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Influence of differential diagenesis on primary depositional signals in limestone-marl alternations: An example from Middle Permian marine successions, South China

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ABSTRACT

The diagenetic alteration of rhythmic successions remains one of the main challenges in paleoclimatology and cyclostratigraphy. To address this very important problem, thin sections and geochemical data of the limestone-marl alternations from Middle Permian carbonate successions in South China are examined to identify differential diagenetic effects in the petrography, organic and inorganic compositions, strontium concentrations and stable isotopic compositions of limestone beds and marl interlayers. In the Lengshuixi outcrop and the JY66-1 drill core, the most conspicuous features are that the limestone beds exhibit dense cementation, high strontium concentrations, negative oxygen isotopic values and positive carbon isotopic values. In contrast, the marl interlayers contain talc and exhibit strongly deformed and oriented bioclasts, low strontium concentrations, positive oxygen isotopic values and negative carbon isotopic values.

Although differential diagenesis has occurred, some paleoclimate proxies (e.g., computed gamma-ray values) still preserve their primary signals and thus are suitable for cyclostratigraphic research. Eccentricity rhythm and millennial-scale rhythm are obviously recorded in Middle Permian limestone-marl alternations in South China. The variations in the oxygen and carbon isotopic values of limestone-marl alternations from different basins represent responses to different processes of differential diagenesis. This knowledge assumes that differential diagenesis occurs in diagenetically closed systems under the deep sea-floor. However, this assumption may not be valid in diagenetically open systems, where exotic fluids may add unexpected disturbances. Hence, it is crucial to understand diagenetic systems by determining the variations in strontium concentrations, which are as important as variations in carbon and oxygen isotopic values.

1. Introduction

Limestone-marl alternations (LMA) are characterized by their conspicuous outcrop appearance, as they feature pronounced cyclic alternations of more weathering-resistant limestone beds and softer marl interlayers (Einsele and Ricken, 1991). They are often characterized by a continuum of repeated bimodal micritic alternations ranging from limestone–chalk to limestone–shale alternations, including nodular limestone beds and well-bedded limestone beds (Westphal et al., 2008a). This group of sedimentary facies is also referred to as fine-grained calcareous rhythmites or calcareous couplets in this study. Furthermore, rhythms are consistently recognized in their oxygen and carbon isotopic ratios, as well as in some of their trace element concentrations (e.g., Bellanca et al., 1996; Tucker et al., 2009; Amberg et al., 2016). Limestone–marl alternations are known in deposits of all Phanerozoic ages, even though their abundances vary strongly across different geologic times (Westphal et al., 2008a). Their abundances roughly follow the oscillations between calcite and aragonite seas (Sandberg, 1983; Stanley and Hardie, 1999), with high abundances during times of “calcite seas” and lower abundances during times of “aragonite seas”; these alternations are particularly widespread within Jurassic and Cretaceous pelagic and hemipelagic successions (Einsele et al., 1991).

The origin of LMA has been extensively debated; they either reflect changes in their primary depositional environment due to variations in climate and sea level (Elder, 1985), or they have been modified by secondary diagenetic processes (Ricken, 1986; Westphal et al., 2008a). In terms of a primary depositional origin, variations in the carbonate

