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Zircon U–Pb geochronology and Hf isotopes of major lithologies from the Yishui Terrane: Implications for the crustal evolution of the Eastern Block, North China Craton

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ABSTRACT

As an important component of the Western Shandong Complex in the Eastern Block of the North China Craton, the Yishui Terrane consists of Neoarchean high-grade supracrustal rocks, granitoid gneisses and charnockites. LA-ICP-MS zircon U–Pb dating and Hf isotopic analyses on these lithologies have been carried out and the results provide new insights into the Neoarchean crustal evolution of the Eastern Block of the North China Craton. New zircon dating results reveal that the magmatic precursors of the supracrustal metapelites and granitoid gneisses were generated at 2.54–2.53 Ga and 2.57–2.55 Ga, respectively, and the charnockites were emplaced contemporaneously around 2.56–2.53 Ga. Single metamorphic zircon grains and overgrowth rims from these rocks document consistent metamorphic ages at ~2.50 Ga, suggesting that the Yishui Terrane experienced a high-grade metamorphic event at the end of the Neoarchean. Detrital zircons from pelitic gneisses yield $^{207}Pb/^{206}Pb$ ages of 2.89–2.65 Ga, with a major age peak at ~2.53 Ga and a subordinate age peak at ~2.70 Ga, implying that the sedimentary protoliths of the pelitic gneisses may have been sourced from ~2.53 Ga rocks in the Yishui Terrane and ~2.70 Ga rocks in the adjacent Luxi Granite-Greenstone Terrane. Hf isotopic compositions show that the Neoarchean magmatic zircons have positive $\varepsilon_{Hf}(t)$ values ranging from +1.4 to +7.8 and depleted mantle model ages of 2.92–2.60 Ga with a prominent peak at 2.8–2.7 Ga, suggesting that the Neoarchean crust was derived mainly from juvenile sources and partly from the recycling of old continental crust in the Yishui area. Combined with previous data from the adjacent Luxi Granite–Greenstone Terrane and other complexes in the Eastern Block, it is concluded that the Neoarchean was an important period of crust accretion in the Eastern Block of the North China Craton.

1. Introduction

A major advancement has been made in understanding the Neoarchean accretion and Paleoproterozoic amalgamation of the North China Craton (NCC) following recognition of three Paleoproterozoic orogenic belts, named the Trans-North China Orogen, Khondalite Belt and Jiao-Liao-Ji Belt (Fig. 1), of which the NS-trending Trans-North China Orogen divides the NCC into the Western and Eastern Blocks, whereas the EW-trending Khondalite Belt separates the Western Block into the Yinshan Block in the north and the Ordos Block in the south, while the Jiao-Liao-Ji Belt divides the Eastern Block into the Longgang and Langrim Blocks (Zhao and Zhai, 2013; Zhao et al., 2001, 2005 and references therein). There is now a broad consensus that the NCC formed by accretion and amalgamation of these microcontinental blocks along the three Paleoproterozoic orogenic belts (Faure et al., 2007; Jian et al., 2012; Kusky, 2011; Kusky and Li, 2003; Liu et al., 2000; Lu et al., 2008; Santosh, 2010; Trap et al., 2007; Wilde and Zhao, 2005; Wilde et al., 2002; Zhai, 2004, 2011; Zhai and Liu, 2003; Zhai and Peng, 2007; Zhai and Santosh, 2011; Zhai et al., 2005, 2010; Zhao et al., 1998, 2001, 2010a,b). In the past decade, researchers have carried out extensive structural, metamorphic, geochemical and geochronological investigations on these Paleoproterozoic collisional belts, and produced large amounts of new data and competing interpretations (e.g. Dan et al., 2012; Guo et al., 2002, 2005, 2012; He et al., 2009; Kröner et al., 2006; Li and Zhao, 2007; Li et al., 2011, 2012; Liu et al., 2006, 2011a,b, 2012a,b,c,d; Luo et al., 2008; Peng et al., 2011, 2012a; Santosh et al., 2007, 2009a,b, 2012, 2013; Tam et al., 2011, 2012a,b,c; Trap et al., 2011, 2012; Xia et al., 2008, 2009; Zhang et al., 2006, 2007, 2009, 2012a,b,c,d; Zhao and Zhai, 2013; Zhao et al., 2001, 2006, 2007, 2008a, b, 2012). Now there is a coherent outline of timing and tectonic processes involved in the amalgamation of the Yinshan and Ordos Blocks along the Khondalite Belt to form the Western Block (Yin et al., 2009, 2011; Zhao, 2009), and the amalgamation of the Longgang and Langrim Blocks

