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A positive C-isotope excursion induced by sea-level fall in the middle Capitanian of South China

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ABSTRACT

A new carbon isotope excursion was recovered from the Capitanian marine carbonates at the Rencunping (RCP) section of South China. Significantly, a pronounced excursion with elevated $\delta^{13}C_{carb}$ values over +5‰ was coeval with the conodont *Jinogondolella prexuanhanensis* Zone and resembles the Kamura event recorded in Tethys. The excursions in $\delta^{13}C_{carb}$, constrained by conodont biostratigraphy, however, present inconsistent carbon cycle behaviors, especially between the separated basins in South China, and evidently reflect regional litho-facies controls. In addition, a transitional environment in association with a fall in sea level, was recovered from deposits of anoxic cherty carbonates subsequent to shallow-water carbonates around the positive excursion in $\delta^{13}C_{carb}$. Accordingly, instead of this being a signal of global-scale climatic cooling, we suggest that the positive excursion in $\delta^{13}C_{carb}$ can be attributed to eutrophication effects regionally along a continental shelf. In this scenario, the increasing dissolved O_2 level in the mixing zone that induced by the initial sea-level fall will efficiently impede denitrification and increase the bio-available N in N:P ratio to satisfy the demands of primary producers in surface waters. Subsequently, deposits of shallow-water carbonates comprising calcareous algae and massively-bedded lime muds accumulated widely around South China. These deposits appear to represent an unusual environment and ecosystem fertilized, perhaps, by the weathering products from the earliest stages of volcanism prior to the main Emeishan flood basalt eruptions at the Guadalupian-Lopingian boundary (GLB).

1. Introduction

The end-Guadalupian biotic crisis has been widely discussed and debated in recent times following initial suggestions by Jin et al. (1994), Stanley and Yang (1994), of this being the first of a pair of Late Permian mass extinctions. The biological losses amounted to about 58% of marine invertebrate genera, comprising mainly tropically-adapted faunas of brachiopods, rugose corals, bryozoans, and large-sized benthic fusulines and foraminifers (Wang and Sugiyama, 2000; Weidlich, 2002; Ota and Isozaki, 2006; Isozaki, 2006; Shen and Shi, 2002, 2009; Bond and Wignall, 2009; Groves and Wang, 2013). Debates about this biotic crisis have largely concerned the timing of taxon loss and potential killing mechanisms. Some researchers have asserted most loss took place ca. 260 Ma at the Guadalupian-Lopingian transition (Wang and Sugiyama, 2000; Wang et al., 2004; Kaiho et al., 2005) or even much earlier in the Wordian Stage (Clapham et al., 2009; Groves and Wang, 2013). Others identified the main crisis being the middle-late Capitanian extinctions of foraminifers, calcareous algae, and brachiopods (Shen and Shi, 2002, 2009; Wignall et al., 2009a, 2009b; Ota and Isozaki, 2006; Isozaki, 2006; Isozaki and Aljinović, 2009; Bond et al., 2010; Saitoh et al., 2013a; Groves and Wang, 2013). Proffered killing mechanisms include sea-level regression with resultant loss of marine habitat (Ross and Ross, 1985; Hallam and Wignall, 1999; Wang and Sugiyama, 2000; Haq and Schutter, 2008; Shen and Shi, 2002, 2009; Bond and Wignall, 2009; Wignall et al., 2009a), or redox condition changes in water column (Saitoh et al., 2014; Zhang et al., 2015; Wei et al., 2016), or the environmental consequences of the emplacement of massive flooding of the Emeishan basalt in South China (Courtillot et al., 1999; Wignall, 2001; Ali et al., 2002; Lai et al., 2008; Isozaki, 2009; Wignall et al., 2009b; Bond et al., 2010; Chen et al., 2011).

