

Melt-Peridotite Reactions In The Upper Mantle: Geochemistry Of Peridotite And Pyroxenite From The Beni-Bousera Massif

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The Beni-Bousera massif contains ubiquitous pyroxenites of various types, organized into conspicuous layers ranging from 0.5 to 100 cm in thickness, hosted by peridotites. Integrated field features, petrographic observations, and geochemical analyses from 92 samples (whole rock major and trace elements data: 55 samples, microprobe data for minerals: 48 samples, and mineral trace elements data: 30 samples) from pyroxenites provide information to classify the rock types into four different groups typified as: (1) garnet pyroxenites, (2) spinel-garnet websterites, (3) spinel websterites, and (4) spinel chromium websterites. Type 1 rocks, occurring at the base of the massif, are considered as the most primitive type, garnet pyroxenites layers represent the vestiges of an old veined subcontinental lithosphere. They generally indicate temperatures <970°C (based on two-pyroxene thermometry) and a low to very low Mg# (<76%). Trace element contents show enrichment in heavy and middle rare earth elements but strong depletion in light rare earth elements (LREE). Paradoxically, the host peridotites show enrichment in LREE, which give new insights into their genesis history. Based on our field observations and geochemical results, we suggest that garnet-pyroxenite layers metasomatised the host peridotite successively by the partial melting as a consequence of subsequent heating phase(s) of the lithosphere. The magmatic event that led to the diversity and zoning of mafic layers was caused by melting of the base of thinned subcontinental lithosphere by upwelling asthenosphere, followed by infiltration of asthenospheric melts. The different groups of mafic layers record several stages of this event.

Keywords: Geochemistry, Beni Bousera, Pyroxenite, Peridotites

Petrology and geochemistry of the ultramafic metamorphic rocks from the Masora domain, east-central Madagascar

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Madagascar is located within the interior of the Neoproterozoic East African Orogen (Jacobs and Thomas, 2004) that marks the join between East and West Gondwana. In the east Madagascar, the Paleo-Mesoarchean Antongil-Masora domains are exposed (Collins, 2006; Tucker et al., 2011). In this study we report the petrological and whole rock and REE geochemical characteristics of the ultramafic metamorphic rocks exposed within the Masora domain and we discuss their origin and tectonic settings. The Masora domain is mainly composed of the Paleo-Mesoarchean felsic metamorphic rocks with subordinate amounts of metasedimentary rocks (e.g. Randriamananjara, 2008; Tucker et al., 2011). This domain was intruded by Neoproterozoic granitoids and mafic-ultramafic rocks (e.g. Smith et al., 2008).

The ultramafic metamorphic rocks are exposed in the north and south Masora domain. Three types of ultramafic metamorphic rocks are identified in the north: peridotite, pyroxenite and hornblendite. The peridotite is mainly composed of olivine and anthophyllite with subordinate amounts of serpentine, magnesite and magnetite. The pyroxenite is mainly composed of clinopyroxene and hornblende with subordinate amount of magnesite and magnetite. The hornblendite is mainly composed of hornblende with subordinate amount of actinolite and magnetite. Some of the hornblendite has spinel. An ultramafic metamorphic rock body occurs as a lens within metasedimentary rock in the south. This metasedimentary rock is kyanite+biotite+muscovite schist. The mineral assemblage of the ultramafic lens differs between core and rim. It is mainly composed of olivine, tremolite, actinolite and chlorite with subordinate amounts of serpentine, magnetite and altered minerals in the core. The rim is mainly composed of tremolite, actinolite and chlorite with subordinate amount of magnetite and ilmenite.