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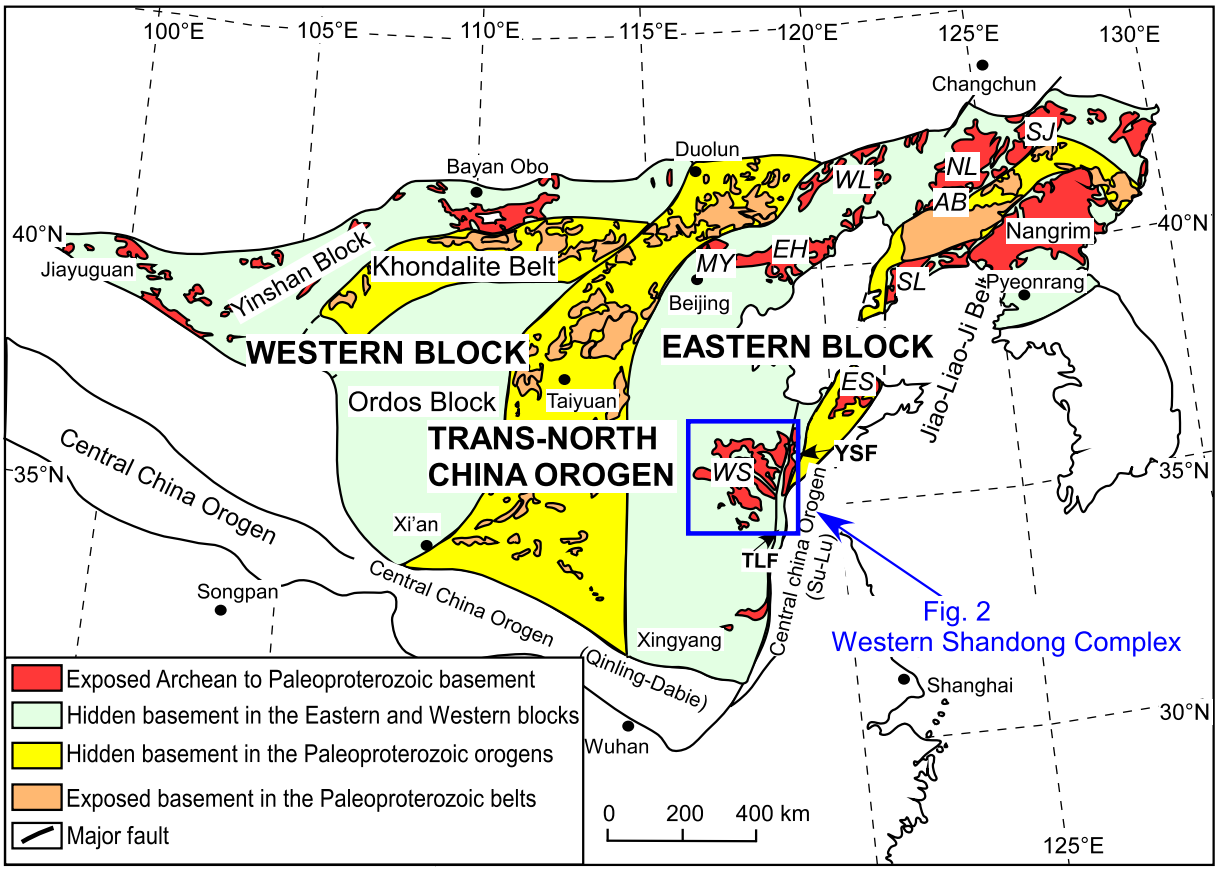

Fig. 1. Tectonic subdivision of the North China Craton (revised after Zhao et al., 2005). Abbreviations: MY = Miyun; EH = Eastern Hebei; WS = Western Shandong; ES = Estern Shandong; SL = Southern Liaoning; NL = Northern Liaoning; WL = Western Liaoning; SJ = Southern Jilin; AB = Anshan–Benxi; TLF = Tancheng–Lujiang fault; YSF = Yishu fault.

