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Carbon isotope variation through the Neoproterozoic Doushantuo and Dengying Formations, South China: Implications for chemostratigraphy and paleoenvironmental change

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Abstract

Primary carbon isotope trends in marine carbonate rocks are particularly useful for chemostratigraphic correlation and paleoenvironmental reconstruction of the Neoproterozoic Earth System. Differences, however, exist between the published carbonate C-isotope profiles from the Neoproterozoic Yangtze platform and the global C-isotope record through the equivalent time interval. More C-isotope profiles are required for the Yangtze platform from where excellently preserved early animal fossils have been discovered. We studied C, O and Sr isotope compositions and Mn–Sr concentrations of two successions of the Neoproterozoic Doushantuo and Dengying Formations in Guizhou and Zhejiang Provinces, South China. Most of the $^{87}Sr/^{86}Sr$ ratios lie above 0.709, higher than the contemporaneous seawater values, and are likely to represent diagenetic alteration and possible leaching of clay detritus. The $\delta^{18}O$ profiles exhibit more fluctuation than the $\delta^{13}C$ profiles, indicating that oxygen isotopes are more sensitive to diagenetic effects. Both $\delta^{13}C$ profiles in Zhejiang and Guizhou show negative excursions to −3 to −4‰ in the Doushantuo cap carbonate overlying the Nantuo (Marinoan) diamictite and at the Doushantuo–Dengying boundary, and positive shifts to +3 to +4‰ through the rest of the Doushantuo and Dengying Formations. We suggest that oceanic overturn was responsible for both the negative $\delta^{13}C$ excursion within the Doushantuo cap carbonate and that at the Doushantuo–Dengying boundary. However, the mechanisms for the two overturn events are different. The former overturn occurred under conditions of high temperature and high evaporation rates after thawing of the Nantuo (end-Cryogenian) Snowball Earth that had resulted in the stagnant and stratified ocean under sea ice. The Doushantuo interval witnessed sustained high bioproductivity, elevated rates of organic matter accumulation in deep water and sediment, and progressive $\delta^{13}C$ stratification in the ocean, CO_2 drawdown to sediments and thus cooling, which led eventually to high latitudinal glaciation, vigorous thermohaline circulation and oceanic overturn at the end of the Doushantuo period. This latter overturn released CO_2 back to the atmosphere, thus raising the temperature and preventing further cooling. High productivity revived subsequently during the Dengying interval. More work will be needed to further constrain and interpret C-isotope evolution across the Precambrian–Cambrian boundary on the Yangtze platform.

Keywords: Paleoenvironmental change; Chemostratigraphy; Carbon isotopes; Neoproterozoic; Yangtze Platform

1. Introduction

Carbon isotope data have proven to be very useful not only in global Neoproterozoic stratigraphic correlation,

