MINERALOGY AND THERMOMETRY OF DEEP XENOLITHS FROM THE KHARCHINSKY VOLCANO (CENTRAL KAMCHATKA DEPRESSION)

Sekisova[1], V., Smirnov[1], S., Kuzmin[1], D., Shevko[1], A., Gora[1], M.
[1]V.S. Sobolev institute of Geology and Mineralogy SB RAS, Novosibirsk, Russia

Xenoliths of deep rocks are a very valuable source of information about composition and structure of the lithosphere and different processes, occurred in the upper mantle and the crust basement. In case of supra-subduction zones, deep xenoliths provide the opportunities to study the influence of mantle-rock interactions and mantle metasomatic events.

We studied different xenoliths from the Kharchinsky volcano, located in the north of the Central Kamchatka Depression. The Kharchinsky is almost entirely composed of magnesian basalts (MgO up to 13.7 wt.%). The Kharchinsky volcano xenoliths are observed only in dike-like body or neck. According to mineral composition, the studied xenoliths were subdivided into two groups: peridotites and clinopyroxenites. Peridotite xenoliths are presented by spinel wehrlite, spinel-amphibole wehrlite with olivenite veinlet, spinel harzburgite and amphibole lherzolite. They are mainly composed of olivine, clinopyroxene, amphibole, accessory Cr-spinel and rarely orthopyroxene. The second group is clinopyroxenites, main rock-forming minerals of which is clinopyroxene, olivine, amphibole, and magnetite. Two samples of pyroxenites are plagioclase-rich. Moreover, the studied xenoliths have interstitial segregations and veinlets, composed of chlorite, plagioclase, orthopyroxene, apatite, titanite, ilmenite, alkaline feldspar, barite, rarely anhydride, phlogopite, etc.

All these samples are presented by mafic SiO_2-undersaturated rocks, that has high contents of large-ion lithophile elements (for example, up to 435 ppm Ba). The studied xenoliths are also characterized by light-REE enrichment, that many scientists, as a rule, explain by metasomatic alteration, caused by fluid or/and melt effect (Frey, Green, 1974).

Thus, the studied xenoliths contain two mineral assemblages: primary and secondary. Secondary minerals replace primary assemblages, indicating a metasomatic overprint. Moreover, large-sized primary minerals such as olivine and rarely clinopyroxene are intensively fractured, and healed fractures contain abundant fluid and melt inclusions. According to Raman spectra fluid inclusions in xenolithic minerals contain pure CO_2. Scanning SEM EDS analyzes of melt inclusions indicate presence of silica, calcite, etc. as daughter phases. In addition secondary melt inclusion in olivine from the olivinite vein has extremely unusual chemical composition , because silicate glass is characterized by high alkali contents (Na_2O + K_2O = 13.2 wt.%) with relatively low SiO_2 57.3 wt.%.

Compositions of rock-forming minerals vary widely, forming several groups on based of magnesian number (Mg#) values. Olivine forms three groups Fo_{89-90}, Fo_{79-87} и Fo_{70-77} (Fig. 1). They also differ on MnO, CaO and Al_2O_3 contents. Olivine compositions from one sample (XP-11) are similar to those of the upper-mantle rocks found on Avachinsky (Ishimaru et al., 2007) and Bezymyanny volcanoes (Ionov et al., 2013; Shcherbakov, Plechov, 2010) and Shiveluch (Bryant et al., 2007), but this olivine is depleted by nickel (Fig. 1). In addition, the XP-11 olivines simultaneously have low CaO contents and high Fo values that indicates their mantle formation (Simkin, Smith, 1970). Thus we think this xenolith (XP-11) is the most primitive that allows doing PT-estimations of the mantle beneath the Kharchinsky volcano.

