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Coupled sedimentary and $\delta^{13}C$ records of late Mississippian platform-to-slope successions from South China: Insight into $\delta^{13}C$ chemostratigraphy

Jitao Chen [a,b,*], Isabel P. Montañez [b], Yuping Qi [a], Xiangdong Wang [a], Qiulai Wang [a], Wei Lin [a]

[a] LESP and LPS, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China
[b] Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA

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ABSTRACT

Variability in stratigraphic accumulation rates and distribution of stratal hiatuses along with strong endemism of index fossils hinder regional to global stratigraphic correlation of the Visean–Serpukhovian (V–S) boundary interval (late Mississippian) and thus geological inferences regarding the onset of the late Paleozoic ice age. Here we integrate high-resolution $\delta^{13}C$ time series with detailed sedimentary facies analysis of late Visean–early Serpukhovian (V–S) carbonate platform-to-slope successions from South China to evaluate the influences of local depositional and diagenetic processes on $\delta^{13}C_{carb}$ and to address the correlation issue.

Analysis of 11 sedimentary facies from 5 outcrop sections indicates a restricted platform setting (Yashui section) dominated by bioclastic wacke-packstone to lime mudstone in which paleokarst developed, and contemporaneous carbonate slope settings dominated by thin-bedded lime mudstones intercalated with slumps and calciturbidites. Based on vertical facies assemblages, three depositional units are recognized, recording a significant sea-level drawdown across the V–S boundary. Multiple negative $\delta^{13}C$ excursions (>1‰) can be correlated across the V–S boundary interval in several slope sections (Naqing, Luokun, and Narao sections). Variability in the V–S boundary $\delta^{13}C$ record in some sections is interpreted to record truncation physically by submarine erosion by slumps or chemically during karstification. A long-term decrease in $\delta^{13}C$ values through the Serpukhovian of the Yashui section likely records local influences on carbon cycling in the restricted platform setting. This negative $\delta^{13}C$ trend and associated depositional facies at the Yashui section can be correlated to the Arrow Canyon section, USA, which, together with other coeval global sedimentary and geochemical records, indicate a widespread eustatic drawdown in the late Visean with initial buildup of Gondwanan ice sheets. We conclude that integrated sedimentary facies analysis and $\delta^{13}C$ chemostratigraphy can be used for stratigraphic correlation when interpreted within a well-constrained sedimentary and carbon-isotope regional framework.

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1. Introduction

In addition to being an important proxy for paleoclimate reconstruction and paleoceanographic perturbation (Kump and Arthur, 1999; Montañez et al., 2000, 2007; Jiang et al., 2007), carbon isotopic compositions ($\delta^{13}C$) has been widely used for marine stratigraphic correlation ranging from the Precambrian to Quaternary (Saltzman and Thomas, 2012). However, marine carbonate $\delta^{13}C$ ($\delta^{13}C_{carb}$) does not necessarily reflect the global $\delta^{13}C$ of seawater given the potential influence of local to regional factors including compositional/mineralogical variability, water mass differences, and diagenesis among other processes (Patterson and Walter, 1994; Holmden et al., 1998; Swart and Eberli, 2005; Batt et al., 2007; Swart, 2008, 2015; Buggisch et al., 2011; Grotzinger et al., 2011; Dyer and Maloof, 2015). It is for these reasons that careful petrographic screening and microdrilling are necessary to evaluate the reliability of measured $\delta^{13}C_{carb}$ (Batt et al., 2007; Bishop et al., 2009; Brand et al., 2012; Metzger and Fike, 2013; Swart, 2015) coupled with interpretation of the $\delta^{13}C_{carb}$ values within a facies and depositional environment context (Swart, 2008, 2015; Saltzman and Thomas, 2012).

