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Deep shelf biostrome of Late Permian in South China and its implications for the adaptability of calcisponges to water depth

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ABSTRACT

The Yangtze platform of South China was an area of extensive carbonate accumulation during the Late Permian, with abundant benthic fossils and reef buildups. Its northern margin has long been considered to be bordered by deep shelf sediments rich in radiolarians and ammonoids. However, recent investigations found a sponge biostrome in deeper shelf settings in the uppermost Permian. The biostrome is about 0.45 m thick with an organic framework formed by autochthonous calcisponges. In contrast to more diverse shallow marine reef communities at this time, the biostrome was almost entirely constructed by the sponge genus *Peronidella* as the only frame-building organism. This low biodiversity reflects a relatively deep-water environment. *Peronidella* individuals in the biostrome are apparently larger than the same genus in shallow platform settings, including the diameters of both the sponge bodies and the central tubular spongocoel, as well as the thicknesses of the body walls. This increased size may be related to the low biodiversity and therefore to reduced competition, with sponge individuals having increased space in which to develop. Biostrome development was terminated by volcanic clay deposition.

1. Introduction

Widespread reef communities flourished during the Late Permian Changhsingian stage in South China. Most reefs at that time were located in the Nanpanjiang Basin, mainly within Guangxi (Zhang and Zhang, 1990; Lin, 1992; Zhou and Zhang, 1995; Wang et al., 1996), the eastern Sichuan Basin (Fan et al., 1982; Qiang et al., 1985; Fan and Zhang, 1987; Wang and Qiang, 1992), and the middle and lower Yangtze River Basin (Wang et al., 1990, 1997; Xu et al., 1997; Shen and Kawamura, 2001) (Fig. 1). In the Nanpanjiang Basin, reefs formed along the southern margin of the Yangtze platform as well as on isolated platforms scattered throughout the otherwise deep basin. Eastern Sichuan and western Hubei contain the largest quantities of Changhsingian reefs, which formed along the platform margin or as patch reefs within the platform. Reefs in the middle and lower Yangtze River Basin were paleogeographically located along the northern margin of Yangtze platform. Almost all of the abovementioned reefs are mainly constructed by calcisponges, and have been considered to have formed in normal shallow marine environments (Feng et al., 1997). However, the Changhsingian sponge biostrome reported here from Jingshan, in Hubei Province, was formed in a deeper shelf setting, long regarded as a deep-water basin dominated by radiolarian cherts and clastic sediments (Feng et al., 1997). The discovery of a sponge biostrome in this area not only extends the variety of organic buildups of Late Permian age in South China, but also provides new insights into the paleoecology of calcisponges and, in particular, their adaptation to relatively deep marine environments.

2. Geological background

There was an increased paleogeographical environmental differentiation during the Changhsingian in South China. The middle area of South China, including Sichuan, Guizhou and the middle and lower Yangtze River Basin, was essentially a shallow platform occupied by a variety of carbonate sediments referred to as the Changxing Formation, while the northern and southern margins were dominated by siliceous and siliciclastic basinal sediments known as the Dalong Formation (Feng et al., 1997) (Fig. 1). The Changxing limestone, typically consisting of shallow platform facies, is rich in benthic organisms, such as brachiopods, calcareous algae, foraminifers, and reefs formed mainly by inozoan and sphinctozoan sponges (Rigby et al., 1989a,b). In contrast, the Dalong Formation is characterized by abundant planktic and nektonic fossils, such as radiolarians and ammonoids (Cai et al., 2011).

The Jingshan area, situated well into the basin at the northern of Yangtze platform, has long been considered a deep basin environment during the Late Permian (Fig. 1). The succession here begins with

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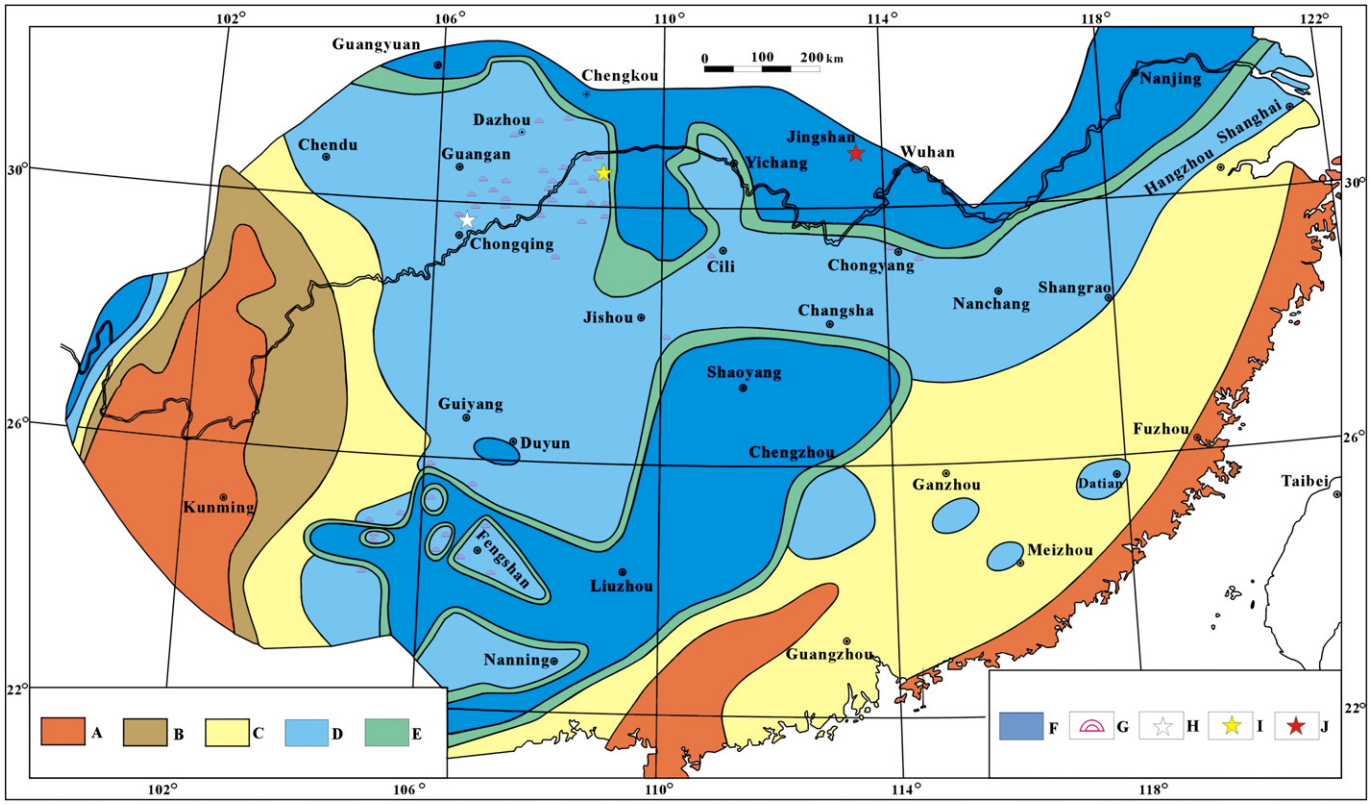

