Oxygen isotope heterogeneity of olivine crystals in orogenic peridotites from Songshugou, North Qinling Orogen: Petrogenesis and geodynamic implications

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Abstract

Olivine grains from Songshugou mylonitized peridotite massif record δ18O both lower and higher than in pristine mantle samples in North Qinling Orogen, Central China. Olivines from dunites exhibit large variations in δ18O (4.03–7.07‰), and some porphyroclasts display negative correlations between δ18O and forsterite content [Fo = 100×Mg/(Mg+Fe2+)]. The porphyroclast cores have low-δ18O values, indicating that they formed in the oceanic lithospheric mantle prior to subduction. We attribute low-δ18O values to seawater-peridotite interaction under high-temperature conditions. The porphyroclast rims and small olivines exhibit high-δ18O values. These features suggest that high-δ18O olivines formed during mylonitization in the exhumation process. Olivines reacted with 18O-rich melt/liquids released from subducted altered oceanic basalts and continental sediments at low temperature (<610–680 °C). The 18O-rich melt/liquids selectively affected porphyroclast rims and small olivine grains. Unlike the olivines in the dunites, the olivines and orthopyroxenes in the harzburgites show limited variations in δ18O (4.21–5.45‰ and 5.5–5.8‰, respectively), due to orthopyroxene exchange with melt/fluid at a slower rate than the coexisting olivine. The preservation of the low-δ18O signature in olivines indicates a short residence time (<20 Ma) for subducting peridotites to mantle depths.

Keywords: Oxygen isotope heterogeneity, olivine, orthopyroxene, Songshugou peridotites, North Qinling Orogen

Introduction

The formation and evolution of the orogenic peridotites is an important topic in solid earth science. The oxygen isotopic compositions of minerals from orogenic peridotites can provide important geodynamic insights. Numerous investigations have established that continental crustal materials have been recycled into the mantle and interacted with peridotites through oceanic subduction to continental collision during the orogenic process. Barnicoat and Cartwright (2008) established that continental crustal materials have been recycled into the mantle and interacted with peridotites through oceanic subduction to continental collision during the orogenic process (Barnicoat and Cartwright 1995; Zheng et al. 1998; Michael et al. 2000; Dijkstra et al. 2002; Song et al. 2006; Zou et al. 2017). The distinction between oxygen isotopic compositions of mantle vs. crustal materials suits the system well to studies of magma source and evolution (Bindeman et al. 2008a, 2008b; Wang and Eiler 2008; Genske et al. 2013; Moore et al. 2016; Kim et al. 2021), metamorphism of crustal rocks (Barnicoat and Cartwright 1997; Zheng et al. 1998; Putlitz et al. 2000; Riches et al. 2016), as well as mantle metasomatism (Deines and Haggerty 2000; Zhang et al. 2000a; Widom and Farquhar 2003; Perkins et al. 2006; Guo et al. 2013; Liu et al. 2014; Hao et al. 2015; Marshall et al. 2017; Dallai et al. 2019). Pristine mantle olivines generally have homogeneous oxygen isotope compositions of δ18O = 5.7 ± 0.2‰ (Mattey et al. 1994; Harmon and Hoefs 1995; Eiler et al. 1997). However, when orogenic peridotites have undergone subduction with crustal materials and experienced HP-UHP metamorphism, they may have oxygen isotopic compositions remarkably different from the normal mantle. During subduction, devolatilization of the hydrated oceanic crust and continental sediments release substantial amounts of fluid with variable δ18O compositions. The δ18O values of orogenic peridotites increase through interaction with melt/fluid of high-δ18O composition derived from sediments (Dobosi et al. 2003; Liu et al. 2015; Hu et al. 2019), low-T altered oceanic crust and carbonates (Gregory and Taylor 1981; Vroon et al. 2001; Carmody et al. 2013; Jakob et al. 2018), and decrease through meteoric/hydrothermal fluid and seawater interaction (Stakes and Taylor 1992; Putlitz et al. 2000; Roumén et al. 2018; Sharp et al. 2018; Radu et al. 2019; Zakharov and Binde-man 2019). Thus, oxygen isotopes can be applied to deciphering the potential origin of the varied rocks found in orogenic belts, but little research has been conducted on the formation processes of orogenic peridotites.

The Songshugou mylonitized peridotite massif occurs as several hundred blocks within amphibolites of the Qinling Group, North Qinling Orogen of Central China. The petrogenesis and tectonic implications of these peridotites are under debate. One model considers the Songshugou peridotites as fragments of oceanic lithosphere formed during the late Mesoproterozoic to early Neoproterozoic (Wang et al. 2005; Dong et al. 2008; Nie et al. 2017; Sun et al. 2019). Some authors argue against this notion and regard the rock as a cumulate of ultramafic magma (Song et al. 1998), or a melt-rock reaction product associated with mantle plume activity (Su et al. 2005), or as melting residue in forearc mantle (Cao et al. 2016). Recent studies suggest that the