Unrelated to the volcanism-induced climatic cooling, a cooling episode termed the Kamura event, one associated with $\delta^{13}C_{carb}$ values over +5‰, is proposed to have occurred around the Capitanian fusuline *Yabeina* Zone. It was initially reported from the mid-Panthalassa seamount $\delta^{13}C_{carb}$ record in Japan (Isozaki et al., 2007a, 2007b;

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Isozaki, 2009), and later observed in the western Paleo-Tethys Ocean isotope record in the Velebit Mountain region of central Croatia (Isozaki et al., 2011). Nevertheless, this event is only rarely recognized in other areas apart from the marine sites of Guizhou Province in South China (Bond et al., 2010). Recently, for example, a detailed investigation of the marine carbonate sequence at Penglaitan of Guangxi Province, the GSSP Section for the GLB, showed a relatively constant C-isotopic signal devoid of any trend that could reflect the Kamura event (Chen et al., 2011).

Here, we report new $\delta^{13}C_{carb}$ data from a Capitanian marine carbonate sequence of the Rencunping section (RCP) in Hunan Province, South China. Using biostratigraphic constraints we identify a central Paleo-Tethys Kamura-like interval with prominent high $\delta^{13}C_{carb}$ values over +5‰ in the late Capitanian conodont *J. prexuanhanensis* Zone of the Yangtze region.

2. Geological setting

Middle Permian (Guadalupian) marine carbonates, locally known as the Maokou Limestone, are extensively developed over South China to form the Yangtze carbonate platform at paleo-equatorial latitudes (Wang and Jin, 2000). During the Late Guadalupian, a basin deformation, resulting from a putative rifting system (Fig. 1A), led to the development of a series of narrow basins along the northern and southern edges of the Yangtze Platform (Zhou, 1957; Guo, 1959; Feng, 1991; Mou et al., 1997; Hu, 2000; Shen et al., 2007; Wignall et al., 2009a; Wei et al., 2016; Wang et al., 2018). Sets of basin-facies deposits, typified by organic-rich and siliceous-laminated marls and shales, regionally known as the Kuhfeng Formation, sharply cap the underlying Maokou Limestone. By the end of Guadalupian, the Dongwu Uplift Movement has been widely observed over South China. Evidence comes by way of a depositional hiatus with subsequent deposits of terrigenous clastics, coal seams and ash-clay layers termed the Wangpo Shale. This unit is recognized across South China as the lithological G-L boundary.

The RCP section is located in a semi-closed basin of E'Xi in western Hubei Province and along the northwestern edge of the Yangtze Platform (Fig. 1A) (Mou et al., 1997; Wang and Jin, 2000). A marine sequence outcrops along the Lishui River where Permian strata from the Chihsia, Maokou, and Talung formations, along with the Early Triassic Daye Formation, are exposed. Since 1980s, geological surveys were conducted here and mostly focused on the biostratigraphy of brachiopods, ammonoids, and conodonts of the entire Permian System (Zhao and Tan, 1984; Tian, 1993; Zhang et al., 2009), although with little attention to the detail of the Capitanian conodont succession. Recently, we recovered a conodont succession, comprising the *Jinogondolella postserrata* to *J. xuanhanensis* zones, that define the early to late Capitanian interval (Cao et al., 2013a).

The Middle Permian sequence (the Maokou Formation) at the RCP section, of 220 m in total thickness, comprises two parts based on lithology (Zhao and Tan, 1984). The lower part (112 m in total thickness) is composed of the typical Maokou limestone deposits in form of the well-bedded bioclastic packstone with intermittent cherty concretions and lenses. Various fossils, including the brachiopods, corals, and fusulines (*Chusenella*, *Kahlerina*), all belong to the Wordian conodont *Jinogondolella asserrata* Zone (Tian, 1993; Cao et al., 2013a). The uppermost 4-meter interval is characterized by a thickly-bedded wackstone that yields an abundance of faunas typical of shallow-water environments, including brachiopods, rugose corals, bryozoans, crinoids, gastropods, pyrite-mineralized foraminifers and fusulines. Abundant conodonts recovered here allow to be confidently placed in the early Capitanian conodont *J. postserrata* Zone (Cao et al., 2013a) by comparison to the coeval conodont succession in the GSSP Section of Penglaitan (Jin et al., 2006). The upper part of the Maokou Formation is characterized by organic-rich basin-facies deposits at the base, which rapidly develop above a sharp contact with the lower part of Maokou Limestone (Fig. 2A). In order to effectively describe the depositional environment, we subdivide this interval into 4 subunits from C1 to C3, and C4 in ascending order based on litho-assemblages (Fig. 3).

