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A pronounced negative $\delta^{13}C$ excursion in an Ediacaran succession of western Yangtze Platform: A possible equivalent to the Shuram event and its implication for chemostratigraphic correlation in South China

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ABSTRACT

A pronounced negative $\delta^{13}C$ shift that can be potentially correlated with the Shuram excursion has been reported from middle Ediacaran strata in the Yangtze Gorges area of South China. Whether it represents a perturbation to the ocean carbon cycle or a record of post-depositional alteration is still open to debate. Resolving this controversy will help clarify if $\delta^{13}C$ variations can be used for chemostratigraphic correlation of Ediacaran successions. To further understand the regional pattern of Ediacaran carbon isotopic excursions in the Yangtze platform, we carried out a detailed $\delta^{13}C$ analysis of the Lianghong section in the western part of the Yangtze platform. The Ediacaran System at Lianghong is overlain by the Maidiping Formation yielding early Cambrian small shelly fossils and underlain by the Cryogenian Lieguliu Formation diamictite and tuffaceous siltstones. It comprises the Guanyinya and Hongchunping formations, which have been traditionally correlated with the Doushantuo and Dengying formations, respectively, in the Yangtze Gorges area. Two negative $\delta^{13}C$ excursions occur in the Lianghong section. The lower one at the uppermost Guanyinya Formation, with a nadir at −8.6‰, may be correlated with the pronounced negative $\delta^{13}C$ shift (EN3) in the uppermost Doushantuo Formation in the Yangtze Gorges area and possibly with the well known Shuram event in Oman. The upper negative $\delta^{13}C$ excursion occurs in the upper Hongchunping Formation and may be correlated with negative excursions (EN4) near the Ediacaran/Cambrian boundary. Other negative $\delta^{13}C$ excursions (e.g., EN1 and EN2) are not expressed in the Lianghong section because the lower Guanyinya Formation is dominated by siliciclastic rocks. Combined with previously published Ediacaran $\delta^{13}C$ profiles, our results indicate that the EN3 excursion (likely a Shuram equivalent) may occur widely in South China and can be a useful chemostratigraphic feature for regional and global stratigraphic correlation.

1. Introduction

The Yangtze platform in South China offers excellent opportunities to test Ediacaran chemostratigraphic models because of the well-preserved carbonate successions. There have been numerous studies of Ediacaran $\delta^{13}C$ chemostratigraphy in South China (e.g., Chu et al., 2003; Jiang et al., 2007; Zhu et al., 2007; McFadden et al., 2008; Zhu et al., 2011; Xiao et al., 2012), which allow the construction of a composite $\delta^{13}C$ profile (Zhou and Xiao, 2007; Zhu et al., 2007). The composite curve reveals multiple negative $\delta^{13}C$ excursions in the Ediacaran System. Of special interest is the pronounced negative excursion (EN3) in the upper Doushantuo Formation, which may represent a strong perturbation to the carbon cycle in Earth's surface systems (Rothman et al., 2003; but see Derry, 2010 for different interpretations). The possible global extent of this event is supported by pronounced negative $\delta^{13}C$ excursions of similar magnitude (to a nadir of <−10‰, VPDB) and approximately middle Ediacaran age from Oman (Fike et al., 2006; Le Guerroue et al., 2006), Death Valley (Kaufman et al., 2007; Bergmann et al., 2011; Verdel et al., 2011), Australia (Calver, 2000), Norway (Melezhik et al., 2008), Scotland (Prave et al., 2009), Siberia (Pokrovskii et al., 2006; Melezhik et al., 2009) and South China (Jiang et al., 2007; Zhu et al., 2007; McFadden et al., 2008). This negative $\delta^{13}C$ excursion has been ascribed to the remineralization of a large oceanic reservoir of dissolved organic carbon (DOC) (Rothman et al., 2003; Fike et al., 2006; McFadden et al., 2008) or the massive release of methane hydrates from an anoxic DOC-rich ocean (Bjerrum and Canfield, 2011). After EN3 and a late Ediacaran $\delta^{13}C$ plateau (EI, with $\delta^{13}C$ values around 2.5‰, VPDB), a marked $\delta^{13}C$ negative excursion with a nadir of <−5‰ (VPDB) occurs near the Ediacaran/Cambrian boundary (Shen et al., 1998; Amthor et al., 2003; Zhou and Xiao, 2007; Ishikawa et al., 2008; Jiang et al., 2012). Oceanic overturn or expansion of anoxic deep-water masses charged with isotopically light carbon onto shallow shelves may have contributed to the development of this isotope excursion (Schröder and Grotzinger, 2007).