We used olivine-spinel (Ballhaus et al., 1991; Fabries, 1979) and olivine-clinopyroxene (Loucks, 1996) geothermometers. Olivine with Cr-spinel inclusions shows equilibrium temperatures, varying 880-890 °C (Ballhaus et al., 1991) at pressure 15 kbar, and oxygen fugacity is $\Delta\log fo_2$ = from -0.7 to +1.0 log.units. Another olivine-spinel geothermometer (Fabries, 1979) shows temperature of 1,090-1,140 °C. Olivine-clinopyroxene pairs (Loucks, 1996) show the temperature range between 1,090 and 1,140 °C. Heating experiments of primary melt inclusions in clinopyroxene, comprising glass and gas bubble, show homogenization temperature of 1,250 °C.

Clinopyroxene also forms three groups $En_{47-48}Fs_{5-7}Wo_{45-48}$, Na_2O up to 0.2 wt.%, Mg# = 90-92; $En_{40-47}Fs_{7-14}Wo_{45-49}$, Na_2O up to 0.2 wt.%, Mg# = 76-89 and $En_{35-37}Fs_{19-20}Wo_{44-46}$, Na_2O up to 0.8 wt.%, Mg# = 66-69. Its groups differ on MnO, Al_2O_3 и TiO_2 contents.

Amphibole is Al-rich (Al_2O_3 up to 7-15 wt.%) and presented by pargasite in clinopyroxenites and edenite in peridotites. Its composition varies into two groups with Mg# = 86-88 and Mg# = 62-81, which differ on Al_2O_3, MnO и Cr_2O_3 contents. Al-in-amphibole geobarometer (Hollister et al., 1987) gives pressure estimations, varying 2-7 kbar in peridotites and 5-10 kbar in clinopyroxenites.

To obtain T-estimations by means of secondary assemblages, we utilized two-feldspar (Putirka, 2008) and amphibole-plagioclase (Holland, Blundy, 1994) geothermometers, that show similar temperature intervals 780-950 and 780-820 °C respectively. Values of oxygen fugacity for olivine-spinel pairs (Ballhaus et al., 1991) from the peridotite xenoliths at pressure 10 kbar is $\Delta \log fo_2$ = from -0.7 to +2.0 log.units. They correspond to highly oxidized lithospheric mantle (Ballhaus, 1993) and forearc peridotites (Parkinson, Pearce 1998; Parkinson, Arculus, 1999; Pearce et al., 2000). The values obtained also fall into the field of strongly metasomatized xenoliths of spinel-peridotites (Ballhaus, 1993).

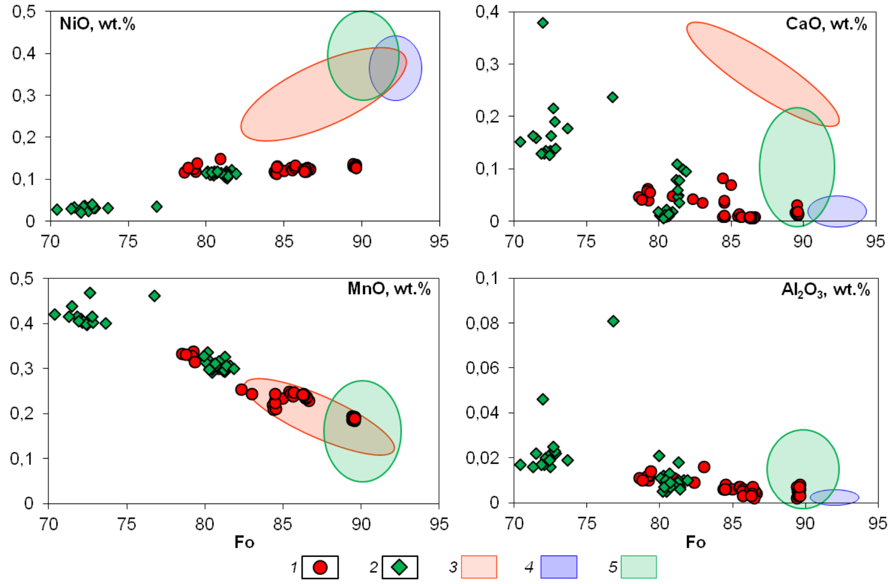

Fig. 1. Chemical composition of olivine from the studied xenoliths. Symbols: 1 – olivine from peridotites; 2 – olivine from clinopyroxenites; 3 – olivine from Troodos ophiolite (Cameron, 1985); 4 – olivine from forearc peridotites (Ishii et al., 1992); 5 – olivine from xenoliths of Kamchatka (Bryant et al., 2007; Ishimaru et al., 2007; Ionov et al., 2013; Shcherbakov, Plechov, 2010).