The application of $\delta^{13}C_{carb}$ excursions for stratigraphic correlation has been questioned given the influence of non-global processes. The correlation of $\delta^{13}C_{carb}$ excursions among sections, which are poorly constrained geochronologically, by alignment of lithologic units can be misleading given the diachronous nature of facies (Dyer and Maloof, 2015). On the other hand, where biostratigraphic constraints exist they can be used to variable levels of success for $\delta^{13}C$ chemostratigraphic correlation and (Glumac and Spivak-Birndorf, 2002; Chen et al., 2012; Shen et al., 2013; Qie et al., 2015). An integrated sedimentologic, stratigraphic, and

* Corresponding author at: Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China.
E-mail addresses: jtchen@nigpas.ac.cn (J. Chen), ipmontanez@ucdavis.edu (I.P. Montañez), ypqi@nigpas.ac.cn (Y. Qi), xdwang@nigpas.ac.cn (X. Wang), qiulai.wang@yandex.com (Q. Wang), wlin@nigpas.ac.cn (W. Lin).

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geochemical approach has proven to provide robust constraints on paleoenvironmental conditions and the nature of C isotopic variation within and between stratigraphic successions (e.g., Jiang et al., 2007; Bishop et al., 2009; Qie et al., 2015).

The Visean–Serpukhovian (V–S) boundary interval (late Mississippian) has been proposed to record the onset of the late Paleozoic ice age (LPIA) on the basis of stratigraphic and isotopic evidence (Smith and Read, 2000; Fielding et al., 2008; Bishop et al., 2009; Barham et al., 2012; Montañez and Poulsen, 2013; Fielding and Frank, 2015). A better understanding of the nature and timing of the onset of the LPIA is largely hindered by the incomplete nature of stratigraphic successions that were deposited during glacioeustatic drawdown (Richards and Task Group, 2003; Kabanov et al., 2013). Global stratigraphic correlation of this interval is further challenged by the strong endemism of index fossils, including conodonts, foraminifers, and ammonoids (Bishop et al., 2009; Groves et al., 2012; Cózar and Somerville, in press). To that end, carbonate slope successions, which are interpreted to record near continuous sedimentation, have become the main focus for the effort to define the V–S GSSP (Global Stratotype Section and Point). The Naqing section in South China (Fig. 1) has been selected as one of two potential candidates (Groves et al., 2012; Qi et al., 2014b). Bed-by-bed, high-resolution conodont biostratigraphy of the Naqing and other slope sections (e.g., Dianzishang, Luokun, and Narao sections) from South China (Qi et al., 2014a,b; Wang et al., 2014) provides a robust framework for global correlation. Correlation of the slope successions with the contemporaneous shallow-water platform carbonates in South China and elsewhere, however, remains poorly constrained due to the strong endemism of index fossils (Groves et al., 2012).

Here we present high-resolution $\delta^{13}C$ time-series of bulk rock samples and petrographically-screened, microdrilled samples coupled with detailed sedimentary facies analysis to address this stratigraphic-correlation dilemma for the V–S boundary interval. We document coupled changes in depositional facies and isotopic compositions across a carbonate platform-to-slope transect. The South China records are compared to the Arrow Canyon, USA succession to evaluate the potential for global stratigraphic correlation and the reconstruction of climatic and sea-level conditions across the V–S boundary interval.

2. Geological settings

During the Mississippian, the South China Block was located in the northeast Paleotethys Ocean near the paleoequator (~0–15°S) (Fig. 1). The block consists of the Yangtze and Cathaysia blocks that were merged toward the end of the early Paleozoic (Mei et al., 2005). The southwestern part of the South China Block was subdivided into several paleogeographic elements during the Mississippian, including the Yangtze Land, Dian-Qian-Gui-Xiang Platform, and Qian-Gui Basin (Jiao et al., 2003). The Qian-Gui Basin, which was inherited from an active Devonian rifted basin, was tectonically quiescent by the late Mississippian (Li, 1997; Qie and Wang, 2012). Thick carbonate deposits accumulated on the relatively stable settings of the Qian-Gui Basin and Dian-Qian-Gui-Xiang Platform (Jiao et al., 2003). Outcrop sections (Naqing, Luokun, Narao, Dianzishang, and Yashui sections) used in this study are from the Qian-Gui Basin and Dian-Qian-Gui-Xiang Platform (Fig. 1), which are located in the middle and south of the Guizhou Province.

