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Provenance and temporal constraints of the Early Cambrian Maotianshan Shale, Yunnan Province, China

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ABSTRACT

The Cambrian Maotianshan Shale in Yunnan Province, China contains the well-preserved soft-body fossils of the Chengjiang Biota. The high quality preservation of the non-mineralizing biota (soft tissues and whole carcasses) shows regional and temporal differences, suggesting that paleogeography and local environmental conditions might have contributed to the taphonomy of these fossils. In this paper we present new results from petrographic, geochemical and detrital zircon analyses, and provide a new interpretation about the provenance of the Maotianshan Shale, as well as add to the understanding of the paleogeography of the South China Block during the Cambrian Stage 3. Results from petrographic analysis indicate that the provenance of the Maotianshan Shale is a recycled orogen overall, bordering the western and southwestern margin on the Yangtze Block. The most likely source of the terrigenous material is an exhumed area extending from the Kangdian paleoland to the southeast, paralleling the Song Ma fault zone. Minor regional differences in geochemical and petrographic proxies between the northwestern Jianshan/Ercai area and the southeastern Maotianshan/Xiaolantian area suggest influence of local sources. Sediments of the southeastern province are less mature and samples include minor elements commonly associated with mafic sources. Sediments from the northwestern province are more mature, largely lack mafic components and are enriched in Zr and Hf. The major population of the Maotianshan Shale detrital zircons group at ~800 Ma. This crystallization age matches well with the age of a widely spread felsic volcanic and intrusive event associated with the Neoproterozoic Kangdian rift, suggesting that these igneous rocks are most likely a major provenance for the Maotianshan sediments. The youngest zircon population yields consistent Concordia ages of ~520 Ma, representing a maximum age constraint on the timing of deposition of the Maotianshan Shale. The zircon crystals of the ~520 Ma populations are euhedral with magmatic zoning, indicative of short-distance transport. Volcanic activity along the Song Ma suture zone is a potential source for the ~520 Ma detrital zircon suite.

1. Introduction

The Early Cambrian Maotianshan Shale deposits in Yunnan Province, China are well known for their exceptional preservation of the soft-bodied fossil fauna known as Chengjiang Fauna or Maotianshan Shale fauna. The high abundance and variety of species display a diversification of disparate anatomical architectures yielding critical insight into the evolutionary explosion of animal body plans known as the Cambrian Explosion. The fossil preservation of the labile tissues is widely distributed in central Yunnan but its spatial and stratigraphical restrictions within the Maotianshan Shale, and environmental controls remain a mystery.

Provenance analysis traditionally focuses on the compositional analysis of sand sized grains (e.g. Dickinson and Suczek, 1979; Ingersoll et al., 1984), despite the fact that silt sized grains are the most common grain size fraction in many depositional environments (e.g. Hay, 1998; Allison et al., 2003; Curray et al., 2003). Finer sediment components also have the advantage that they are commonly less permeable than their coarser grained counterparts, minimizing the impact of diagenetic alterations in this grain size fraction, and consequently more reliably preserving information about the original depositional setting (Blatt and Sutherland, 1969; Blatt, 1985). Compositional information from silt and smaller sediment components therefore can't be ignored and is essential to conduct an unbiased provenance study (Cullers, 1988; Garzanti et al., 2011).

Here, we present a multi-proxy approach to decipher the provenance of the Maotianshan Shale and add to the understanding of the taphonomic conditions that lead to the preservation of the Chengjiang Biota in the Chengjiang, Haikou, and Shankou fossil sites.

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2. Geologic setting

The study area is located near the western edge of the Yangtze Block, in Yunnan Province, South China (Fig. 1). The northwestern margin of the Yangtze Block is defined by the Longmenshan fault, separating the Yangtze Block from the Tibetan plateau (Fig. 1).

The Precambrian strata of the Yangtze Block is largely composed of Mesoproterozoic lowgrade metamorphic (greenschist facies) clastic sedimentary rocks, and abundant Neoproterozoic granites that intruded in the Mesoproterozoic strata (Guo et al., 1985; Zhou et al., 2002). Mesoproterozoic basement rocks are the oldest in the western Yangtze Block (Greentree and Li, 2008), and some of the basement rocks date back as far as the Archean (Guo et al., 2014). Less common are 822 Ma old calc-alkaline volcanic rocks, mainly composed of basalts and rhyolites, with rare andesites (X.H. Li et al., 2002; Z.X. Li et al., 2002; X.H. Li et al., 2008; Z.X. Li et al., 2008), and 786 Ma granites and granitoids (Shen et al., 2000; Li et al., 2009).

A thick stack of Sinian deposits is largely constrained by the present day Anninghe fault to the west, and the Xiaojiang fault to the east (Fig. 1; Liu, 1991). In the study area, the Cambrian (Stage 3) deposits of the Maotianshan Shale Member of the Yu'anshan Formation are well exposed south of the city of Anning and west of the city of Chengjiang (Figs. 1 and 2). The Maotianshan Shale is largely composed of mudstones, siltstones, and very fine sandstones (Fig. 2; Hu, 2005; Zhao et al., 2012; MacKenzie et al., 2015). The fossil bearing intervals are primarily associated with the middle to upper parts of the Maotianshan Shale (Fig. 2; Babcock and Zhang, 2001; MacKenzie et al., 2015).

