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The earliest clastic sediments overlying the Xiong'er volcanic rocks: Implications for the Mesoproterozoic tectonics of the southern North China Craton

Yao Meng[a], Pengfei Zuo[a], Deshun Zheng[a,*], Fengbo Sun[b,*], Pengxiao Wang[c], Zhenjiang Wang[a], Yu Li[a]

[a] School of Resources and Environment, Henan Polytechnic University, Jiaozuo, China
[b] Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China
[c] No. 4 Team, Henan Coalfield Geology Bureau, Zhengzhou, China

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ABSTRACT

Xiong'er volcanism and the accompanying sedimentation that occurred along the southern margin of the North China Craton (NCC) are thought to be related to the breakup or outgrowth of the Columbia supercontinent. A series of conglomerates, pebbly sandstones, coarse- to fine-grained sandstones, siltstones, and argillaceous rocks that comprise the Bingmagou Formation unconformably overlie the Paleoproterozoic Xiong'er volcanic rocks, which themselves are unconformably overlain by Mesoproterozoic sediments (Wufoshan and Ruyang Groups) within the southern margin of the NCC. The Bingmagou Formation is considered to be one of the oldest known clastic deposits, providing information on tectonic evolution subsequent to the Xiong'er volcanism. These rocks comprise a fan delta facies sequence and can be divided into fan delta plain, fan delta front, and pro-fan delta subfacies. Detrital zircons from the formation reveal the presence of two major age peaks at ca. 2700 Ma and 2500 Ma, and one minor age peak at ca. 2100 Ma; indicative of an NCC basement provenance. Samples from the Ma'anshan Formation (Wufoshan Group) yield a major age peak at ca. 1850 Ma, a minor peak at ca. 2500 Ma, and include several younger ages between ca. 1698 Ma and 1798 Ma. These ages are indicative of progressive evolution of provenance between the Bingmagou Formation and the overlying Ma'anshan Formation. The geochemistry of Bingmagou Formation sediments is indicative of felsic source rocks with arc-like affinities, which is markedly distinct from the upper groups. Sedimentary facies, regional unconformities, and detrital zircon data may indicate an uplift in the source area.

1. Introduction

The North China Craton (NCC) is one of the world's oldest continental blocks (Liu et al., 1992, 2008a; Song et al., 1996; Zhai, 2014; Wan et al., 2015), including rock records that document the assembly and breakup of the Columbia supercontinent (e.g., Zhai and Bian, 2001; Lu et al., 2002; Kusky and Li, 2003; Santosh et al., 2009; Zhao et al., 2009; Yang et al., 2014b). Currently, there is a broad consensus that the Western and Eastern Blocks of the NCC developed independently during the Archean and early Paleoproterozoic, and collided along the Trans-North China Orogen (TNCO) to form a coherent craton ca. 1850 Ma (Zhao et al., 2001a, 2005, 2008, 2010; Guo et al., 2002, 2005; Wilde et al., 2002, 2005; Wu et al., 2005; Liu et al., 2006, 2011a,b, 2012b; Faure et al., 2007; Trap et al., 2007; Zhang et al., 2007, 2009; Zhao and Zhai, 2013; Yang et al., 2014a, 2016; Lu et al., 2015; Yang and Santosh, 2015a, b). However, as to whether subduction-related outgrowth during the Paleo-Mesoproterozoic (between 1800 Ma and 1300 Ma) occurred during the existence of the Nuna or Columbia supercontinents (Hoffman, 1996; Rogers and Santosh, 2002; Zhao et al., 2002a,b, 2004a, 2009) is still debated.

The Xiong'er volcanic belt is present along the southern margin of the NCC and is thought to be the result of outgrowth from the Columbia supercontinent (He et al., 2008; Zhao et al., 2009). Extensive Meso-Neoproterozoic sedimentary sequences that comprise terrigenous clastic and carbonate rocks (Wufoshan, Ruyang and Guandaokou Groups, respectively) unconformably overlie the Xiong'er volcanic rocks or Archean-Paleoproterozoic basement (Guan et al., 1988; BGMRH, 1989). A number of geochronological and geochemical investigations have addressed the Xiong'er Group and overlying Meso-Neoproterozoic sediments, and aimed at interpreting the tectono-

* Corresponding authors.
E-mail addresses: zhengdeshun@hpu.edu.cn (D. Zheng), sunfengbonnn@126.com (F. Sun).

