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Highly heterogeneous lithospheric mantle beneath the Central Zone of the North China Craton evolved from Archean mantle through diverse melt refertilization

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ABSTRACT

High-Mg# peridotite xenoliths in the Cenozoic Hebi basalts from the North China Craton have refractory mineral compositions (Fo > 91.5) and highly heterogeneous Sr–Nd isotopic compositions ($^{87}Sr/^{86}Sr = 0.7031$–0.7048, $^{143}Nd/^{144}Nd = 0.5130$–0.5118) ranging from MORB-like to EM1-type mantle, which are similar to those of peridotites from Archean cratons. Thus, the high-Mg# peridotites may represent relics of the ancient lithospheric mantle. Published Re–Os isotopic data for Cenozoic basalt-borne xenoliths show T_{RD} ages of 3.0–1.5 Ga for the peridotites from Hebi (the center of the craton), 2.2–0 Ga for those from Hannuoba and Jining (north margin of the craton), and 2.6–0 Ga for those from Fanshi and Yangyuan (midway between the center and north margin of the craton). In situ Re–Os data of sulfides in Hannuoba peridotites suggest that whole-rock Re–Os model ages represent mixtures of multiple generations of sulfides with varying Os isotopic compositions. These observations indicate that initial lithospheric mantle beneath the Central Zone of the North China Craton formed during the Archean and was refertilized by multiple melt additions after its formation. The refertilization became more intensive from the interior to the margin of the craton, leading to the high heterogeneity of the lithospheric mantle: more ancient and refractory peridotites with highly variable Sr–Nd isotopic compositions in the interior, and more young and fertile peridotites with depleted Sr–Nd isotopic composition in the margin. Our data, coupled with published petrological and geochemical data of peridotites from the Central Zone of the North China Craton, suggest that the lithospheric mantle beneath this region is highly heterogeneous, likely produced by refertilization of Archean mantle via multiple additions of melts/fluids, which were closely related to the Paleoproterozoic collision between the Eastern and the Western Blocks and subsequent circum-craton subduction events.

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1. Introduction

Characterization of subcontinental lithospheric mantle has made contributions to our understanding of the formation and secular evolution of continents. Mantle xenoliths entrained in mantle-derived magmas are direct samples of lithospheric mantle and record wealth of information about the formation and evolution of the lithospheric mantle. Many investigations based on mantle xenoliths have shown that the North China Craton (NCC) has been severely destroyed during the Phanerozoic (e.g., Fan and Menzies, 1992; Griffin et al., 1992; Menzies et al., 1993; Griffin et al., 1998; Menzies and Xu, 1998; Fan et al., 2000; Xu, 2001; Wu et al., 2006; Zhang et al., 2007; Zheng et al., 2007; Xu et al., 2008a; Zhang et al., 2009; Xu et al., 2010). Diamond inclusions, mantle xenoliths and minerals xenocrysts in the Ordovician kimberlites indicate that the lithospheric mantle beneath the NCC was thick (about 200 km), cool (geotherms 36–40 mW/m^2), and typically Archean in compositions prior to the Paleozoic. However, the Tertiary basalt-borne xenoliths reveal the presence of thin (<80 km), hot (50–105 mW/m^2) and fertile lithosphere in the Cenozoic (Fan and Menzies, 1992; Menzies et al., 1993; Griffin et al., 1998; Menzies and Xu, 1998; Xu et al., 1998; Zheng et al., 1998; Fan et al., 2000; Xu, 2001; Gao et al., 2002; Zhang et al., 2009). This suggests the great changes in compositions and character of the lithospheric mantle during the Phanerozoic. Coupled with the changes is the widespread Mesozoic–Cenozoic magmatism (Zhou and Armstrong, 1982; Zhang et al., 2002; Yang et al., 2003; Zhang et al., 2003, 2004). Geochronological and geochemical studies of the igneous rocks and their mantle xenoliths have provided valuable information on the timing and mechanism of destruction of the NCC (e.g., O'Reilly et al., 2001; Xu, 2001; Gao et al., 2002; Zhang et al., 2002; Rudnick et al., 2004; Xu et al., 2004; Wu et al., 2006; Zheng et al., 2006; Menzies et al., 2007; Zhang et al., 2010a). However, the mechanism and process of the destruction are still subjects of considerable debate.

