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# Carbon isotope chemostratigraphy and sedimentary facies evolution of the Ediacaran Doushantuo Formation in western Hubei, South China

Maoyan Zhu[a,*], Miao Lu[a], Junming Zhang[a], Fangchen Zhao[a], Guoxiang Li[a], Yang Aihua[b], Xin Zhao[a,c], Meijuan Zhao[a,d]

[a] State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China
[b] Department of Earth Sciences, Nanjing University, Nanjing 210008, China
[c] Paleontological Institute, Shenyang Normal University, Shenyang 110034, China
[d] Geological Science Research Institute, Shengli Oilfield, Sinopec, Dongying, Shangdong 257000, China

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ABSTRACT

The Doushantuo Formation of South China, consisting of intercalated siliciclastic and carbonate rocks which exhibit considerable variation in thickness and sedimentary facies, is one of the key sedimentary units in the world for understanding Ediacaran geobiological processes. However, stratigraphic correlation and sedimentary facies evolution of the Doushantuo Formation remain controversial. Sedimentary facies analysis of the well-known sections of the Yangtze Gorges area and new sections in northern Yichang, western Hubei indicate that the Doushantuo succession in the Yangtze Gorges area was deposited in an offshore intra-shelf basin within the Yangtze platform. In contrast, the Doushantuo Formation in the northern Yichang area which is characterized by one or a few phosphate-rich horizons represents deposition on the subtidal or intertidal shelf, and so is similar to the succession in the Weng'an area (central Guizhou Province). The carbon isotope profiles of the different sections exhibit significant variation, which is interpreted to result from facies differences. Sequence and high-resolution carbon isotope stratigraphy have clarified problematic correlations and the temporal relationship between fossil assemblages of the Doushantuo Formation on the Yangtze platform. The results confirm that a prominent negative $\delta^{13}C_{carb}$ excursion (BAINCE, nadir down to −5‰) in the middle portion of the second sequence of the Doushantuo Formation is a widely traceable event. BAINCE together with three other $\delta^{13}C_{carb}$ excursions, namely CANCE at the base, WANCE near the first sequence boundary near the middle, and DOUNCE at the top of the Doushantuo Formation, constitute a complete carbon isotope profile for the Doushantuo Formation that reflects contemporaneous seawater and so serves as a reference chemostratigraphic profile for global stratigraphic correlation and for evaluating the chemical evolution of seawater during the Ediacaran Period.



## 1. Introduction

The Ediacaran Doushantuo Formation of South China covers the critical time interval from 635 to 551 Ma, immediately following the global end-Neoproterozoic ice age (Condon et al., 2005) and has become a focus of global research on Neoproterozoic geology and paleobiology over the past decade. This is because (1) it yields rich and exquisitely preserved multicellular fossils, including microscopic embryos (Li et al., 1998; Xiao et al., 1998; Chen et al., 2006, 2009; Yin et al., 2007), macroscopic algae (Xiao et al., 2002; Yuan et al., 2011 and references therein) and Ediacara-type soft-bodied fossils (Zhu et al., 2008); and (2) although relatively condensed (ca. 100–200 m, or even less than 100 m in some sections), it comprises both carbonate and siliciclastic strata exposed across a large area of South China which exhibit various facies ranging from shallow marine shelf to deep marine basin (Zhu et al., 2003, 2007a). The Doushantuo Formation, therefore, currently provides the best rock succession worldwide for global subdivision and correlation of Ediacaran stratigraphy and for reconstruction of Ediacaran palaeoenvironments using multiple geochemical proxies. However, despite intense debates on the paleobiology of the Doushantuo fossils (e.g. Bengtson and Budd, 2004; Chen et al., 2004; Bailey et al., 2007; Xiao et al., 2007) and interpretation of geochemical signatures reported from the Doushantuo Formation (e.g. Jiang et al., 2003; Bao et al., 2008; McFadden et al., 2008; Li et al., 2010; Zhou et al., 2010), stratigraphic correlation and sedimentary facies reconstruction of the Doushantuo Formation on the Yangtze platform remains problematic (Vernhet, 2007; Zhu et al., 2007a; Bristow et al., 2009; Vernhet and Reijmer, 2010; Jiang et al., 2011).

* Corresponding author. Tel.: +86 25 83282159; fax: +86 25 83282159.
*E-mail address:* myzhu@nigpas.ac.cn (M. Zhu).

