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Ultra-depleted peridotite xenoliths in the Northern Taihang Mountains: Implications for the nature of the lithospheric mantle beneath the North China Craton

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ABSTRACT

We report the finding of peridotite xenoliths in the Early Cretaceous Longmengou olivine-bearing diabase (138 Ma) in the Northern Taihang Mountains in the central North China Craton. Based on the modal proportions of olivine, clinopyroxene, amphibole and anorthite, these peridotite xenoliths can be divided into three zones: clinopyroxene-bearing olivine zone (COZ), olivine-clinopyroxene zone (OCZ), and amphibole-bearing anorthite-clinopyroxene zone (AACZ). The core of olivine grains in clinopyroxene-bearing olivine zone have higher $Mg^{\#}$ (>95), SiO_2 (41.80–42.53 wt%) and lower CaO (<0.07 wt%), FeO (3.91–4.54 wt%) than the rim ($Mg^{\#}$ = 92.5–93.4, SiO_2 = 41.27–41.98 wt%, CaO = 0.20–0.34 wt%, and FeO = 7.02–8.87 wt%), suggesting that rim is reaction product. The core of olivine grains with higher $Mg^{\#}$ (>95) and lower NiO content (<0.04 wt%) in the clinopyroxene-bearing olivine zone was derived from ultra-depleted mantle subsequently altered by high $Mg^{\#}$ melts/magma with low Ni. Two generations of olivine grains occur in the OCZ where the first generation shows exsolution of ilmenite and magnetite rods containing up to 0.35 wt% TiO_2, and was likely derived from garnet peridotite hydrated by water. The second generation shows high $Mg^{\#}$ (96.2–97.1) and cataclastic texture, and was possibly formed by decomposition of the COZ. The occurrence of aluminous spinel suggests the role of melts with extremely high Al and Mg. Clinopyroxene in the AACZ shows systematic core-rim compositional variation with CaO and SiO_2 contents increasing towards the rim, and MgO and Fe_2O_3 concentrations decreasing from the core to the rim, indicating that the amphibole-bearing anorthite-clinopyroxene zone is a product of the reaction between mantle xenoliths and mafic magma. Plagioclase with high An value (92.0–99.95, average 97.79) indicates that the metasomatic melts have high Ca/Na and Al/Si ratios, possibly produced by the partial melting of ultra-depleted mantle under "wet" conditions. Combined with the data on other mantle xenoliths discovered in the NCC, our results suggest that the Mesozoic lithospheric mantle beneath the North Taihang Mountains within the central NCC is composed of ultra-depleted Archean and Paleoproterozoic peridotites and dunites modified by complex melts. We also propose that the destruction of eastern part of the NCC mainly occurred during Early Cretaceous, and that the boundary of the lithospheric destruction coincides with the Taihang Mountains.

1. Introduction

The North China Craton (NCC), one of the world's oldest Archean cratons (Zhai and Santosh, 2011; Yang et al., 2016), preserving crustal remnants as old as 3800 Ma (Zheng et al., 2004; Wu et al., 2008), has been extensively modified by tectonic and magmatic events since the Paleoproterozoic, and especially during the Mesozoic (Zhai and Santosh, 2013). Petrological, geochemical and Re-Os isotopic studies of highly refractory peridotites trapped within Ordovician diamond-bearing kimberlite (Wu et al., 2003, 2008; Gao et al., 2002; Zhang et al., 2008) and fertile mantle xenoliths in Cenozoic basalts (Wu et al., 2003, 2006) indicate that a thick (>200 km), cool (~40 mW/m^2) Archean lithospheric mantle was replaced by a thin (<80 km), hot (~65 mW/m^2) lithospheric mantle (Menzies et al., 1993, 2007; Zhang et al., 2013) with relicts of ancient lithospheric mantle (Menzies et al., 1993; Zheng et al., 2001) during the Phanerozoic (Xu et al., 2010a, 2010b). However, the timing and lateral extent of the lithospheric destruction remain debated (O'Reilly et al., 2001; Zhang, 2005; Zhang et al., 2011, 2012; Xu et al., 2005). The

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controversy is partly due to a lack of direct evidence for the state of the Mesozoic lithospheric mantle in the NCC, especially in the central part of the NCC along the Taihang Mountain region which is considered as the boundary of the lithospheric destruction of the NCC (Zheng et al., 2007; Xu et al., 2003).