It should be noted that the NCC is divided into the Eastern and Western Blocks, separated by a Central Zone, and most of the above studies were based on the Eastern Block of the NCC (Fig. 1). Compared to the tectonothermal reactivation of the eastern NCC since

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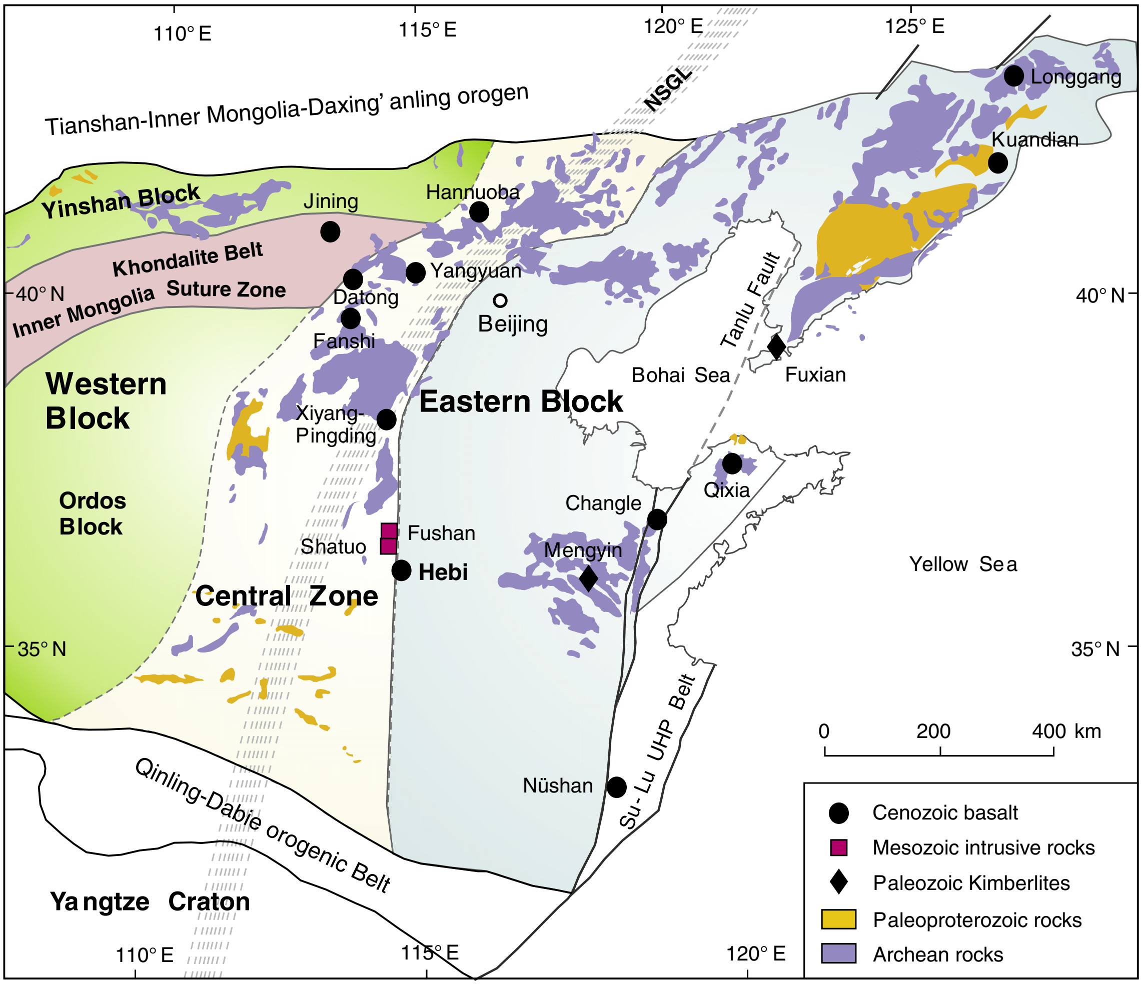

