Immiscible melt droplets in garnet, as represented by ilmenite–magnetite–spinel spheroids in an eclogite-garnet peridotite association, Blanský les Granulite Massif, Czech Republic

Stanislav Vrána1,*, Lukáš Ackerman1,2, Vojtěch Erban1, and Patricie Halodová1

1Czech Geological Survey, Klárov 3, 118 21 Praha 1, Czech Republic
2Institute of Geology v.v.i., Academy of Sciences of the Czech Republic, Rozvojová 269, 165 00, Praha 6, Czech Republic

Abstract

Interlayered eclogite and symplectitic garnet rock that is interpreted as former garnetite are found in the Gföhl Unit of the Bohemian Massif. They show unusual Fe–Ti-rich compositions, characterized by TiO2 contents up to 2.34 wt%, and Mg# of 59.8 and 51.6, respectively. Equilibration conditions of 1250 °C and 4.0 GPa are calculated for eclogite. The petrogenesis of this rock association can be best explained as high-temperature and ultrahigh-pressure magmatic cumulates. Highly decoupled Sr-Nd isotopic composition with nearly constant radiogenic 87Sr/86Sr values and a slightly negative eNd value suggests interaction of aqueous fluid most likely derived from a subducting slab and/or from parental magmas. The garnetite contains large (up to 0.5 mm) Fe–Ti-rich spheroids of ilmenite–magnetite–spinel, interpreted as frozen droplets of a melt incorporated in the growing garnet. The interstices between these garnet crystals are filled by ilmenite–magnetite–spinel aggregates, with concave outer surfaces with trapped Fe–Ti-rich melt. These ilmenite–magnetite–spinel spheroids represent possibly the first record of such an oxidized assemblage in mantle rocks, and probably the first description of Fe–Ti-rich melt in eclogite-garnetite mantle rocks. A calculation based on mineral proportions in the spheroids and mineral composition indicates that the immiscible Fe–Ti-rich melt consisted of 28.7 TiO2, 3.7 Al2O3, 0.2 Cr2O3, 27.9 Fe2O3, 37.0 FeO, 0.8 MnO, and 1.7 MgO wt%. Petrology and geochemistry of the garnetite indicates an unusual composition for an upper mantle melt with a high oxygen fugacity and relatively high Fe content.

Keywords: Ilmenite–magnetite–spinel, Fe–Ti-rich melt, UHP crystallization, garnetite, eclogite, garnet peridotite, Moldanubian Zone, Invited Centennial article

Introduction

Eclogite and garnet pyroxenite represent volumetrically minor but very important rock types, inasmuch as they provide direct evidence for heterogeneity in the upper mantle. Their petrogenesis is a matter of debate. They have been variously interpreted as basaltic protoliths recycled back to the upper mantle (e.g., Allègre and Turcotte 1986) and/or high-pressure crystal cumulates derived from migrating transient basaltic melts (e.g., Becker 1996; Medaris et al. 1995; Pearson et al. 1993). Eclogites show a wide range of major element, trace element, and isotopic composition reflecting the heterogeneity of their protoliths and/or parental melts. Exceptionally Fe–Ti-rich eclogites are rare, and their petrogenesis is a matter of debate (e.g., Liu et al. 2007). In the Gföhl Unit of the Moldanubian Zone, Bohemian Massif, garnet peridotites, associated eclogites, and garnet pyroxenites are widespread (Medaris et al. 1995a, 1995b, 2005, 2006, 2013; Faryad 2009; Faryad et al. 2013). The peridotites usually form variably serpentinitized decimeter- to kilometer-sized bodies enclosed in high-temperature and high-pressure crustal rocks such as granulate, gneiss, and/or migmatite. The crustal rocks occur as centimeter-to-decimeter sized lenses, layers, and/or dikes within, or closely associated with, garnet peridotite. Here, we show new results on ilmenite–magnetite–spinel spheroids, which we interpret as melt droplets, and that appear to record conditions of immiscibility.

Spheroid is a non-genetic term for a spheroidal or spherical particle. Spheroidal shape is obtained by rotating an ellipse about one of its principal axes (shape more or less similar to a sphere). Examples in the literature include tiny metallic spheroids at impact sites (e.g., Meteor Crater, Arizona), in some tektites and lunar regolith (Mead et al. 1965; Blau et al. 1973), ilmenite–magnetite aggregates in gabbro (Liu et al. 2014), pyrite aggregates formed in various environments (McClay and Ellis 1983), reduction spheroids in sediments (Hofmann 1991), and various applications in technology (Jacobs et al. 1976). Spheroid is not a common term in upper mantle petrology.

In this study, we report detailed petrography, major/trace element and Sr-Nd isotopic geochemistry for the Fe–Ti-rich eclogite–symplectitic garnet rock. We interpret the ilmenite–magnetite–spinel assemblage as having crystallized from an immiscible Fe–Ti melt under upper mantle conditions at relatively high oxygen fugacity. The spheroids of ilmenite–magne-