Subunit C1 (from the sampling position at 0 m to 13.3 m) typically consists of organic-rich marls with thinly-bedded black shales at the base (Fig. 2A). This is followed by basin-facies deposits which are typically laminated with siliceous layers in upper portion (Fig. 2B). Various fossils, including brachiopods, gastropods, and bryozoan debris are found in the low portion and these are replaced by a pelagic fauna comprising ammonoids, sponge spicules, and radiolarians in the upper portion. Index fossils for conodont biostratigraphy are specimens belonging to the Capitanian *J. postserrata* to *J. shannoni* zones. Therefore, an early to middle Capitanian deepening trend for the basin environment is clearly in evidence based on the bio- and litho-assemblages.

The basal sharp contact, clearly seen in outcrops at the top of lower part of Maokou Formation, is devoid of karstic debris or other evidence for a depositional hiatus (Fig. 2A). However, evidence for an unconformity including karstic debris and erosional soils has been reported at the adjacent sites of Jianshi in Hubei Province (Chen et al., 2000; Li et al., 2001) and the Chenjiahe section 13 km away from the RCP section (listed in Fig. 1). Similar evidence of a karst surface and associated debris was proposed to indicate a putative basin deformation entitled as the “Mingshan” around the Chuandong to E'Xi basins, and the “Pan-Xi” rifting movement in the Nanpanjiang Basin, respectively, and roughly assigned to the Late Guadalupian (e.g., Guo, 1959; Feng, 1991; Mou et al., 1997; He et al., 2003; Shen et al., 2007; Wignall et al., 2009a; Wang et al., 2018). Accordingly, we place the para-conformity interface at the base of Subunit C1 for a type-3 sequence interface (SB_3) at the RCP section. If correct, the basin deformation recorded at the base of Subunit C1 would be a response to the Mingshan tectonism in the early Capitanian conodont *J. postserrata* Zone around the Chuandong to E'Xi basins and, thus, suggests a relative sea-level drop rather than a transgression (Fig. 3).

Subunit C2 (from 13.3 m to 35.7 m) is composed of thinly-bedded cherty micrite with intermittent cherty layers. Abundant pyrite framboids can be found in the lower portion but are rare in the upper portion (Fig. 2C). The topmost 3-meter interval is a single bed of packstone bearing abundant cherty concretions and occasional fusulines. This interval is poorly fossiliferous apart for a few of conodont species belonging to the *J. altudaensis* and *J. prexuanhanensis* zones. Consequently, this cherty micrite with intermittent cherty layers appears to mark development in an anoxic environment on the shelf setting, gradually alternating with suboxic conditions in the upper interval.

Subunit C3 (from 35.7 m to 85.3 m) is characterized by a massively-bedded limestone with partial recrystallization (over 50 m thick in total) and yielding abundant calcareous algal bodies which are occasionally silicified (Fig. 2D). Fossils are dominated by fusulines of the genera *Chusenella*, *Schwagerina*, *Yabeina*, *Neoschwagerina*, *Verbeeina*, *Wutuella*, *Reichelina*, *Kahlerina*, and *Parafusulina* together with a few brachiopod genera such as *Derbyia*, *Vediproductus*, *Neoplicatifera* etc. (Zhao and Tan, 1984; Cao et al., 2013a). Specimens of *J. xuanhanensis* are the only late Capitanian conodont species recovered here.

A similar series of deposits in form of massively-bedded limestone (over 80 m in thickness) is also developed at the marine site of Daxiakou of Hubei Province and characterized by an abundance of calcareous algae and small-sized fusulines with less recrystallization. Newly recovered conodonts here date it as coeval with the Capitanian *J. xuanhanensis* Zone (unpublished data). Similar deposits in the form of massively-bedded Capitanian Stage limestones can also be recognized in the adjacent site of Chenjiahe of Hunan Province, the Liangshan section of Shaanxi Province, and the Wenjiangsi section of Guizhou Province (over 60 m thick) (all sites are listed in Fig. 1). At the well-studied Capitanian sites in the Guangxi Province, the correlative interval can be placed in Bed 19 at the Penlaitan section (Jin et al., 2006; Fig. 5 *therein*) and Bed 5 at the Tieqiao section (Wignall et al., 2009a;