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Editorial

From snowball earth to the Cambrian bioradiation: Calibration of Ediacaran–Cambrian earth history in South China

1. Introduction

Earth experienced major changes during the late Neoproterozoic (Cryogenian and Ediacaran) to early Cambrian transition. Notably, these include continental rearrangement following the break-up of the Neoproterozoic supercontinent Rodinia, multiple occurrences of extreme glacial conditions, major perturbations in the chemical composition of the atmosphere–ocean system, the advent of biomineralisation and the radiation of multicellular life on earth. The well developed and well exposed sedimentary successions of the Yangtze Platform, with their wide range in facies and exquisitely preserved fossil assemblages (e.g. the Weng'an and Chengjiang biotas), offer an unsurpassed opportunity to study these major geo- and bio-events, their interactions and causal relationships. The Yangtze Platform is an ideal candidate area for constructing a chronostratigraphic framework that will help towards the global calibration of this key interval and to a more complete understanding of Earth System evolution during the Neoproterozoic-Cambrian bioradiation.

Under the auspices of the Sino-German Cooperation Program "From Snowball Earth to the Cambrian bioradiation: a multidisciplinary approach", scientists from Chinese and German universities and research institutions collaborated on deciphering evolutionary trends with the aim to calibrate Earth history during this critical transition. Funded by the National Natural Science Foundation of China (NSFC) and the Deutsche Forschungsgemeinschaft of Germany (DFG) between September 2001 and September 2004, this program included jointly conducted field work in China, joint lab research in Germany, and two major scientific meetings in Potsdam, Germany (March 2002) and Nanjing, China (September 2004). Results from the Potsdam meeting were jointly published in Progress in Natural Sciences (Special Issse; Zhu and Steiner, 2004). The present volume of Palaeogeography Palaeoclimatology Palaeoecology summarises the major advances of this Sino-German Cooperation Project. Research results are presented in 19 individual articles, grouped in four sections that reflect the character of this truly Interdisciplinary Sino-German Project: Introduction, Sedimentology, Geochemistry, Palaeobiology.

2. Stratigraphy

An understanding of biological and geological processes requires knowledge of the precise ordering of bio- and geo-events, which is something that remains unresolved for the key Neoproterozoic–Cambrian transition. The lack of a detailed global time scale and the dearth of practical stratigraphic criteria for global correlation of late Neoproterozoic and early Cambrian rock successions hinder progress not just at the global, but also at the local scale. Inevitably, this results in controversial interpretations concerning the age and timing of the various climatic, chemo-oceanographic and biological evolutionary events that take place during this transition.

In order to resolve these controversies, the construction of a high-resolution stratigraphic framework was a primary objective of the Sino-German program. In the present volume, *Zhu et al*. provide such a detailed chronostratigraphic framework for Ediacaran time, based on their analysis of sedimentary facies, sequence stratigraphy and carbon isotope chemostratigraphy for 62 reference sections. Accordingly, the Ediacaran Period in South China can be subdivided into five stages, with clear implications for global stratigraphic correlation. The current state and future developments in Cambrian chronostratigraphy are then presented by *Babcock and Peng*. An improved biostratigraphic framework, in particular for small shelly fossils (SSF), will be essential for global correlation of the Early Cambrian. In this regard, the detailed analysis of

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abundant SSF occurrences across the Yangtze Platform presented by *Steiner et al*. leads to a revised biostratigraphic correlation of early Cambrian strata in South China. Their analysis reveals that taxonomic similarities exist between the Yangtze Platform and the Tarim Platform as well as with other West Gondwana platform fragments, advancing global correlation schemes of the early Cambrian. Clear differences in fossil assemblages, however, appear to contradict the proposed position of South China during the early Cambrian between Australia and Siberia (Li and Powell, 1999).