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sedimentary evolution of the southern NCC (e.g., Chen et al., 1992; Zhao et al., 2001b, 2002c, 2004a,b, 2007b, 2009; Lu et al., 2002, 2008; Peng et al., 2005, 2008; He et al., 2008, 2009, 2010; Zhu et al., 2011; Hu et al., 2012a,b, 2014; Liu et al., 2015; Li and Shi, 2016; Zhai et al., 2016; Zhang et al., 2016). While the overlying Wufoshan and Ruyang Groups are considered representative of successive fluvial-marine environments (e.g., Sun et al., 1981, 1982; Zuo, 2002; Hu et al., 2012b, 2014; Zhao et al., 2012), it is unclear as to whether the Bingmagou or coeval Xiaogoubei Formations in the southern NCC belong to the overlying Wufoshan or Ruyang Groups (e.g., Sun et al., 1982; BGMRH, 1989, 1997; Wu, 2002; Zhao et al., 2012; Zhu, 2015; Zheng et al., 2016a,b, 2017).

To address the above uncertainties, we discuss the sedimentary facies of the Bingmagou Formation, and present an integrated study of whole-rock major and trace element data in concert with a discussion of the U-Pb age dating of the sediments from both this unit and the overlying strata. Compared to previous research on the Wufoshan and Ruyang Groups, our research is the first to place constraints on the sedimentary provenance of the sequence. Our results also provide further insights regarding the evolution of the southern NCC subsequent to Xiong'er volcanism.

2. Geological background

The NCC is bounded by the Paleozoic Central Asian Orogenic Belt in the north, the early Paleozoic Kunlun-Qilian Orogenic Belt in the west, the Qinling-Dabie Orogenic Belt in the south, and the Sulu Ultrahigh Pressure Metamorphic Belt in the east (Fig. 1a and b). The Archean to Paleoproterozoic metamorphosed basement of the NCC has been tectonically divided into Western and Eastern Blocks and the intervening TNCO (Zhao et al., 1998, 2001a, 2005, 2007a; Zhao and Cawood, 2012), and is overlain by Meso-Neoproterozoic volcanic-sedimentary successions and Phanerozoic cover (Santosh et al., 2007, 2008, 2016; Zhai and Santosh, 2011; Wan et al., 2011; Zhai et al., 2015). The crystalline basement in the southern region of the NCC is comprised of Neoarchean tonalitic-trondhjemitic-granodioritic (TTG) gneiss, Mesoarchean-Paleoproterozoic supracrustal rocks of the Taihua Group, Paleoproterozoic metamorphic quartzite of the Songshan Group, and a small number of mafic dyke swarms, and is unconformably overlain by the late Paleoproterozoic Xiong'er volcanic rocks, Meso-Neoproterozoic Wufoshan Group, and coeval Guandaokou and Ruyang Groups (Zhao et al., 2002a, 2004b, 2009; He et al., 2009).

In contrast, the Dengfeng Complex is comprised of a series of Neoarchean granitic plutons (dated between 2488 Ma and 2553 Ma) (Wang et al., 2004a,b; Wan et al., 2009; Zhou et al., 2009a,b, 2011; Diwu et al., 2011) and supracrustal rocks, the latter of which are subdivided into the Dengfeng and Songshan Groups (BGMRH, 1989). The Dengfeng Group is a greenschist-facies metamorphosed volcanic-dominated assemblage. The group's lower sections consist mainly of amphibolites, amphibolite-schists, granulites, and minor banded iron formations, with marble, mica schists, mica quartz schists, and minor amphibolite units towards the top (Guan, 1996; Diwu et al., 2011; Liu et al., 2012a; Fig. 1c). The majority of these supracrustal rocks, including the meta-mafics, formed during the late Neoarchean (Kröner et al., 1988; Wan et al., 2009; Zhou et al., 2009b; Diwu et al., 2011; Zhang et al., 2016). The overlying Songshan Group unconformably overlies the Dengfeng Group and mainly comprises greenschist-facies, metaclastic rocks, including basal conglomerates, quartzites, schists with minor dolomites, and phyllites (Ma et al., 1981; Diwu et al., 2008; Liu et al., 2012a) (Fig. 1c). Along the southern margin of the NCC, the Xiong'er volcanic belt is bounded to the northwest by the Jiangxian-Lintong Fault and to the northeast by the Luoyang-Baofeng Fault. This belt is separated from the Kuanping Complex in the south by the Luonan-Luanchuan Fault (Fig. 1b). The extensively exposed Xiong'er volcanic rocks unconformably overlie the Archean-Paleoproterozoic basement and are characterized by the presence of dominant andesites and basaltic andesites with minor dacites, rhyolites, and interlayered sedimentary rocks. Xiong'er volcanic rocks are mainly exposed in the Zhongtiaoshan, Xiaoshan, Xiong'ershan, and Waifangshan areas (Zhao et al., 2002c, 2003; Fig. 1b). The use of U-Pb zircon dating demonstrates that the majority of these volcanic rocks formed between 1800 Ma and 1750 Ma (Zhao et al., 2004b; He et al., 2009), while the use of lithological assemblages and geochemical data suggest that they formed in a Paleo-Mesoproterozoic, Andean-type continental margin

