Late Pennsylvanian Tubiphytes reef in southern Guizhou Province, China: new insights into the peculiar reef-building association and the global environment change

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Abstract

Hybrid carbonates are widespread and diverse throughout geological history and can reflect critical transformations in biosphere and earth surface processes. Late Pennsylvanian increase in microbial carbonates, together with the appearance of locally conspicuous sparry crusts, marked the inception of a significant interval of abiotic-microbial-skeletal triple hybrid carbonates formation that continued until the Middle Triassic (Riding and Virgone, 2020). Here, we present a new type of reef-building association from the uppermost Pennsylvanian (Gzhelian) strata of southern Guizhou Province, China. The reef is mainly composed of in situ *Tubiphytes* boundstone, *Tubiphytes*-cementstone, extensive synsedimentary cements, microbial bounsdstone, and coral framestone. The reef reported in this study is a peculiar reef-building association because of its extensive syndepositional marine cement, and was classified as abiotic-microbial-skeletal triple hybrid carbonates formed on the carbonate platform margin during the Late Pennsylvanian.

The main reef-building organisms are *Tubiphytes*, colonial rugose coral *Ivanovia* sp., encrusting calcimicrobes, and bryozoans in order of their content. Syndepositional marine cement is an important component of this reef, and locally forms cementstone. The following characteristics are found in the studied reef: (1) The primary reef-building organisms, including *Tubiphytes*, colonial rugose coral *Ivanovia*, and lamellar calcimicrobes, have a good encrusting habit; (2) Most of the bioclasts have micritized envelopes with a microbial origin. The lamellar encrusting calcimicrobes *Archaeolithoporella* is considered as the connecting bridge structure (linkage) between *Tubiphytes*, botryoidal cements, and clotted micritic microbialite; (3) Most of the biogenic components are surrounded by botryoidal radial fibrous cement, and remaining interstitial spaces are filled with blocky calcite cement; (4) Throughout the reef, allochthonous sediment is conspicuously absent; (5) The high proportion of early marine cement (especially botryoidal cement) in the reef indicates high original porosity. The massive coral *Ivanovia* could provide a protected environment for *Tubiphytes* and encrusting calcified microbes *Archaeolithoporella* to form the micro-frameworks in shallow marine with high energy conditions. Interstitial-filling radiaxial fibrous cement (syndepositional marine cement) were also formed under high energy conditions with good water circulation, enhancing the

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rigidity of the framework.
The widespread triple hybrid carbonates during Pennsylvanian and early Permian were considered as the result from extensive precipitation of synsedimentary cement, coinciding with climate cooling, sea level drop, increase continental washout, and slow-spreading seafloor intervals. In addition, the seawater chemistry was favorable for the aragonitic organisms and cement during these intervals. In the Late Pennsylvanian, the increase in microbial carbonates and the appearance of locally conspicuous sparry crusts marked the inception of a significant interval of abiotic-microbial-skeletal triple hybrid carbonates formation. The occurrence of the studied *Tubiphytes*-cement reef may indicate a significant change in the Pennsylvanian reef system of south China, consistent with a global environment during the Late Pennsylvanian (icehouse period). Thus, it also reflects an important development in the construction of shallow-water tropical reefs under late Paleozoic glaciation events.

Keywords: Reef, Tubiphytes, Hybrid carbonates, Late Pennsylvanian, South China