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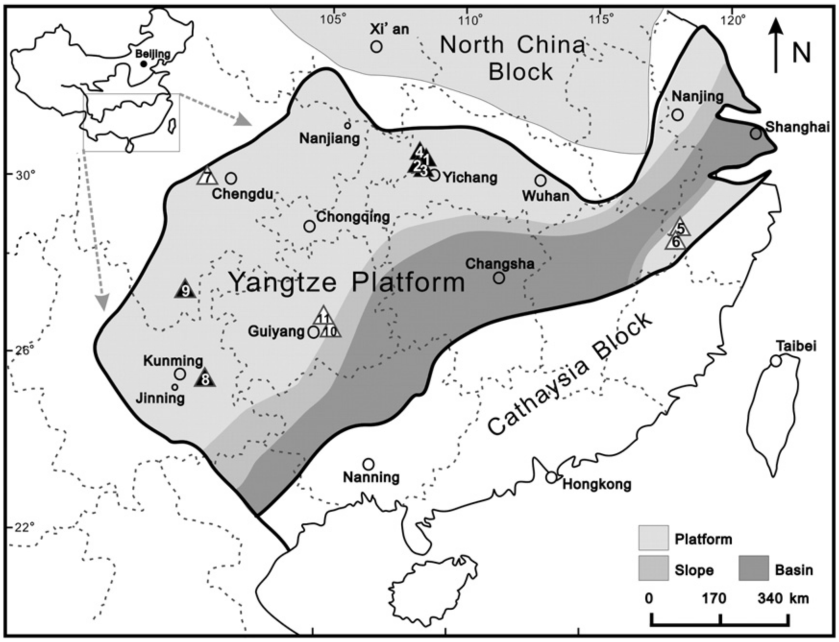

Fig. 1. Ediacaran paleogeography of the Yangtze Block (modified from Guo et al., 2007 and Zhou and Xiao, 2007). Numbered triangles indicate locations of Ediacaran sections mentioned in the text and Fig. 5. Yangtze Gorges area: 1, Jiulongwan section (Jiang et al., 2007); 2, Huajipo section (Jiang et al., 2007); 3, Wuhe section (Sawaki et al., 2010); 4, Tianjiayuanzi section (Yang et al., 1999). Eastern Yangtze platform: 5, Jiujiawu section (Liu et al., 1992); 6, Chaoyang section (Zhou and Xiao, 2007). Western Yangtze platform: 7, Danba section (Huang and Buick, 2002), 8, Feidatian-Dongdahe section (Zhu et al., 2007), 9, Lianghong section (this study). Central Yangtze platform: 10, Yangtiao section (Zhu et al., 2007), 11, Weng'an section (Zhou et al., 2007). Filled triangles represent sections where possible equivalents to the Shuram excursion have been reported.