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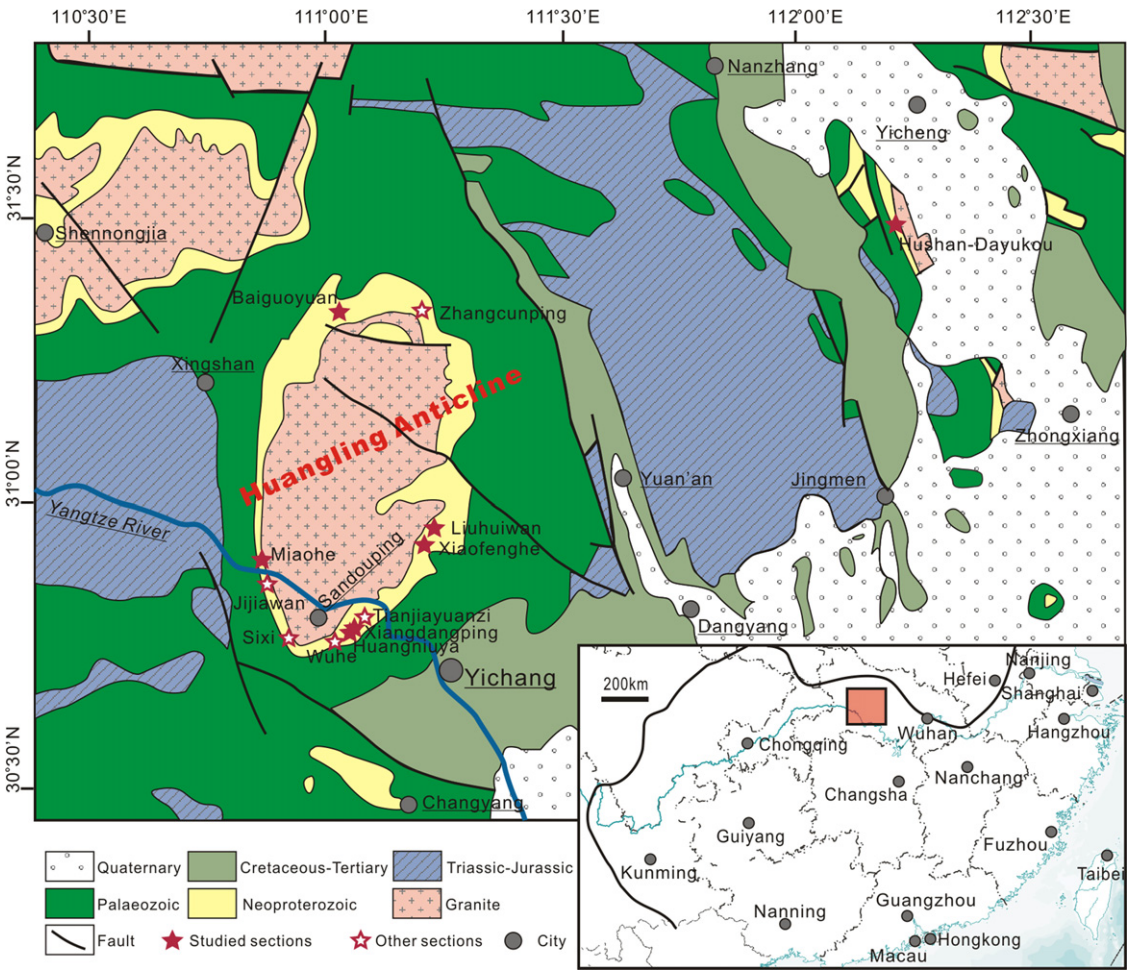


**Fig. 1.** Geological map showing locations of the investigated sections.

Such uncertainty hampers complete understanding of temporal, spatial and causal relationships of the bio- and geo-events recorded in the Doushantuo Formation.

In the general absence of global Ediacaran marker fossils, sequence and carbon isotope stratigraphy has been widely adopted to subdivide and correlate the Doushantuo Formation (Jiang et al., 2007; Zhou and Xiao, 2007; Zhu et al., 2007a). However, because published carbon isotope data are from sections of different facies, previous chemostratigraphic profiles of the Doushantuo Formation are mutually inconsistent, while the three negative $\delta^{13}C_{carb}$ excursions commonly used for stratigraphic correlation and palaeonenvironmental interpretation are different in both amplitude and stratigraphic level. In addition, sequence boundaries are more easily recognized in shallow water facies than in deeper water facies, thus resulting in correlation problems between the two most representative areas of the Doushantuo Formation: the Weng'an area (central Guizhou, shallow realm of outer platform) and the Yangtze Gorges (deeper realm of inner platform). Stratigraphic and palaeoenvironmental ambuity has led to interesting arguments about whether the Doushantuo Formation was deposited in a non-marine basin (Bristow et al., 2009), an intra-shelf basin (Vernhet and Reijmer, 2010) or a shelf lagoon (Jiang et al., 2011). High resolution carbon isotope stratigraphy and detailed sedimentary facies analysis need to be applied to resolve these problems.

In order to resolve the above problems, the well-known sections in the Yangtze Gorges area and new sections in northern Yichang, western Hubei, which show a similar succession to that in the Weng'an area (central Guizhou), have been investigated and sampled in detail (Fig. 1). The aim of the present study is to develop a high resolution carbon isotope stratigraphy for the Doushantuo Formation in order to clarify the inconsistent carbon isotope profiles and problematic correlations of previous studies, as well as providing new information for sedimentary facies reconstruction of the Doushantuo Formation.

## 2. Materials and methods

All samples for carbon and oxygen isotopic analyses are from fresh, relatively unweathered, fine-grained carbonate rocks. Carbonate concretions and thin irregular beds or lenses within shale-dominated intervals were avoided during sampling. The methods used for carbon and oxygen isotope analyses were the same as that applied by Zhu et al. (2007a). Each sample was broken into small fragments first, then about 500 mg of thin chips with a homogeneous texture were pulverized into fine powder. Twenty milligrams of powder from each sample were used for analysis. Limestone samples were reacted with 100% $H_3PO_4$ at 25 °C for more than 12 h, and dolomite samples were reacted with 100% $H_3PO_4$ at 50 °C for more than 24 h in the laboratory of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences. Prepared gas samples were analysed for $\delta^{13}C$ and $\delta^{18}O$ using the Chinese national standard, an Ordovician carbonate from a site near Beijing (reference number GBW 04405: $\delta^{13}C = 0.57 \pm 0.03‰$ VPDB; $\delta^{18}O = -8.49 \pm 0.13‰$ VPDB). Analysis was carried out by a Finnegan MAT 252 mass spectrometer in the State Key Laboratory for Mineral Deposits Research, Nanjing University, and a Finnegan