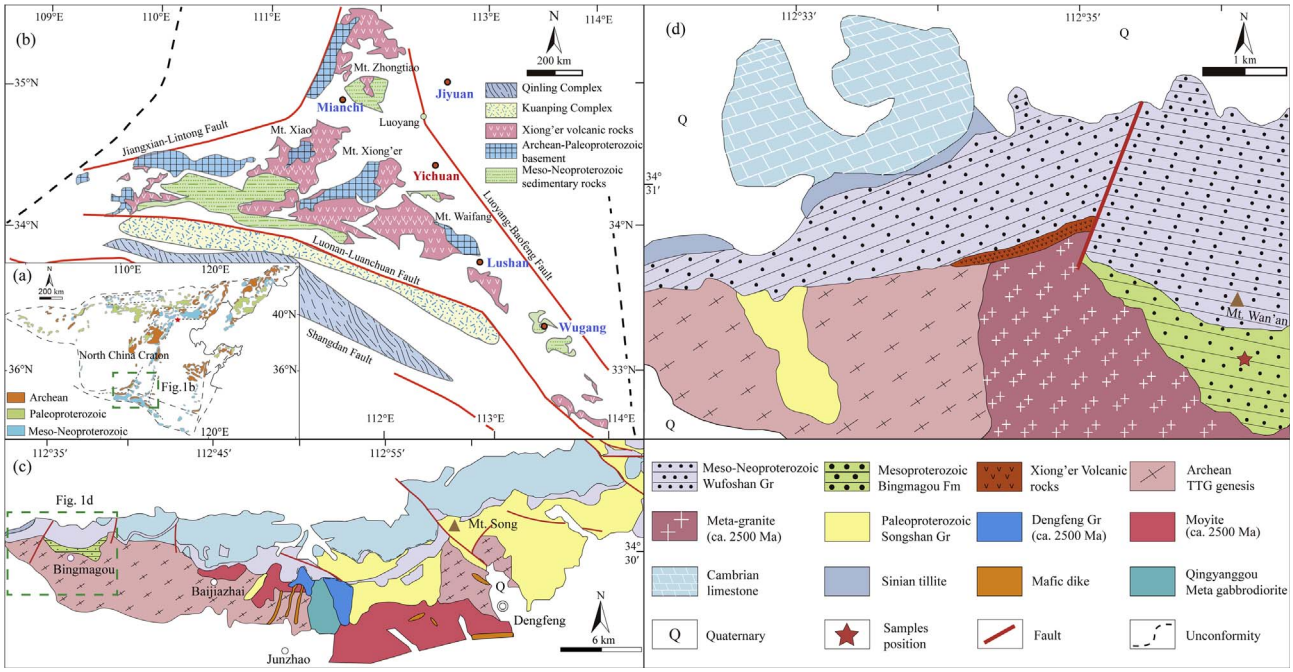

Fig. 1. (a) The geological distribution of the NCC during the Precambrian era (modified from Peng et al., 2008); (b) Generalized geological map of the southern NCC, showing the distribution of the Bingmagou Formation (modified from He et al., 2008); (c) the Dengfeng region (modified from Zhou et al., 2009a); (d) Simplified geological map of the Bingmagou Formation (modified from Xie et al., 2014).