Because of poor biostratigraphic resolution and the absence of radiometric data in Ediacaran sections, caution has to be applied when using $\delta^{13}C$ trends in chemostratigraphic correlation (Corsetti and Kaufman, 2005; Zhou and Xiao, 2007; Zhu et al., 2007; Yuan et al., 2011). Some researchers argue that Ediacaran $\delta^{13}C$ records may have been compromised by diagenetic alteration. Derry (2010), for example, proposed that profound Ediacaran negative $\delta^{13}C$ anomalies can be explained by interaction with diagenetic fluids. Similarly, Knauth and Kennedy (2009) proposed that the decrease in $^{13}C/^{12}C$ ratios in Neoproterozoic carbonate rocks may have resulted from post-depositional processes involving photosynthetic carbon from terrestrial phytomass. The lateral extent, independence of lithology, and stratigraphic consistency of the Ediacaran carbon isotopic excursions, however, are difficult to reconcile with a diagenetic origin (Bjerrum and Canfield, 2011; Grotzinger et al., 2011).

Although the shallow-water Ediacaran carbonate successions in the Yangtze platform of South China show generally consistent $\delta^{13}C$ variations (Zhou and Xiao, 2007; Zhu et al., 2007), previous $\delta^{13}C$ studies were primarily focused on the Yangtze Gorges area in the northern Yangtze platform (Fig. 1). To test the regional consistency of Ediacaran carbon isotopic excursions, especially the geographic extent of the extreme carbon isotope excursion across the Yangtze platform, we carried out a detailed $\delta^{13}C$ analysis for the Ediacaran System at the Lianghong section (Sichuan Province) in the western Yangtze platform. The new data extend the geographic range of previously identified Ediacaran $\delta^{13}C$ features from the Yangtze Gorges area, and support the usefulness of $\delta^{13}C$ chemostratigraphy in the correlation of the Ediacaran successions in South China and beyond.

2. Geological background and Ediacaran lithostratigraphy

2.1. Ediacaran System in the Yangtze platform

The Ediacaran System in the Yangtze platform developed over a rifting continental margin formed about 800 Ma (Wang and Li, 2003; Jiang et al., 2011). The Ediacaran System is bounded by distinct lithologies of the underlying Nantuo diamictite (late Cryogenian in age) and overlying phosphorites and cherts that contain basal Cambrian shelly fossils and acritarchs (Zhou and Xiao, 2007; Dong et al., 2009). Detailed facies analysis and paleogeographic reconstruction indicate that a northwest–southeast directed shallow-water platform, slope, and basin configuration developed in the upper Yangtze platform during the Ediacaran (Cao et al., 1989; Wang and Li, 2003; Jiang et al., 2011) (Fig. 1). In shallow-water platform areas (e.g., the Yangtze Gorges area), the Ediacaran System consists of, in ascending stratigraphic order, the Doushantuo and Dengying formations. The Doushantuo Formation in the Yangtze Gorges area is traditionally subdivided into four lithological members, which include, in ascending order, the cap dolostone (Member I), interbedded black shale and thin-bedded dolostone (Member II), medium to thick-bedded dolostone and limestone (Member III), and organic-rich mudstones (Member IV) (Jiang et al., 2003; Zhou and Xiao, 2007). The Dengying Formation consists of the Hamajing, Shibantan and Baimatuo members. The Hamajing Member is characterized by light-gray, medium- to thick-bedded dolostones with tepees and dissolution structures indicative of a peritidal environment. The Shibantan Member is distinguished by dark-gray thin-bedded subtidal limestones. The Baimatuo Member is composed of light-gray, thick-bedded peritidal dolostones (Zhou and Xiao, 2007). In contrast to the carbonate-rich successions in shallow-water facies, Ediacaran successions in slope and basinal facies of South China are typically devoid of carbonate rocks: the Doushantuo Formation in deep-water environments consists of organic-rich black shales, whereas the Liuchapo Formation (a stratigraphic equivalent of the Dengying Formation) is dominated by black chert (Guo et al., 2007; Chen et al., 2009).

The Doushantuo Formation is constrained by radiometric ages between 635 Ma and 551 Ma, and the Dengying Formation between 551 Ma and 542 Ma (Condon et al., 2005). The Ediacaran–Cambrian contact is disconformable in many places, particularly in shallow-water platform facies (Xue and Zhou, 2006).