3. Methods

Five outcrop sections that were previously measured by colleagues as part of the effort to define the GSSPs for the Serpukhovian, Moscovian, Kasimovian, and Gzhelian stages of the Carboniferous (Fig. 2) were utilized in this study to define a platform-to-slope transect. Bed-by-bed sedimentologic logging and description (Fig. 3) were carried out using a metric tape and the aluminum spikes with metric

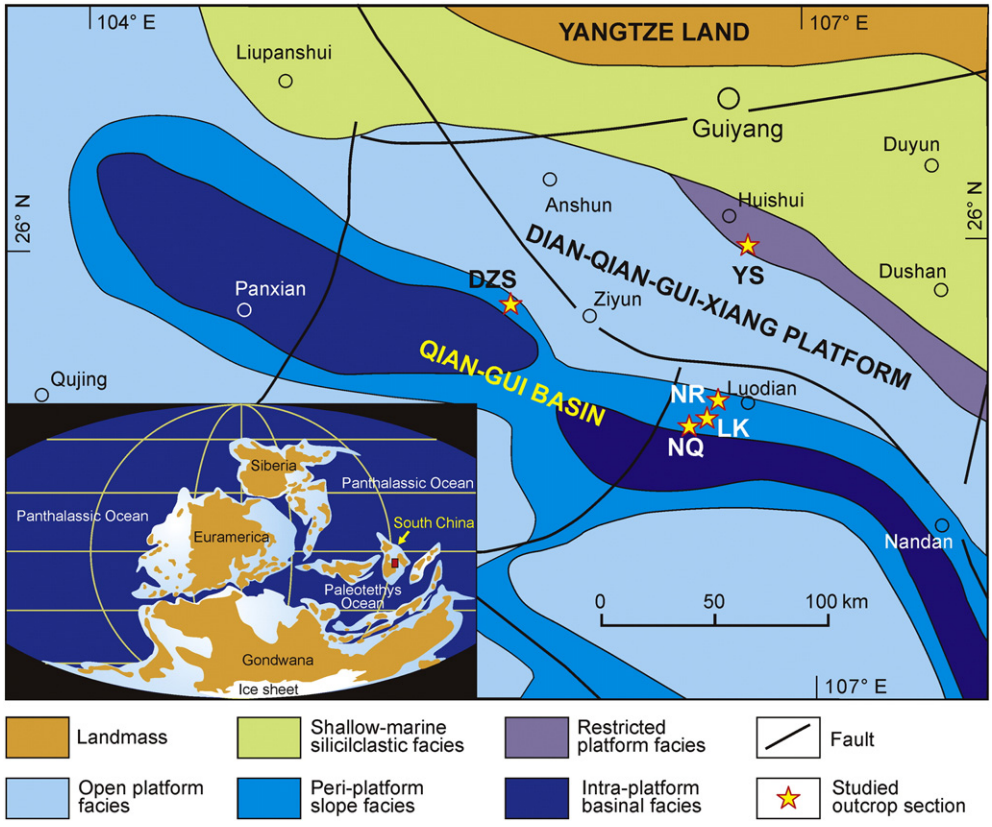

Fig. 1. Paleogeographic map of the study area in Guizhou Province, South China (modified after Jiao et al., 2003). The red box in the inset Mississippian global paleogeographic map (after http://jan.ucc.nau.edu/~rcb7/RCB.html, courtesy of Ron Blakey) indicates the study area in South China Block. YS = Yashui section; DZS = Dianzishang section; NR = Narao section; LK = Luokun section; NQ = Naqing section.

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