The ultramafic metamorphic rocks except for the hornblendites have $\text{SiO}_2 = 42.7\text{-}51.7$ wt.%, $\text{Al}_2\text{O}_3 = 1.5\text{-}7.5$ wt.%, $\text{MgO} = 19.8\text{-}35.4$ wt.%, and $\text{CaO} = 3.5\text{-}16.5$ wt.%. They have high Mg# (molar ratio of $\text{Mg}^{2+}/(\text{Mg}^{2+} + \text{Fe}^{2+})$) of 0.76-0.83. On the basis of bulk rock CIPW normative Ol-Cpx-Opx composition, the ultramafic metamorphic rocks except for the hornblendites plot in the field of the lherzolite, olivine websterite and websterite (Streckeisen, 1976). Compared with the geochemical characteristics of abyssal peridotites (Niu, 2004), the ultramafic metamorphic rocks shows lower MgO, higher TiO_2 and CaO than those in the abyssal peridotites. On the MgO-Ni diagram (Pfeifer, 1990 in Katzir et al., 1999) one of the samples plot in the typical abyssal lherzolite field whereas the others plot in higher-Ni (orogenic) field. Chondrite normalized REE patterns of the ultramafic metamorphic rocks show flat HREE with variable LREE patterns. One of the samples shows enriched LREE pattern and the others show depleted LREE patterns. The depleted LREE samples have flat HREE with about twice amount of chondritic HREE abundances. This is typical characteristic of an orogenic lherzolite such as Ronda massif in the southern Spain and Lanzo lherzolites in the Italian Alps (Bodinier and Godard, 2003). Enriched LREE pattern is also a typical characteristic of pyroxenites occurring in orogenic peridotites (Bodinier and Godard, 2003). On the basis of petrological and geochemical characteristics, their protoliths are orogenic lherzolite, websterite and pyroxenite.

Keywords: Gondwana supercontinent, east-central Madagascar, geochemistry, Masora domain, ultramafic metamorphic rocks

Zircon Nano-SIMS U-Pb dating from the country gneiss beside Horoman peridotite, Hokkaido, Japan

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Hidaka Metamorphic Belt, Hokkaido, Japan includes the youngest granulites and the Horoman peridotite complex in the highest grade zone. Age of the Hidaka gneiss and amphibolite have been determined by various methods (e.g. K-Ar, U-Pb, Rb-Sr and etc). However, the age of Horoman peridotite complex has not been determined yet. Only Yoshikawa et al (1993) reported the cooling age of the complex as 23 Ma based on whole rock Rb-Sr isochron method. This study performed U-Pb dating of zircons from the paragneiss surrounding the Horoman peridotite complex in order to determine the intrusive age of the Horoman peridotite complex from the upper mantle into the lower crustal conditions. The zircons have detrital cores and thin rims (<20 microns). Therefore we used Nano-SIMS because it is possible to focus the secondary beam diameters down to submicrons for the analysis. As a result of this measurement, rim ages of the zircons show that ²³⁸U-²⁰⁶Pb age are 7-11Ma (n=7) and detrital core ages show 25.6 Ma, 34-35 Ma, 78 Ma and 150 Ma (n=8). The rim ages are the youngest in Hidaka metamorphic rocks and there is a discrepancy with zircon rim ages (19Ma) from the granulite (Kemp et al. 2007; Usuki et al. 2006). The present rim ages (7-11 Ma) fit well with the tectonic scenario of the collision process of Hokkaido Island proposed by Yamamoto et al. (2010). It is considered that the Horoman peridotite complex was juxtaposed onto the Hidaka metamorphic belt at 7-11Ma by the subducting Pacific plate after the collision between North American and Eurasian plates.

