Lithos 256–257 (2016) 197–210

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Re–Os and Lu–Hf isotopic constraints on the formation and age of mantle pyroxenites from the Bohemian Massif

Lukáš Ackerman [a,b,*], Michael Bizimis [c], Eva Haluzová [a,d], Jiří Sláma [a,e], Martin Svojtka [a], Takao Hirajima [f], Vojtěch Erban [b]

[a] Institute of Geology, The Czech Academy of Sciences, Rozvojová 269, 165 00 Praha, Czech Republic
[b] Czech Geological Survey, Geologická 6, 152 00 Praha, Czech Republic
[c] Department of Earth and Ocean Sciences, University of South Carolina, Columbia, SC 29208, United States
[d] Faculty of Science, Charles University, Albertov 6, 128 43, Praha, Czech Republic
[e] Department of Earth Science and Centre for Geobiology, University of Bergen, Allégaten 41, N-5007 Bergen, Norway
[f] Department of Geology and Mineralogy, Kyoto University, Kyoto 606-8502, Japan

ARTICLE INFO

Article history:
Received 1 September 2015
Accepted 31 March 2016
Available online 8 April 2016

Keywords:
Mantle
Pyroxenite
Re–Os
Lu–Hf
Bohemian Massif

ABSTRACT

We report on the Lu–Hf and Re–Os isotope systematics of a well-characterized suite of spinel and garnet pyroxenites from the Gföhl Unit of the Bohemian Massif (Czech Republic, Austria). Lu–Hf mineral isochrons of three pyroxenites yield undistinguishable values in the range of 336–338 Ma. Similarly, the slope of Re–Os regression for most samples yields an age of 327 ± 31 Ma. These values overlap previously reported Sm–Nd ages on pyroxenites, eclogites and associated peridotites from the Gföhl Unit, suggesting contemporaneous evolution of all these HT–HP rocks. The whole-rock Hf isotopic compositions are highly variable with initial ε_{Hf} values ranging from −6.4 to +66. Most samples show a negative correlation between bulk rock Sm/Hf and ε_{Hf} and, when taking into account other characteristics (e.g., high $^{87}Sr/^{86}Sr$), this may be explained by the presence of recycled oceanic sediments in the source of the pyroxenite parental melts. A pyroxenite from Horní Kounice has decoupled Hf–Nd systematics with highly radiogenic initial ε_{Hf} of +66 for a given ε_{Nd} of +7.8. This decoupling is consistent with the presence of a melt derived from a depleted mantle component with high Lu/Hf. Finally, one sample from Bečváry plots close to the MORB field in Hf–Nd isotope space consistent with its previously proposed origin as metamorphosed oceanic gabbro. Some of the websterites and thin-layered pyroxenites have variable, but high Os concentrations paralleled by low initial γOs. This reflects the interaction of the parental pyroxenitic melts with a depleted peridotite wall rock. In turn, the radiogenic Os isotope compositions observed in most pyroxenite samples is best explained by mixing between unradiogenic Os derived from peridotites and a low-Os sedimentary precursor with highly radiogenic $^{187}Os/^{188}Os$. Steep increase of $^{187}Os/^{188}Os$ at nearly uniform $^{187}Re/^{188}Os$ found in a few pyroxenites may be connected with the absence of primary sulfides, but the presence of minor late stage sulfide-bearing veinlets likely associated with HT–HP metamorphism at crustal conditions.