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but also in reconstructing paleoenvironmental change (e.g. Knoll et al., 1986; Kaufman et al., 1993; Hoffman et al., 1998; Walter et al., 2000; Kennedy et al., 2001a). Lambert et al. (1987) obtained the first $\delta^{13}C$ evolution curve for Neoproterozoic Yangtze Platform carbonate from the Doushantuo Formation (Fm hereafter) that overlies diamictite of the Nantuo Fm (Marinoan glaciogenic sediments), and the Dengying Fm in the Yangtze Gorges sections near Yichang, South China. Subsequently, Wang et al. (1996) and Yang et al. (1999) obtained another $\delta^{13}C$ evolution curve for carbonate rocks of the Doushantuo Fm and Dengying Fm in the same region. Condon et al. (2005) confirmed the negative excursion at Doushantuo–Dengying boundary (DDB). However, these $\delta^{13}C$ curves are somewhat different from the global $\delta^{13}C$ curve summarized by Knoll (2000) based on data mainly from Canada and Australia (Walter et al., 2000). There are more than two positive and negative excursions in the Doushantuo Fm, whereas the global curve has only one positive shift and two negative excursions within the Doushantuo interval; and the positive excursion immediately follows the negative excursion at DDB, whereas on the global curve the positive excursion occurs in the upper part not far below the Precambrian–Cambrian boundary (Fig. 8). Therefore, one may ask whether these published $\delta^{13}C$ curves are representative of the Yangtze Platform. For the Dengying strata in Yunnan province, a clear positive $\delta^{13}C$ excursion was observed by Shen (2002) and Shen and Schidlowski (2000), which is similar to the global curve (Knoll, 2000). Many factors can affect the $\delta^{13}C$ value of carbonate (e.g. Goodfellow, 1986; Kaufman et al., 1993; Kennedy et al., 2001b; Shields et al., 2002). The driving forces for the Neoproterozoic global negative excursions are controversial (e.g. Kump, 1991; Kaufman and Knoll, 1995; Hoffman et al., 1998; Walter et al., 2000; Kennedy et al., 2001b; Goldberg et al., 2005). Due to the mismatch in $\delta^{13}C$ profiles between the Doushantuo–Dengying strata and the global equivalent strata, more work is required for the Doushantuo–Dengying strata in different regions of the Yangtze Platform, since data of the Dengying strata in Yuannan province (Shen, 2002) seems to match well the global profile. We studied C and Sr isotopes and trace elements on carbonate samples from sections in Guizhou and Zhejiang provinces in southwestern and southern margins of the Yangtze Platform for the purpose of stratigraphic correlation and unraveling paleoenvironmental change.

2. Sections

In different places of the Yangtze Platform, the Doushantuo Fm overlying the Nantuo glaciogenic sediments occurs as various lithological facies such as carbonate, phosphatic carbonate, phosphorite, black shale or a combination of some of these facies. The Dengying Fm occurs as carbonate, black chert, interbedded carbonate–shale or carbonate–chert in different places. Overlying the Dengying Fm is the basal Cambrian Meishucunian Fm, which consists of interbedded carbonate–phosphate containing the first appearance of small shelly fossils. In some places, however, Meishucunian strata are absent and Dengying strata are disconformably overlain by black shale of the early Cambrian Niutitang Fm.

We studied three sections in Guizhou province, one section in Zhejiang province (Fig. 1).

2.1. Sections in Guizhou

The three sections in Guizhou province are located at Weng'an, Zhongnan and Zhijin (Fig. 1). The Weng'an section consists of Nantuo Fm, Doushantuo Fm and Dengying Fm in ascending order (Fig. 2). The Nantuo Fm comprises shallow marine diamictite (He, 1998), which is widely distributed across the Yangtze Platform. Sedimentary and chronological data from eastern Guizhou indicate a Marinoan age for the Nantuo glaciation (Zhou et al., 2004). The Doushantuo Fm conformably overlies the Nantuo Fm and consists of cap carbonate, phosphatic carbonate and phosphorite, which is overlain by Dengying Fm. The lower and upper phosphorite sequences were dated at 599±4 Ma and 576±14 Ma, respectively (Barfod et al., 2002; Chen et al., 2004). Animal embryos and other fossils that might predate diverse Ediacara-type fossil assemblages were discovered within the phosphorite sequence (Xiao et al., 1998; Li et al., 1998; Xiao et al., 2000). We collected samples

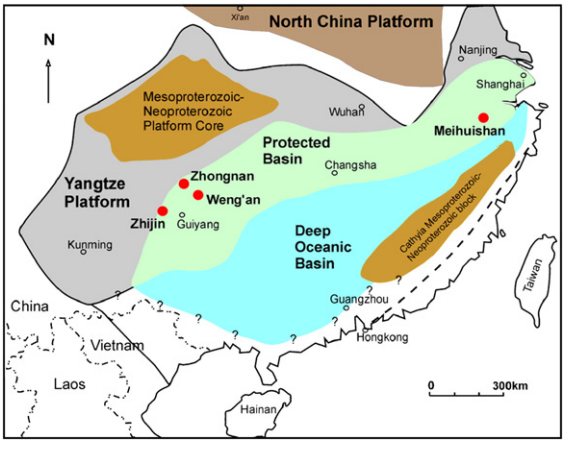

Fig. 1. The Neoproterozoic Yangtze Plate and the section locations.