Keywords: Zircon, U-Pb, Nano-SIMS, Horoman peridotite, country gneiss, juxtaposition age

3 types of Ca-Amp found from Nove Dvory UHP eclogites and their origin, Moldanubian Zone of the Bohemian Massif

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The upper-stability limit of Ca/Na amphibole (Amp) in meta-mafic rocks are considered to be around 2-3 GPa in pressures (Schmidt & Poli, 1998). Thus, most Ca-Amp in (ultra)-high pressure metamorphic rocks have been considered as retrograde products. The peak metamorphic conditions of Nové Dvory eclogites are estimated to be 4.5-4.9 GPa and 1050-1150°C. However, some Ca-Amp inclusions in Grt are likely to be interpreted as prograde relicts survived the ultra-high pressure metamorphism. This paper reports the mode of occurrence and the chemical compositions of Ca-Amp and the coexisting minerals in Nové Dvory eclogite, and discusses when Ca-Amp crystallized. Investigated two eclogite samples, ND0107 and ND120, collected from the same outcrop, are composed mainly of garnet (Grt) and Omphacite (Omp) with minor amounts of apatite (Apt) and rutile (Rt) at the UHP stage, and suffered hydration reactions, represented by Ca-Amp and plagioclase (Pl) formation, with various degree during the exhumation stage.

Ca-Amp in studied eclogite can be classified into 3 types based on their modes of occurrence; Type 1 Amp occurs in sporadic euhedral shaped polyphase mineral aggregates (PMAs) in Grt along with Omp, Rt, and Apt. Type 1 Amp is identified only from ND0107, and is classified as pargasite (Prg) or kaersutite (Krs). Omp inclusions associated with Type 1 Amp are homogeneous and have high X_{Jd} of 40-45, suggesting that the associated Omp did not suffer retrogressive reactions. On ACF diagram, Type 1 Amp is plotted between the associated Omp and host Grt. It suggests that Type 1 Amp could be a relict of the following reaction, $Amp = Omp + Grt + W$, during the subduction stage. Type 2 Amp is identified as a member of PMAs in Grt along with spinel (Spl) and diopside (Di). Those PMAs with Type 2 Amp show unidiomorphic shapes and straight alignment in Grt. They are classified as Prg or magnesio-hastingsite (Mg-Hs). Type 3 Amp is a member of the symplectite along with Omp, Di, Spl, and Pl developed at Grt rim. These facts suggest that Type 2/3 Amp were formed during the exhumation stage reacted with infiltrated fluids to the host eclogite.

The different stage origins of Type 1/2 Amp mentioned above is supported by F and Cl contents in them. Type 1 Prg contains 0.21-0.30 wt% of F, but is almost free from Cl (<0.01wt%). Type 2 Prg contains 0.43-1.17wt% of Cl. Type 2 Prg in ND0107 with Type 1 Amp contains 0.05-0.29wt% of F. On the other hand, Type 2 Prg in ND120, which is free from Type 1 Amp, is scarce in F (<0.05wt%). Type 3 Amp is free from Cl.

It is generally considered that Ca-Amp enriched in $(Na+K)^A$, ^{IV}Al , and $^{VI}Fe^{2+}$ can incorporate more Cl (Makino, 2000). However, Type 1/2 Amp have a similar major element compositions such as $(Na+K)^A = 0.79-0.95$ pfu (for $O+OH+F+Cl=24$ basis), $^{IV}Al = 2.01-2.45$ pfu, and $^{VI}Fe^{2+} = 0.56-0.97$ pfu, in spite of a scarce but significant difference in Cl content among them. Cl-free Type 3 Amp contains similar amount of $(Na+K)^A$ (0.75-0.96 pfu) and ^{IV}Al (1.95-2.38 pfu), but less in $^{VI}Fe^{2+}$ content (<0.47pfu) compared with those of Type 1/2 Amp.

As a present stage conclusion, Type 1 Amp crystallized under F-bearing and Cl-poor environment during the prograde stage, and Type 2/3 Amp crystallized during the retrograde stage along with supply of Cl from outside of the rock. F identified in Type 2 Amp in ND0107 with F-bearing Type 1 Amp could be supplied from the Type 1 Amp through the retrogressive reactions.

Keywords: Eclogite, Amphibole, Ultra-high pressure metamorphism, Bohemian Massif, Fluorine, Chlorine