During the Cambrian, the Kangdian paleoland separated the Yangtze Block from the Paleo-Tethys (Wang et al., 1985). The Kangdian paleoland initially formed during the Sibao orogeny (Grenville orogeny equivalent), that resulted in granitic intrusions dated to ~880 Ma. Rifting, related to the formation of the Kangdian rift basin, resulted in the formation of widespread volcanic rocks and granitic intrusions between ~850 and 820 Ma (e.g., Li et al., 1995; Li, 1999; Zhao and Cawood, 1999; X.H. Li et al., 2002; Z.X. Li et al., 2002; Zhou et al., 2002; Greentree et al., 2006; Wang et al., 2006, 2007; Ye et al., 2007; Zheng et al., 2007; X.H. Li et al., 2008; Z.X. Li et al., 2008; Wang et al., 2008). Since its formation, the Kangdian paleoland has been exposed for prolonged geologic periods and has been a major source of terrigenous material to the Yangtze Block since the Ediacaran, including the time of the Maotianshan Shale deposition.

Early to Middle Cambrian volcanic rocks from the Song Ma zone suggest that it was a tectonically active area during the Cambrian

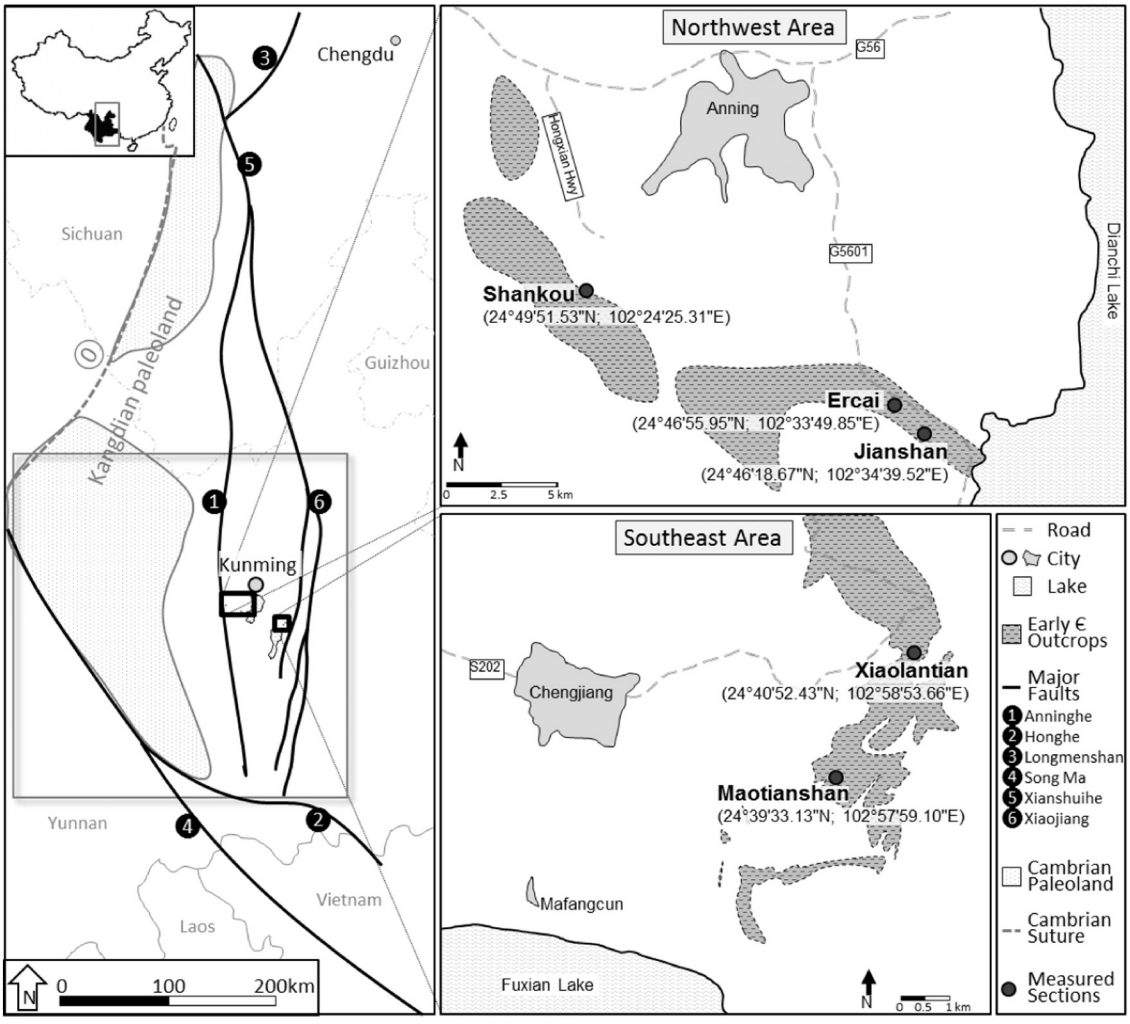

Fig. 1. Maps showing the major tectonic elements along the western margin of the Yangtze Block and the location of the study area. Major Cenozoic faults outline the margin of the Yangtze Block (faults 2–5) and the inferred margins of a major Neoproterozoic depositional center (Kangdian Rift) (faults 1 and 6) respectively (data from Allen et al. (1984); Wang and Burchfiel (2000); Zhou et al. (2002); Wang et al. (2012); Li et al. (2014)). The position of the Kangdian paleoland marked the western edge of the Yangtze Block during the Cambrian Stage 3 (outline of the paleoland from Wang et al. (1985)). The dashed line (0) along the western edge of the Yangtze Block marks an inferred Cambrian suture zone between the Yangtze Block and Indochina (from Cocks and Torsvik (2013)). The study area is located south of Anning (northwestern study area), and east of Chengjiang (southeastern study area). There, Cambrian rocks of the Maotianshan Shale are well exposed in a series of outcrops, including in the five sections that are part of this study.

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