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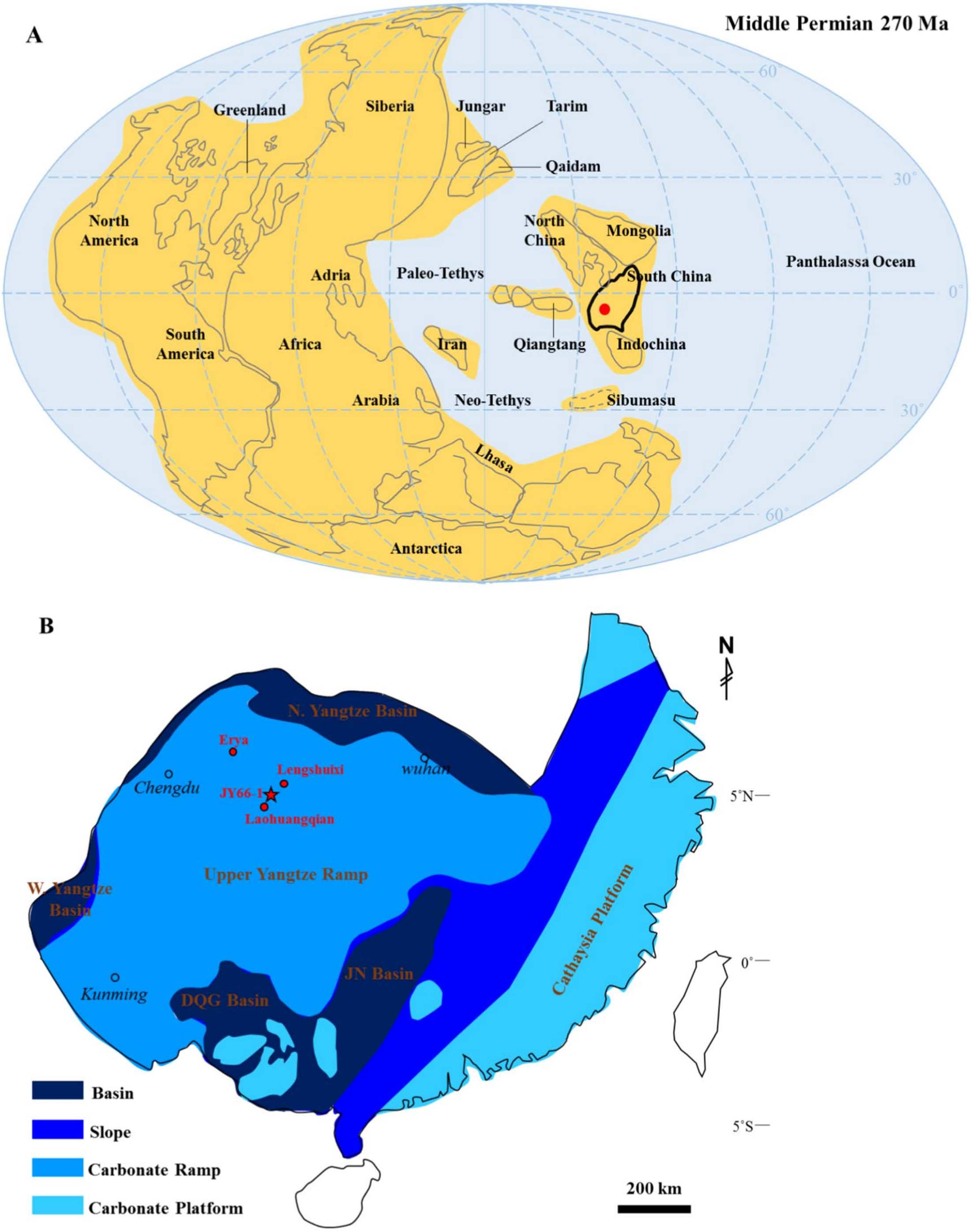

Fig. 1. (A) Middle Permian global paleogeography. The geographic base map is modified from Angiolini et al. (2013). The studied outcrop is located on the South China Block (red dot). (B) Guadalupian paleogeography of South China is modified from Wang and Jin (2000). Red dots indicate studied outcrops (Erya, 106°48′34″ E, 30°22′39″ N; Lengshuixi, 108°16′38″ E, 29°54′9″ N; Laohuangqian, 107°29′8″ E, 29°29′11″ N), and the red pentagram indicates the location of the JY66-1 well (107°33′25″ E, 29°43′17″ N). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

contents, organic carbon and inorganic geochemical compositions within these alternations may reflect changes in carbonate productivity, detrital influx and redox conditions as the result of quasi-periodic climate changes related to Milankovitch cycles (Strasser et al., 2006). Lithologic oscillations have been conclusively determined to be the outcome of four types of depositional mechanisms: productivity cycles, dilution cycles, redox cycles and dissolution cycles (Einsele and Ricken, 1991; Bellanca et al., 1996; Berrocoso et al., 2013; Boulila et al., 2010a; Eldrett et al., 2015a, 2015b; Lathuilière et al., 2015). However, mineralogical and geochemical studies have suggested that divergent diagenetic alteration, commonly termed differential diagenesis, between the limestone beds and marl or shale interlayers involve not only differential mechanical compaction but also the redistribution of calcium carbonate, by dissolving aragonite and/or high-magnesium calcite in the interlayers and reprecipitating calcite cement in the limestone beds (Ricken, 1986; Bathurst, 1987; Thierstein and Roth, 1991; Munnecke and Samtleben, 1996). Differential diagenesis has the potential to build diagenetic cycles of carbonate content, stable isotopic values and trace element compositions and thus to distort or mimic primary signals (Holmes et al., 2004; Westphal, 2006; Beltran et al.,