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Petrology and geochemistry of UHP-metamorphosed ultramafic–mafic rocks from the main hole of the Chinese Continental Scientific Drilling Project (CCSD-MH), China: Fluid/melt-rock interaction Mafic–ultramafic complex from CCSD-MH

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ABSTRACT

Mafic–ultramafic rocks recovered between 600 and 690 m in the main hole (MH) of the Chinese Continental Scientific Drilling (CCSD) Project in the Sulu terrane consist of garnet peridotite, garnet pyroxenite, garnet clinopyroxenite and eclogite. All of the rocks have undergone ultrahigh pressure (UHP) metamorphism with peak conditions of at least ~750–850 °C/3.5–4.0 (GPa). The protoliths were mainly lherzolite, websterite, minor clinopyroxenite and harzburgite, with major and trace element compositions characteristic of crustal layered intrusions. The low Mg# of the whole rocks and mafic minerals, layered textures, and adjacent lithology pairs of garnet peridotite - garnet pyroxenite and garnet pyroxenite–eclogite pair probably reflect fractional crystallization of the protolith magma. Whole-rock MgO and FeO abundances decrease and Al_2O_3, CaO and SiO_2 increase toward the mafic endmembers. Extensive metasomatism and metamorphism influenced REE and trace element patterns. At least three episodes of fluid/melt metasomatism are recognized: a partial melting event that depleted K and Rb during the UHP metamorphism; a retrograde metasomatism that occurred during exhumation, leading to the formation of serpentine + phlogopite veins; and a late subgreenschistfacies hydrothermal event that formed carbonates and calc–silicate minerals. The protoliths of the garnet-bearing mafic–ultramafic rocks of the CCSD-MH are interpreted as crustal cumulates, which were subducted during collision between the Yangtze and Sino-Korean Cratons in the Triassic. During subduction, the original ultramafic rocks of the CCSD-MH were transformed to garnet peridotites and pyroxenites.

1. Introduction

A number of small garnet peridotite massifs occur in the Dabie–Sulu UHP belt of China and one was sampled in the main hole of the Chinese Continental Scientific Drilling Project (CCSD-MH), as well as in the pre-pilot holes (PP1, PP2 and PP3), drilled in the same general area (Figs. 1a and 1b). Previous studies have shown that garnet peridotites in the Dabie-Sulu UHP belt can be classified as either mantle-derived (Type A) or crust-hosted (Type B) (Zhang et al., 2000, 2004). Type A garnet peridotites show very little evidence of crustal fluid/rock interaction (Zhang et al., 2000, 2005b), representing a xenolithic mantle slice of tectonic origin (Zhang et al., 2005). Type B garnet peridotites consist mainly of lherzolite and wehrlite with minor harzburgite and websterite, constituting the ultramafic part of mafic–ultramafic cumulate complexes that result from magmatic intrusions into the continental crust prior to subduction (Zhang et al., 1995; Chavagnac and Jahn, 1996; Rowley et al., 1997; Ayer et al., 2002; Jahn et al., 2003; Yang et al., 2003; Zheng et al., 2008). Both mantle-derived and crust-hosted garnet peridotites have been subjected to UHP metamorphism.

Most of the garnet peridotites in the Dabie–Sulu region are Type A in character. Mafic–ultramafic bodies in the Sulu area, such as in Weihai, Rongchen, Rizhao, Junnan, Xuguo, Yangkou (north of the CCSD-MH), and even Zhimafang (sampled in holes PP1 and PP2 close to the MH, and hole PP3 in the Ganyu area; Figs. 1a and 1b) are believed to have been derived from the mantle (Yang et al., 1993; Yang and Jahn, 2000; Jahn et al., 1999, 2003; Zhang et al., 1994, 2000, 2003; Zhang et al., 2005; Zheng, 2005; Chen et al., 2005; Zheng et al. 2006, 2007; Ye et al., 2009; Yang et al., 2007, 2009). Type A peridotites in the Dabie region have high