One of the keys to resolve these controversies is to determine the nature of the Mesozoic lithospheric mantle beneath the NCC, especially at the boundary of the destruction of the NCC. Several recent studies have focused on the late Mesozoic volcanics/mafic dykes and mafic intrusions from the eastern NCC revealing that the lithospheric thinning more likely occurred during the late Mesozoic (Gao et al., 2008; Pei et al., 2004; Zhang et al., 2002). However, the nature of the Mesozoic lithospheric mantle beneath the NCC is still poorly understood due to the absence of peridotite xenoliths in Mesozoic igneous rocks within the NCC (Xu et al., 2010a, 2010b).

Previous studies on Mesozoic peridotite xenoliths from the boundary of the destruction of the NCC (Taihang Mountains) (Fig. 1a) have reported the occurrence of refractory harzburgite and lherzolite consisting of olivine with $Mg^{\#}$ ranging from 90 to 93 (Xu et al., 2010a, 2010b). Among these, the occurrence of ultra-refractory olivine ($Mg^{\#} > 95$) with low NiO (<0.04 wt%) and rounded olivine grains ($Mg^{\#} = 93$) with exsolution of ilmenite and magnetite rods from the Longmengou peridotite xenoliths entrained by the olivine-bearing diabase, provide an excellent opportunity to investigate the nature of the Mesozoic lithospheric mantle and discuss the evolution of the mantle beneath the central NCC.

2. Geological setting

The NCC is composed of several Archean micro-blocks inducing the Jiaoliao Block, the Qianhuai Block, the Ordos Block, the Jining Block, the Xuchang Block, the Xuhuai Block and the Alashan Block (Zhai and Bian, 2001; Zhai et al., 2005; Zhai, 2011; Zhai and Santosh, 2011; Santosh et al., 2016; Yang et al., 2016). The craton is bound by the Early Paleozoic Qilian orogen and the Late Paleozoic-Early Mesozoic Central Asia orogenic belt to the west and the north, respectively, and the Qinling-Dabie-Sulu high to ultrahigh-pressure metamorphic belt in the south (Fig. 1a). The craton has been divided into the eastern and western NCC along the Trans-North China Orogen (TNCO) and a major gravity lineament referred to as North-South Gravity Lineament (NSGL) runs along this divide (Zhu et al., 2011; Tang et al., 2006a). The Taihang Mountain (TM) region is located in the central part of the NCC (Fig. 1a). The basement of the NCC is dominantly composed of amphibolite to granulite facies Archean gneisses and greenstones and a range of Paleoproterozoic arc and accretionary complexes (Tang et al., 2006b; Zhai and Santosh, 2011; Zhao and Zhai, 2013; Yang and Santosh, 2015), which are overlain by unmetamorphosed sedimentary cover from Mesoproterozoic onwards (Zhao et al., 2001; Wang et al.,