3. Sedimentology

Dobrzinski and Bahlburg provide a detailed sedimentological description and facies analysis of two Cryogenian glaciogenic deposits on the Yangtze Platform. Distinctly different depositional environments were reconstructed for both levels of diamictite deposit: more distal for the older, more proximal for the younger deposits, neither supporting a hard snowball scenario of global ice cover on the ocean. Field evidence suggests the existence of large-scale submarine slides and olistostromes within the Ediacaran Doushantuo Formation. From their sedimentological study, *Vernhet et al.* conclude that the Ediacaran Yangtze Platform evolved from a shallow, rimmed platform with restricted basins to a wave-dominated, shallow subtidal platform.

4. Geochemistry

Geochemical signatures recorded in sediments represent powerful tracers for reconstructing palaeoenvironmental changes and geobiological processes. The joint field and laboratory research between palaeobiologists and sedimentary geochemists was one of the highlights of this multidisciplinary program. In their effort, both sides benefited greatly from frequent dialogue and information exchange during the Sino-German Cooperation Project. For example, significant progress in our understanding of climate evolution during the Neoproterozoic and of related redox changes in the ocean during the Neoproterozoic-Cambrian transition was achieved using a combination of innovative studies on the chemical index of alteration (Dobrzinski et al., 2003), biomarkers (Wang et al., 2003) and sulfur isotopes (Chu et al., 2003; Goldberg et al., 2004).

Informative new data on the geochemical and isotopic evolution of the Ediacaran and early Cambrian succession of the Yangtze Platform are presented in five articles of the present volume. *Guo et al*. provide carbonate and organic carbon isotope data from several sections throughout the Ediacaran and early Cambrian across the entire platform. Globally correlative isotopic patterns can be identified despite a superimposed regional signal related to differences in palaeoenvironmental conditions. Further carbon and strontium isotope data from additional sections through the Ediacaran Doushantuo and Dengying formations are presented by *Ling et al.*, who suggest that oceanic overturn was responsible for both the negative ^{13}C excursion within the Doushantuo cap carbonate and that at the Doushantuo–Dengying boundary, but invoke different mechanisms for each. *Zhang et al*. add to the discussion about strong perturbations of the post-glacial ocean chemistry, based on their isotope records for carbonate-carbon and carbonate-associated sulfate sulfur. In combining biogenic sulfur and organic carbon isotope data, *Goldberg et al.* were able to reconstruct marine redox conditions and distinct metabolic pathways for the early Cambrian sediments deposited on the Yangtze Platform. For the same sedimentary succession, *Guo et al.* provide a palaeoenvironmental assessment based on trace element and REE data. The authors identify a clear relationship between redox conditions, trace metal enrichment and organic burial. They further argue that basinal chert within the Ediacaran-Cambrian succession was formed from biogenic silica, possibly of siliceous plankton origin. *Jiang et al.* studied the widely distributed Early Cambrian polymetallic Ni–Mo–PGE–Au layer, hosted in black shales of the Niutitang Formation. Based on Os isotope and PGE data, the authors favour a submarine hydrothermal origin for this extreme metal enrichment, which took place under anoxic basinal conditions and high organic productivity and burial.

5. Palaeobiology

The sudden origin and radiation of multicellular life during the Neoproterozoic and Cambrian transition are

Fig. 1. The Emerging Standard Chronostratigraphic Framework for the Cryogenian, Ediacaran and the lower half of the Cambrian System of South China showing interpreted time equivalence of key biotas, bioevents, and physico-chemical correlation signals. The $\delta^{13}C$ (‰, VPDB) curve is a composite trend based on various published (e.g., Zhang et al., 1997; Brasier and Sukhov, 1998; Zhu et al., 2004; Maloof et al., 2005; Kouchinsky et al., 2005; Zhu et al., 2007-this volume) and unpublished data sources. Abbreviations of the lithostratigraphic formations: LWM=Longwangmiao, CLP=Canglangpu, YAS=Yu'anshan, SYT=Shiyantou, QXD=Qingxudong, MXS=Mingxinsi. Acronyms of the carbon isotopic excursions are after Zhu et al. (2006) for the Cambrian, and newly proposed acronyms here for the Ediacaran (see explanation in the text).