Fig. 1. Geologic and tectonic map of the North China Craton, revised after Zhao et al. (2000, 2008) and Santosh (2010), showing the distributions of the main tectonic subdivisions, rocks of different ages and mantle xenolith localities mentioned in the text. The NSGL represents the North–South Gravity Lineament (Ma, 1989).

the Mesozoic, the Western Block remains relatively stable since the Precambrian with only few magmatic activities. Thus, the Central Zone is the transitional zone of Phanerozoic magmatism, as well as crustal elevation, morphology, lithospheric thickness and gravity anomalies from the Eastern to the Western Block (Ma, 1989; Griffin et al., 1998; Menzies and Xu, 1998). Therefore, understanding the nature and evolution of the mantle lithosphere beneath the Central Zone is crucial to unravel mechanism and processes of destruction of the NCC. However, these aspects of the Central Zone are not well-constrained.

In this paper, we report the petrological and Sr–Nd isotopic compositions of peridotite xenoliths from Hebi County, Henan Province, which tectonically located in the east edge of the Central Zone (Fig. 1). Our main aim is to further constrain the nature and origin of the lithospheric mantle beneath the Central Zone by reviewing the data available for mantle xenoliths from the Central Zone of the NCC. Our study will provide an insight into the destruction of the NCC.

2. Geologic setting

The NCC is one of the Archean continental nuclei in the world and comprises three subdivisions (Fig. 1), i.e. the Eastern Block, the Central Zone and the Western Block (Zhao et al., 2000; Santosh, 2010; Kusky, 2011). The Western Block is composed of the Yinshan Block and the Ordos Block which were joined by the east–west trending Inner Mongolia Suture Zone at ~1.95 Ga (Santosh, 2010; Zhao et al., 2010a). This suture zone is also termed Khondalite Belt (Zhao et al., 2010a), with dominant lithology of graphite–garnet–sillimantie gneiss, garnet quartzite, felsic paragneiss, calc-silicate rock and marble. The basement of the Western Block mainly consists of granulite-facies tonalitic, trondhjemitic and granodioritic (TTG) gneisses and charnockites, which are unconformably overlain by Archean to Paleoproterozoic metasedimentary belts (Zhao et al., 2000). Paleoproterozoic ultrahigh temperature metamorphism has been observed in the Western Block (Santosh et al., 2007a, 2007b, 2009, 2011). The basement of the Eastern Block primarily consists of Archean TTG gneisses, granitoids, granitic gneisses and supracrustal rocks (Zhao et al., 2000).

The Central Zone is also called Trans-North China Orogen, roughly north–south trending across the NCC (Fig. 1). It consists of 2.5–2.7 Ga TTG gneisses, greenschist facies mafic rocks, amphibolites, high-pressure granulites and retrograded eclogites (Zhao et al., 2000; Zhang et al., 2006; Zhai and Santosh, 2011). This orogen was formed by the collision between the Eastern and the Western Blocks at about 1.85 Ga (Zhao et al., 2000, 2010a; Santosh, 2010), marking the formation of the NCC although the subduction polarity and the amalgamation timing of the various blocks remain debated (Kröner et al., 2005; Santosh, 2010; Zhao et al., 2010b; Kusky, 2011).

The Western Block remains relatively stable since the Precambrian and the lithosphere of this block is about 200 km thick. In contrast, the Eastern Block has experienced widespread tectono-thermal reactivation since the Late Mesozoic, as manifested by the emplacement of voluminous Late Mesozoic granites, mafic intrusions and volcanic rocks (Zhang et al., 2002, 2003; Yang et al., 2003; Zhang et al.,

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