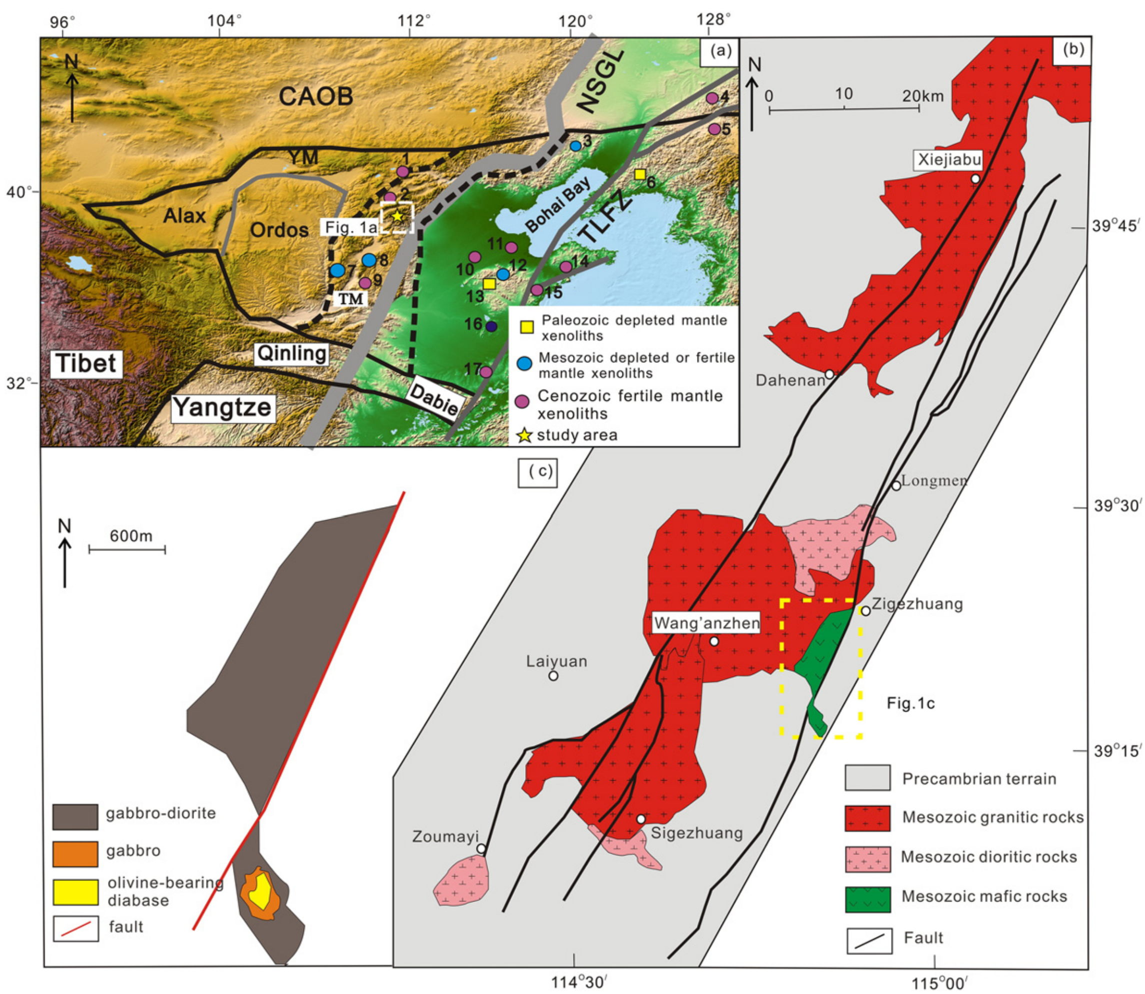

Fig. 1. (a) Tectonic framework and major outcrop locations of mantle peridotites in the eastern North China Craton. (b) Spatial distribution of Mesozoic magmatic rocks in the Northern Taihang Mountains. (c) Simplified geological map of the Longmengou intrusive rocks. CAOB: Central Asian Orogenic Belt; NSGL: North-South Gravity Lineament; TM; Taihang Mountains; YM: Yinshan Mountains; TFLZ: Tanlu Fault Zone; 1: Hannuoba mantle xenoliths; 2: Yangyuan mantle xenoliths; 3: Fuxin mantle xenoliths; 4: Huinan mantle xenoliths; 5: Kuandian mantle xenoliths; 6: Fuxian mantle xenoliths; 7: Xi'anli mantle xenoliths; 8: Fushan mantle xenoliths; 9: Hebi mantle xenoliths; 10: Shanwang mantle xenoliths; 11: Qixia mantle xenoliths; 12: Luxi mantle xenoliths; 13: Menyin mantle xenoliths; 14: Jiaozhou mantle xenoliths; 15: Junan mantle xenoliths;; 16: CCSD; 17: Nvshan mantle xenoliths. Tectonic subdivisions and location of mantle xenoliths are based on Zhu et al. (2011) and Zhang et al. (2006).