Fig. 1. Paleogeography of the Late Permian Changhsingian stage in South China (modified from Feng et al., 1997). A) Erosion area. B) Alluvial plain. C) Debris platform. D) Carbonate platform. E) Slope. F) Basin. G) Reef. H) Location of sponge reef in Beibei, Chongqing. I) Location of sponge reef in Lichuan, Hubei Province. J) Location of sponge biostrome in Jingshan, Hubei Province.

mudstone rich in ammonoids and deep water brachiopods, and passes successively upwards into thin-bedded radiolarian chert interbedded with limestone in the middle part, and then limestone with chert in the upper part. Near the end of Late Permian, 4 m of carbonate rock with no chert abruptly occurs, and is overlain by radiolarian chert interbedded with clays derived from volcanic ash (Fig. 2I). The 0.45 m thick sponge biostrome occurs within the 4 m thick limestone (Figs. 2II, 3A). Obviously different from the moundlike organic reefs or bioherms, the bedded sponge biostrome in this study is in well parallel with both the underlying and overlying limestone layers (Fig. 3B). Nevertheless, the sponges in the biostrome are so rich that they could interconnect to build the organic framework (Fig. 3C).

The lithological sequence and sedimentary facies show that the Jingshan area remained a deep basin environment throughout most of the Late Permian. However, increased limestone deposition in the upper part of the section indicates sea-level fall, which terminated at the top of the 4 m thick limestone. We therefore regard the sponge biostrome as a product of sea-level fall near the end of the Permian. However, thin-bedded chert overlying the carbonate rocks probably indicates a relatively abrupt increase in water depth in this area.

3. Sponge fossils in the biostrome

The term “biostrome” was defined as a distinctly bedded structure that does not develop into lens-like or reef-like form but consists mainly or exclusively of the remains of organisms (Cumings, 1932). Biostromes are often associated with organic reefs and bioherms. Biostromes formed by reef-building organisms are also known as layered reefs (Jia and Li, 1989).

The Changhsingian biostrome at Jingshan is about 0.45 m thick and consists of a single, in situ species of reef-building calcisponge; these sponges were united to form an organic framework (Fig. 4). Because the framework did not develop topographic relief above the seafloor, we term it a biostrome in order to distinguish it from a bioherm (Cumings and Shrock, 1928; Riding, 2002).

The calcisponges in the biostrome belong to the genus *Peronidella* (Hinde, 1893), attributed to the Suborder Inozoa (Steinmann, 1882) of the Order Pharetronida (Zittel, 1878). The *Peronidella* at Jingshan are cylindrical with diameters of about 3 to 4 cm and lengths of 6 to 8 cm. The cross-section shows a circular central spongocoel, 1 to 2 cm in diameter, with about a 1 to 1.5 cm thick skeletal fabric around it. Generally, the skeleton accounts for nearly two thirds of the width of the sponge body, while the central cavity accounts for about one third. The skeletal fabric has a vermicular-like texture composed of granular calcite. The thickness of the skeletal fibers in the middle of the body wall is about 0.05 to 0.15 mm, and becomes thicker up to 0.3 mm near the sponge body surface and around the spongocoel (Fig. 7A). There are a small number of pores penetrating the spongocoel wall to connect the canals. The complex canals are about 0.5 to 1 mm wide in the middle of skeletal fabric, but become narrower (about 0.2 to 0.5 mm) near the spongocoel and body surface due to the thicker skeletal fibers there. The brain-like, striated space between the skeletal fibers, as well as the central spongocoel, is occupied by micritic matrix and fossil fragments. The width of the central spongocoel appears to remain constant throughout the entire cavernosum (Fig. 5).

In comparison with previously described Permian *Peronidella* from shallow reef communities in south China (Fan and Zhang, 1987; Wu, 1991; Fan, 1996), Thailand (Senowbari-Daryan and Ingavat-Helmcke, 1994) and Iran (Senowbari-Daryan et al., 2005, 2007), *Peronidella* individuals in the Jingshan biostrome are significantly larger in terms of both diameter of the sponge body and of the central tubular spongocoel, as well as in the thickness of body wall (Table 1, Fig. 6). The diameters of sponge bodies living in shallow reef communities are mostly less than 2 mm (Fan and Zhang, 1987; Fan, 1996; Fan et al., 2002), while