1. Introduction

Spinel and/or garnet pyroxenites are important mantle lithologies as they provide insights into the spatial heterogeneity and temporal evolution of the Earth's mantle (Allègre and Turcotte, 1986; Becker, 1996a; Downes, 2007; Medaris et al., 1995; Pearson et al., 1993; Sergeev et al., 2014). They are found as minor layers and lenses in peridotite massifs (~1–5% of bulk peridotite massif; e.g., Downes, 2007) and as xenoliths in kimberlites (e.g., Gonzaga et al., 2010) and alkali basalts (e.g., Bizimis et al., 2005). Several hypotheses have been proposed (see Bodinier and Godard, 2014 and references therein) for the origin of mantle pyroxenites, with the two being most often discussed with respect to pyroxenite petrogenesis: (1) formation by metamorphism of subducted oceanic crust (Allègre and Turcotte, 1986; Obata et al., 2006) or (2) origin as high-pressure cumulates that crystallize from melts migrating through the mantle (Becker, 1996a; Bizimis et al., 2013; Bodinier et al., 1987; Medaris et al., 1995; Pearson et al., 1993). In the Gföhl Unit of the Moldanubian Zone, Bohemian Massif, both garnet pyroxenite and eclogite evolution hypotheses were tested and indicate an interesting coincidence. Based on petrological arguments and the presence of zonation in garnets, some eclogites have been interpreted as metamorphic end products of a mafic protolith during

* Corresponding author at: Institute of Geology, The Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6, Czech Republic. Tel.: +420 233087240; fax: +420 220922670.
E-mail address: ackerman@gli.cas.cz (L. Ackerman).

http://dx.doi.org/10.1016/j.lithos.2016.03.023
0024-4937/

subduction (e.g., Faryad, 2009; Faryad et al., 2013; Nakamura et al., 2004), while Medaris et al. (1995) interpreted both garnet pyroxenite and eclogite as high-pressure crystal cumulates (± trapped melt) from silicate melts migrating through the mantle.

The combined Re–Os and Lu–Hf isotopic systems have been proven very helpful in studying the origin, evolution and age of pyroxenites (Pearson and Nowell, 2004). Because of the large difference in the partitioning behavior of Re and Os in the peridotitic mantle, melts have high Re/Os and develop radiogenic $^{187}Os/^{188}Os$ over time, while mantle residues often display unradiogenic $^{187}Os/^{188}Os$. Therefore, interaction of such melts with peridotites can lead to significant modifications of the Re–Os systematics in the target peridotites (e.g., Becker et al., 2001; Büchl et al., 2004; van Acken et al., 2008; Ackerman et al., 2013; Wang and Becker, 2015). In turn, the divergent fractionation of Lu/Hf ratio between pyroxenes (low) and coexisting garnets (high) in pyroxenites allow the generation of precise internal isochrons that can both date the formation of the pyroxenites and provide information on the long-term evolution of the pyroxenite parental melt sources (Gonzaga et al., 2010; Montanini et al., 2012; Pearson and Nowell, 2004).

The Bohemian Massif hosts a wide range of (ultra)mafic rocks of various origins. The majority of the pyroxenites from the Bohemian Massif are interpreted as high-pressure cumulates from melts derived from oceanic and subcontinental mantle sources that also contain a significant amount of recycled crustal component (Becker, 1996a; Medaris et al., 2013; Medaris et al., 1995; Svojtka et al., 2016). In this study, we present Lu–Hf data for a suite of previously well characterized pyroxenites (Svojtka et al., 2016) from the Bohemian Massif together with Re–Os concentrations and Os isotopic determinations. These data are used to constrain the age of pyroxenite formation and evaluate the Hf–Os isotopic compositions of their parental melt sources in order to test for the possible incorporation of recycled crustal and ancient depleted components.

2. Geological setting

The Bohemian Massif (Fig. 1) represents the easternmost part of the European Variscan orogenic belt that resulted from the collision of two major continents—Gondwana to the south and Laurussia (Baltica) to the north. The Variscan continent–continent collision zone of Middle to Late Paleozoic age is traditionally divided from north to south into four main tectonometamorphic domains: the Saxothuringian, the Teplá-Barrandian, the Moldanubian and the Brunia (e.g., Schulmann et al., 2009). The investigated samples come from the Moldanubian Zone, which is the highest metamorphosed zone in the Variscan orogenic belt. The Moldanubian Zone forms the central and southern parts of the Bohemian Massif, and consists of allochthonous units of middle and lower crust with slices of upper mantle that were all assembled during the Variscan orogeny and modified by multiple metamorphic events. The traditional division of the Moldanubian Zone includes the Monotonous Unit, the Varied Unit and the Gföhl Unit, the latter of which shows the highest metamorphic grade (e.g., Matte et al., 1990; Fiala, 1995). While the first two units are mostly composed of amphibolite grade rocks (dominated by garnet–sillimanite paragneiss with minor orthogneiss and amphibolite), the Gföhl Unit also contains granulite and eclogite facies rocks (Carswell and O'Brien, 1993; Medaris et al., 2006).

