines, the new species have much simpler basal diactines of smooth and normal-appearing strongyles.

The new species also shows certain similarities with another bubarid, *Cerbaris* Topsent, 1898. Nevertheless, com-

pared with the species belonging to *Cerbaris*, the new species bears simple basal diactines without any even or uneven acanthose ornaments which are quite common in the former. Moreover, the spicules in both the basal skeleton and the perpendicular layer of *Cerbaris* exhibit a more diverse pattern, including spicule types and size categories.

Except for the characters common to all species of Bubaridae, there are more significant differences between the species of the genus *Hymerhabdia* Topsent, 1892 and the new species. The basal skeleton of the former is composed of interlacing rhabdostyles and/or bent angulate oxeas, rather than of smooth strongyles that the latter has. Furthermore, although both of them have styles in the perpendicular layer, the associated subtylostyles and tylostyles in the *Hymerhabdia* as well as strongyles and strongyloxeas in the new species make them clearly distinguishable from each other.

Compared with species assigned to another bubarid, *Monocrepidium* Topsent, 1898, the new species has nearly the same smooth styles in the perpendicular layer as those in the former, although there is a subtle difference between the two in that the styles in the former are generally bent near the base, but are always curved near the tip of the latter. Moreover, the basal skeleton of the former is usually characterized by stout and ornamented diactines such as vermiculate, tuberculate or annulate strongyles or strongyloxeas that are occasionally arranged in a spiral. In contrast, the basal diactines of the new species exhibit a thinner and simple form of smooth strongyles without any ornaments.

Thus, it seems advisable to assign this new species to Bubaridae, and the remarkable differences make a more than generic separation between the new species and other taxa in Bubaridae.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (NSFC, Nos 42072005, 41702005) and the Strategic Priority Research Program of the Chinese Academy of Sciences (grant XDB26000000). This paper is also a contribution to the IGCP Project 735 'Rocks and the Rise of Ordovician Life'. The publication costs of this article were partially covered by the Estonian Academy of Sciences.

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