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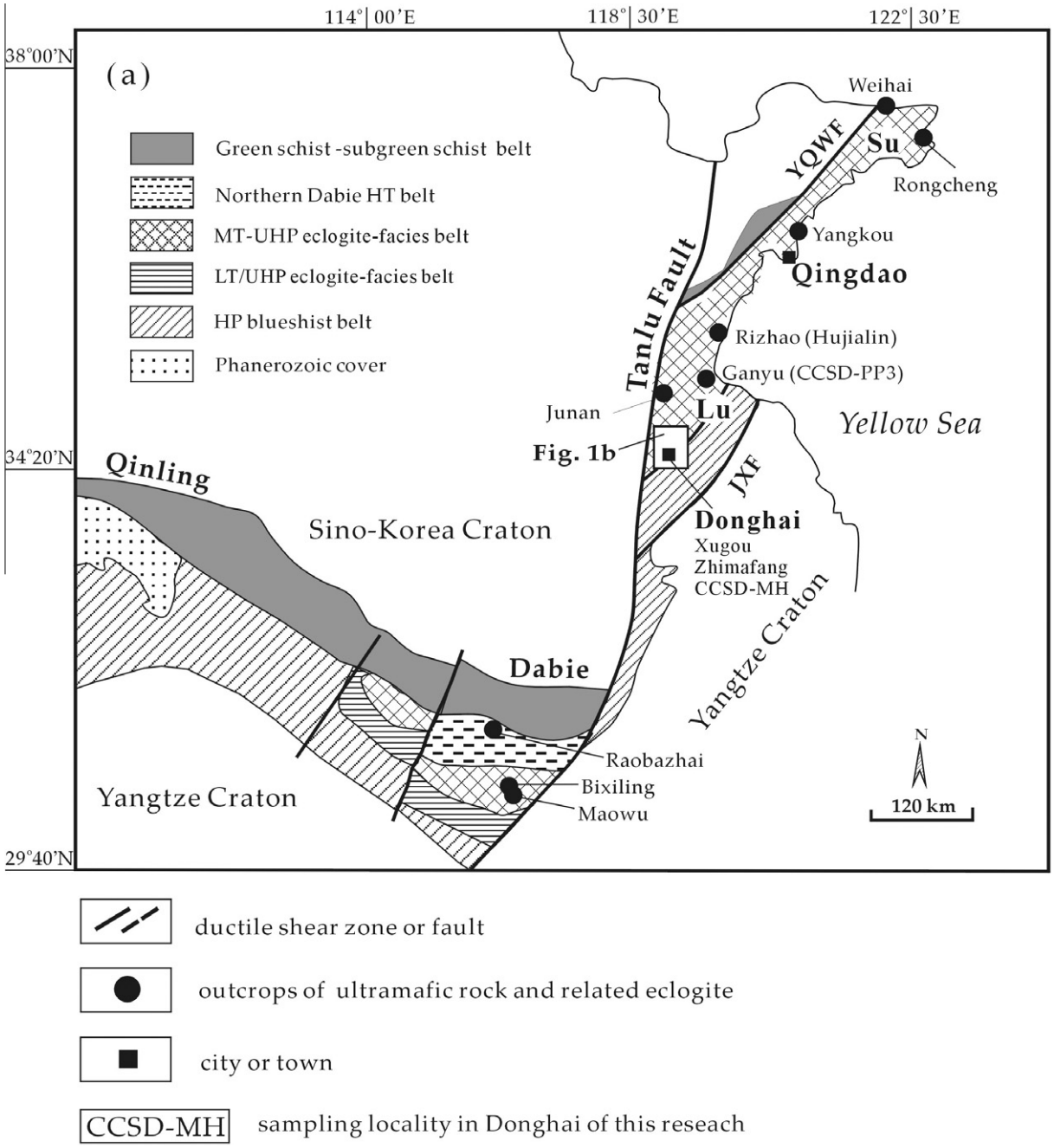

Fig. 1a. Schematic geologic map of the Dabie-Sulu metamorphic belt, showing positions of investigated ultramafic rocks described in this paper. YQWF¾Tantai-Qingdao-Wulian Fault; JXF¾Jiashan-Xiangshui Fault (modified after Li et al., 2004c; Zhang R.Y. et al., 2009).

$^{87}Sr/^{86}Sr$ ratios, low εNd(t) values, and low $\delta^{18}O$ values, all indicating an enriched mantle source (Zheng, 2003; Chen et al., 2007; Zheng et al., 2009). The source had a depleted-mantle geochemical signature and evidence of fluid alteration at crustal levels prior to subduction (Zhang et al., 2000; Jahn et al., 2003).

Well-documented Type B garnet peridotites have only been found at Bixiling and Maowu in the Dabie area, where they form a coherent sequence composed of layers of eclogite, garnet pyroxenite and garnet peridotite (Zhang et al., 1995; Okay, 1994; Liou and Zhang, 1998; Zheng et al., 2008). The Bixiling complex formed as cumulates in a Neoproterozoic, asthenosphere-derived magma chamber in the continental crust (Zheng et al., 2008). The Maowu peridotitic complex was thought to be a Proterozoic ultramafic crustal cumulate body formed by rift magmatism along the northern margin of the Yangtze Block (Liou and Zhang, 1998; Zhang et al., 1998). Both complexes were later carried to garnet-stable depths during subduction of the Yangtze Craton in the Triassic (Okay, 1994; Liou and Zhang, 1998; Zheng et al., 2008).

Although several peridotite bodies in the Dabie–Sulu UHP belt have been studied, it is still unclear whether the mafic–ultramafic rocks from the CCSD-MH are of crustal or mantle origin and what their relationship is to the exposed rocks (Zhang et al., 2006a; Liu et al., 2008). In this study, we present new petrological and geochemical data for the garnet peridotites, garnet pyroxenites, and associated eclogites from the CCSD-MH and use these data to investigate the origin of the rocks and the extent to which they have been modified by interaction with aqueous fluids and/or melts in a subduction zone environment.