The Gföhl Unit consists of amphibolites, migmatitic gneisses, granulites (garnet-kyanite felsic granulite and minor pyroxene granulite), and rare eclogites, peridotites and pyroxenites (e.g., Matte et al., 1990; Fiala, 1995). These high-grade rocks preserve Precambrian to Early Ordovician protolith ages (e.g., Janoušek et al., 2004; Schulmann et al.,

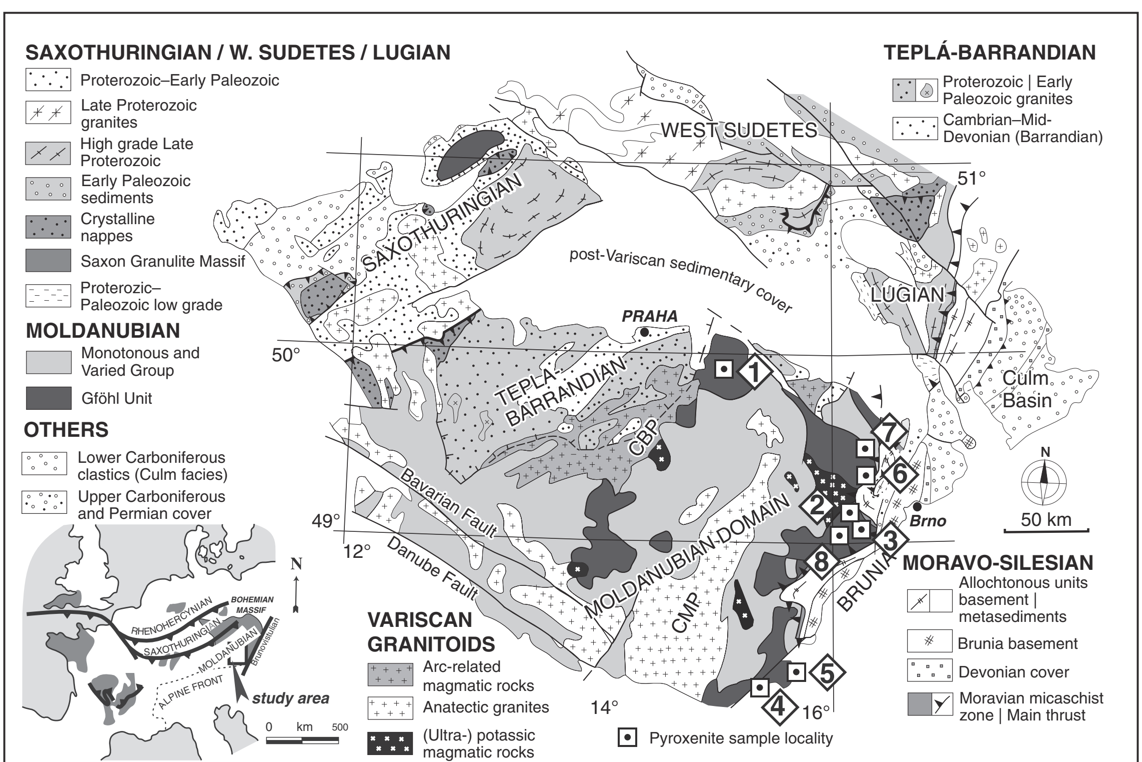

Fig. 1. Simplified geological map of the Bohemian Massif (modified from Lexa et al., 2011) showing the position of the studied localities; inset, bottom left shows major tectonostratigraphic subdivision of the European Variscides (in dark grey). Sampled localities: 1—Bečváry; 2—Mohelno; 3—Horní Kounice; 4—Karlstetten; 5—Meidling im Taal; 6—Níhov; 7—Drahonín; 8—Nové Dvory. For more details on regional geology settings and samples, see Svojtka et al. (2016).