The majority of the rocks represented by the studied xenoliths are probably cumulates, related to basaltic melt fractionation and crystallized apparently in intermediate chambers. Peridotites belong to spinel facies. Both peridotites and pyroxenites experienced intensive metasomatic alteration. Presence of secondary fluid and melt inclusions allow to propose that there was an influence of heterogeneous metasomatic media, containing CO_2-rich fluid and melts with appreciable water and alkali contents.

This study is funded by RFBR according to the research project № 18-35-00491.

References:

Ballhaus C., Berry R.F., Green D.H. High pressure experimental calibration of the olivine-orthopyroxene-spinel oxygen geobarometer: implications for the oxidation state of the upper mantle // Contributions to Mineralogy and Petrology, v. 107, № 1, 1991, pp. 27–40.

Ballhaus C. Redox state of lithospheric and asthenospheric upper mantle // Contributions to Mineralogy and Petrology, v. 114, 1993, pp. 331–348.

Bryant J. A., Yogodzinski G. M., Churikova T. G. Melt-mantle interactions beneath the Kamchatka arc: Evidence from ultramafic xenoliths from Shiveluch volcano // Geochem. Geophys. Geosyst., v. 8, No 4, 2007.

Fabries J. Spinel-olivine geothermometry in peridotite from ultramafic complex // Contrib. Mineral. Petrol., v. 69, 1979, pp. 329-336.

Frey F. A., Green D. H. The mineralogy, geochemistry and origin of lherzolite inclusions in Victorian basanites // Geochimica et Cosmochimica Acta, V. 38 (7), Elsevier, 1974, pp. 1023-1059.

Holland T. and Blundy J. Non-ideal interactions in calcic amphiboles and their bearing on amphibole-plagioclase thermometry // Contrib Mineral Petrol., V. 116, 1994, pp. 433-447.

Hollister, L.S., Grissom, G.C., Peters, E.K-, Stowell, H.H., and Sisson, V.B. Confirmation of the empirical correlation of Al in hornblende with pressure of solidification of calc-alkaline plutons // American Mineralogist, 72, 1987, pp. 231-239.

Ionov D.A., Bénard A., Plechov P.Yu., Shcherbakov V.D. Along-arc variations in lithospheric mantle compositions in Kamchatka, Russia: first trace element data on mantle xenoliths from the Klyuchevskoy Group volcanoes // Journal of volcanology and geothermal research, v. 263, 2013, pp. 122-131.

Ishii T., Robinson P. T., Maekawa H., Fiske R. Petrological studies of peridotites from diapiric serpentinite seamounts in the Izu-Ogasawara-Mariana Forearc, LEG 125[1] // Proceedings of the Ocean Drilling Program, Scientific Results, v. 125, 1992, pp. 445-485.

Ishimaru S., Arai S., Ishida Y., Shirasaka M., Okrugin V. M. Melting and multi-stage metasomatism in the mantle wedge beneath a frontal arc inferred from highly depleted peridotite xenoliths from the Avacha volcano, Southern Kamchatka // Journal of petrology, v. 48, No 2, 2007, pp. 395-433.

Loucks R. R. A precise olivine-augite Mg-Fe-exchange geothermometer // Contributions to Mineralogy and Petrology, v. 125, № 2, 1996, pp 140–150.

Putirka K.D. Thermometers and Barometers for Volcanic Systems // Reviews in Mineralogy and Geochemistry, v. 69, 2008, pp. 61-120.

Shcherbakov V.D., Plechov P.Y. Petrology of mantle xenoliths in rocks of the Bezymyanny Volcano (Kamchatka) // Doklady Earth Sciences, v. 434, № 2, 2010, pp. 1317-1320.

Simkin T., Smith J.V. Minor-element distribution in olivine // J. Geol, v. 78, № 3, 1970, pp. 304–325.