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Refertilization of ancient lithospheric mantle beneath the central North China Craton: Evidence from petrology and geochemistry of peridotite xenoliths

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Abstract

The petrology and geochemistry of peridotite xenoliths in the Cenozoic basalts from Fanshi, the central North China Craton (NCC), provide constraints on the evolution of sub-continental lithospheric mantle. These peridotite xenoliths are mainly spinel-facies lherzolites with minor harzburgites. The lherzolites are characterized by low forsterite contents in olivines (Fo < 91) and light rare earth element (LREE) enrichments in clinopyroxenes. In contrast, the harzburgites are typified by high-Fo olivines (>91), high-Cr# spinels and clinopyroxenes with low abundances of heavy REE (HREE). These features are similar to those from old refractory lithospheric mantle around the world, and thus interpreted to be relics of old lithospheric mantle. The old lithospheric mantle has been chemically modified by the influx of melts, as evidenced by the Sr–Nd isotopic compositions of clinopyroxenes and relatively lower Fo contents than typical Archean lithospheric mantle (Fo > 92.5). The Sr–Nd isotopic compositions of harzburgites are close to EM1-type mantle, and of the lherzolites are similar to bulk silicate earth. The latter could be the result of recent modification of old harzburgites by asthenospheric melt, which is strengthened by fertile compositions of minerals in the lherzolites. Therefore, the isotopic and chemical heterogeneities of the Fanshi peridotite xenoliths reflect the refertilization of ancient refractory lithospheric mantle by massive addition of asthenospheric melts. This may be an important mechanism for the lithospheric evolution beneath the Central NCC.

Keywords: Peridotite xenoliths; Mantle refertilization; Lithospheric mantle; North China Craton

1. Introduction

Asthenosphere–lithosphere and crust–mantle interactions can modify ancient lithospheric mantle roots by the influx of fertile materials (Griffin et al., 1998; Downes, 2001; O'Reilly et al., 2001; Zhang, 2005, Foley et al., 2006; Zhang et al., 2007a). Mantle xenoliths are direct samples of lithospheric mantle fragments, and thus can provide direct information about these mantle processes. Previous studies of mantle xenoliths from the Ordovician diamondiferous kimberlites (Fig. 1) have indicated a thick (>200 km), cold and refractory lithospheric keel beneath the eastern North China Craton (NCC) prior to the Paleozoic, while basalt-borne xenoliths reveal the presence

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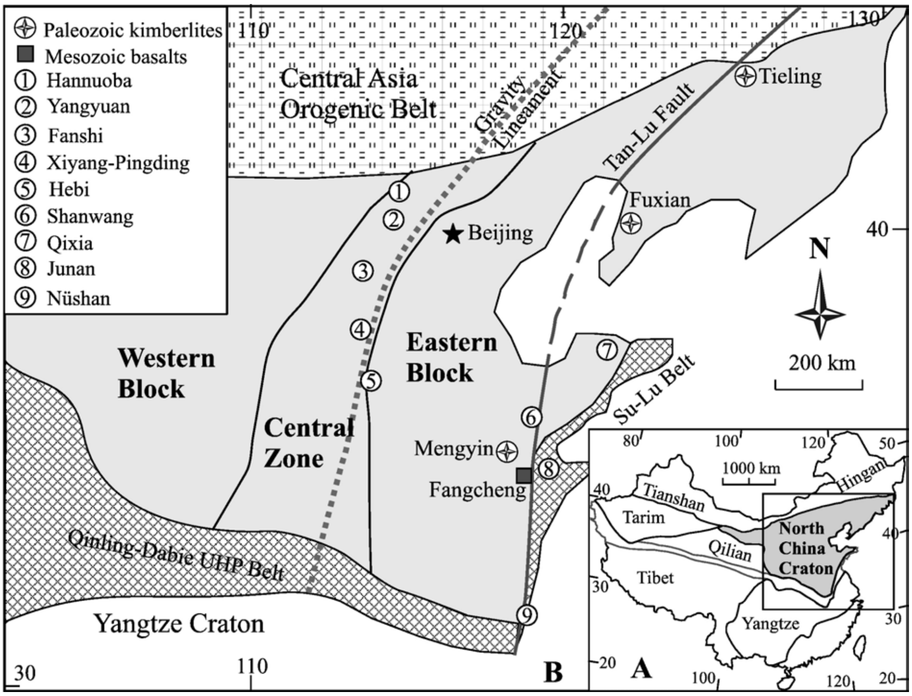

Fig. 1. Simplified geological map showing mantle xenolith localities mentioned in the text. The tectonic subdivisions of the NCC are from Zhao et al. (2002).

of thin (<80 km), hot and fertile lithosphere in the Cenozoic, which indicates the loss of more than 100 km of the ancient lithosphere beneath the eastern NCC during the Phanerozoic (Griffin et al., 1992; Menzies et al., 1993; Griffin et al., 1998; Fan et al., 2000). This remarkable evolution of the old sub-continental lithospheric mantle has attracted considerable attention in recent years (e.g. Menzies and Xu, 1998; Xu, 2001; Zheng et al., 2001; Gao et al., 2002a; Zhang et al., 2002; Zhang et al., 2003; Rudnick et al., 2004; Xu and Bodinier, 2004; Wu et al., 2005; Zhang, 2005; Rudnick et al., 2006; Ying et al., 2006; Tang et al., 2007).

Re–Os isotope data for peridotite xenoliths in Paleozoic kimberlites (Fuxian and Mengyin) and Tertiary alkali basalts (Hannuoba and Qixia, Fig. 1) reveal that the garnet and spinel peridotites from the Fuxian and Mengyin kimberlites have Archean T_{RD} ages (2500–3200 Ma) and the Hannuoba peridotites display a Re–Os isochron age of 1900 Ma, while the Qixia peridotites generally have young T_{RD} ages of 0–700 Ma, which indicates that the ancient refractory lithospheric keel beneath the eastern NCC was replaced by more fertile lithospheric mantle sometime after the Paleozoic (Gao et al., 2002a; Zhang et al., 2007b). Compositions of peridotite xenoliths from Hannuoba, the Central Zone of the NCC, reflect variable degrees (0–25%) of melt extraction from a primitive mantle source, and they are different from typical cratonic lithosphere (Rudnick et al., 2004). Two types of spinel-facies xenoliths, high-Mg# (≥92) and low-Mg# (<91) peridotites based on Fo in olivines, have been observed in the Cenozoic Hebi basalts (Zheng et al., 2001) and late Cretaceous Junan basaltic breccias (Ying et al., 2006) (Fig. 1). The high-Mg# peridotites were interpreted as relics of old lithospheric mantle (Zheng et al., 2001; Ying et al., 2006), while the low-Mg# peridotites are fertile in major elements, similar to the peridotite xenoliths from the Cenozoic Shanwang basalts (Zheng et al., 1998) (Fig. 1). Therefore, they were considered to represent newly accreted lithospheric mantle (Zheng et al., 1998, 2001; Ying et al., 2006). These observations, combined with the relatively low Fo in olivine xenocrysts in the Mesozoic Fangcheng basalts (Zhang, 2005), which are considered to be the products of peridotite–melt reaction that can transform high-Fo peridotite to low-Fo one, suggest that the NCC experienced significant modification after its formation.

The Daxing'anling–Taihangshan gravity lineament (Fig. 1) is an important geologic zone within the NCC, roughly overlapping the Central Zone of the NCC, and separates two topographically, tectonically and seismically different regions: the Western and the Eastern Blocks (Zhao et al., 2001; Xu 2007). Based on the methodology of different geochemical and isotopic