along the Jiao-Liao-Ji belt to form the Eastern Block (Li et al., 2005, 2006; Zhao et al., 2005, 2011; Zhou et al., 2008a,b), which then collided with the united Western Block to form the Trans-North China Orogen, leading to the final assembly of the NCC (Zhao and Cawood, 2012; Zhao and Guo, 2012; Zheng et al., 2013). Comparatively, however, less work has been done on the Archean microcontinental blocks in the NCC and thus little is known about the pre-collisional history of the NCC. This is the case with the Eastern Block, which is one of the oldest cratonic blocks in the world, containing rocks as old as 3.8 billion years but whose formation and evolution still remains unknown or controversial (Geng et al., 2006, 2010, 2012; Lü et al., 2012; Nutman et al., 2011; Sun et al., 2012; Wan et al., 2012a; Wang et al., 2012; Wu et al., 2012; Zhang et al., 2012b,c; Zhao et al., 1998, 2005).

Previous data suggest that the Neoarchean igneous rocks in the Eastern Block were mainly formed at 2.55–2.50 Ga and metamorphosed at ~2.5 Ga (Geng et al., 2006, 2010, 2012; Grant et al., 2009; Kroner et al., 1998; Liu et al., 2011c; Shen et al., 2007; Yang et al., 2008). As a consequence, the NCC is considered different from most other Archean cratons, including the Superior, Wyoming, Baltica, Siberia, Amazonia, Yilgarn, Zambabwe cratons, which experienced their main crust-forming events at some time before ~2.7 Ga (Condie, 1989). On the other hand, however, whole-rock Nd and zircon Hf isotopic data indicate that major juvenile crustal growth of the Eastern Block occurred about 2.8–2.7 Ga (Jiang et al., 2010; Wan et al., 2010; Wang and Liu, 2012; Wu et al., 2005). Most recently, Wan et al. (2011) have reported that the tonalitic–trondhjemitic–granodioritic (TTG) rocks from the Luxi Granite-Greenstone Terrane in the Western Shandong Complex were emplaced at 2.8–2.7 Ga and metamorphosed at ~2.65 Ga, further confirming the existence of the 2.8–2.7 Ga crustal growth event in the Eastern Block of the NCC. However, only few 2.8–2.7 Ga old rocks have been found in the Luxi Granite–Greenstone Terrane in the Eastern Block, and thus it still remains unknown whether or not the whole Eastern Block underwent an extensive crustal growth event at 2.8–2.7 Ga, like most other cratonic blocks in the world. To resolve this issue, it is essential to carry out extensive geological investigations on other terranes in the Eastern Block. This forms a justification for this study in which we carried out LA-ICP-MS U–Pb zircon dating and a zircon Hf isotopic study on the Neoarchean supracrustal rocks, granitoid gneisses and charnockitic rocks from the Yishui Terrane, which is adjacent to the Luxi Granite–Greenstone Terrane. The results combined with previous data will not only place a constraint on the timing of the emplacement and metamorphism of the Yishui Terrane, but will also provide important insights into understanding the Neoarchean accretion and evolution of the Eastern Block of the NCC.

2. Regional geology

The Archean basement rocks in the Eastern Block are mainly exposed in the Miyun, Eastern Hebei, Western Liaoning, Southern Liaoning, Anshan-Benxi, Northern Liaoning, Southern Jilin, Eastern Shandong and Western Shandong complexes (Fig. 1). As one of the largest complexes in the Eastern Block, the Western Shandong Complex consists of the low-grade Luxi Granite–Greenstone Terrane in the west and the high-grade Yishui Terrane in the east, separated by the NS-trending Tancheng–Lujiang Fault (TLF) (Figs. 1 and 2; Bai and Dai, 1998; Shen et al., 1993). The Luxi Granite–Greenstone Terrane makes up 85% of Archean exposure in the Western Shandong Complex, whereas the Yishui Terrane is mainly located within the TLF zone that extends roughly in a NE–SW direction (Fig. 2).