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PERIDOTITIC MANTLE SECTION BENEATH V.GRIB KIMBERLITE PIPE (ARKHANGELSK REGION, RUSSIA): MINERALOGICAL COMPOSITION, P-T CONDITIONS, METASOMATISM.

E.V. Shchukina[1], V.G. Malkovets[1], N.N. Golovin[2], N.P. Pokhilenko[1]
[1]VS Sobolev Institute of Geology and Mineralogy, Novosibirsk, Russia
[2]Arkhangelskgeoldobycha Ltd, Arkhangelsk, Russia

INTRODUCTION

Kimberlite-derived mantle xenoliths contain important information about composition, structure and thermal state of the upper mantle underlying Archean cratons. There are 2 large Late- Devonian diamond deposits on the territory of the Arkhangelsk kimberlite province (Winter Coast, in the north of East-European Platform): the deposit named after M.V. Lomonosov, combined 5 kimberlite pipes, and V. Grib kimberlite pipe. To date about 80 kimberlite pipes are found in Winter Coast. V. Grib kimberlite pipe was discovered in 1996. Though the first kimberlite pipes in Arkhangelsk region were discovered in 1980's, the information about mineralogical composition and P-T conditions of the upper-mantle xenoliths is rare. First of all the main reason is that kimberlites and xenoliths of Lomonosov deposit are extremely altered. Kimberlites of V. Grib pipe derive bundle of fresh megacrysts and weakly secondary altered upper-mantle and lower-crust xenoliths. (Kostrovitsky et al., 2003; Sablukov & Sablukova, 2000; Skublov et al., 2011) The aim of this paper is to report the mineralogical composition and equilibrium P-T conditions of peridotitic xenoliths from V. Grib kimberlite pipe.

GEOLOGICAL POSITION

The V. Grib kimberlite pipe is situated in 35 km to north-east from Lomonosov deposit (Fig. 1). The pipe penetrated Vendian sediments and is covered by carbonate-terrigenous and quaternary formations with total thickness about 70 meters. The age (372 +/- 8 Ma) of V. Grib kimberlite pipe was determined by Rb-Sr isotope analysis of kimberlites (Shevchenko et al., 2004). Thus the V. Grib kimberlite pipe was formed in the same period of time with kimberlite pipes of Lomonosovo group and main diamondiferous pipes of Siberian Platform (Agashev et al., 2004).

SAMPLES AND ANALYTICAL TECHNIQUES

We have studied 20 samples of peridotite xenoliths from V. Grib kimberlite pipe. The peridotite set included 10 phlogopite-bearing garnet lherzolites, 6 garnet lherzolites, 2 phlogopite-bearing garnet harzburgites and 2 garnet harzburgites. All xenoliths possess a protogranular texture with no obvious evidence of deformation.

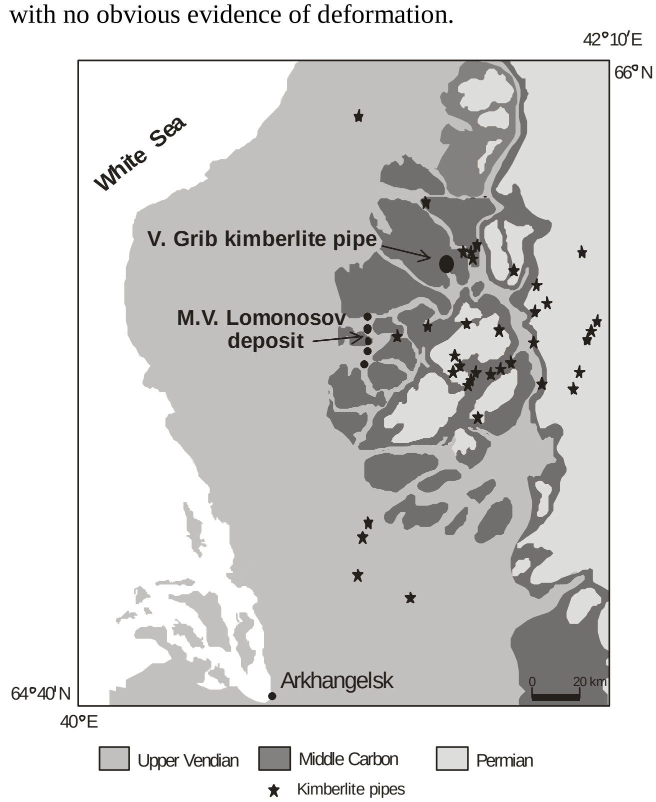

Fig.1. Geological position of kimberlite pipes within the Arkhangelsk kimberlite province

The chemical compositions of major minerals in xenoliths were determined by Jeol 8200 Super Probe in Analytical Center of VS Sobolev Institute of Geology and Mineralogy (Novosibirsk, Russia) at an accelerating voltage of 20 mV and a 50 mA beam current.

MINERAL COMPOSITION

Olivine

The Fo content in olivine from garnet peridotite varies from 92.1 to 93.0. The Fo content in olivine from phlogopite-garnet peridotites is considerably lower and ranges from 90.6 to 92.2. Concentration of NiO in olivine ranges from 0.32 to 0.51wt. % for garnet peridotites and from 0.24 to 0.47 wt. % for phlogopite-garnet peridotites (Fig.2). For comparison the concentration of NiO and Fo content in olivine from diamond inclusion are plotted (Malkovets et al., 2011). The average concentrations of NiO decrease from phlogopite-garnet peridotites (NiO av. = 0.40 wt. %) to garnet peridotites (NiO av. = 0.38 wt. %) and further to diamond inclusions (NiO av. = 0.34 wt. %). And the average Fo contents change in reverse sequence: from diamond inclusions (Fo av. = 92.9) to garnet peridotites (Fo av. = 92.4) and then to phlogopite-garnet peridotites (Fo av. = 91.3).

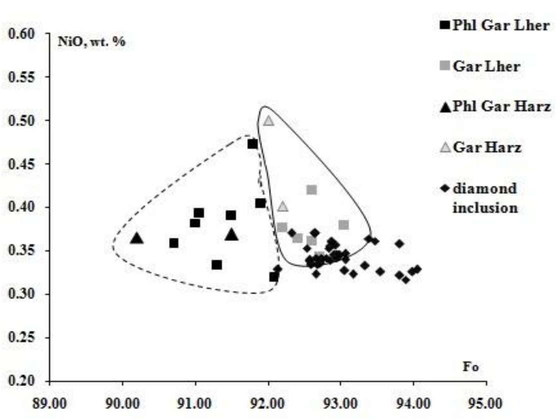

Fig. 2. Correlation between concentration of NiO and Fo content in olivines from peridotite xenolites and diamond inclusions (dates from Malkovets et al. 2011) of V. Grib kimberlite pipe.

Garnet

Garnet from the examined peridotites contains high MgO (18.71-21.64 wt. %), low CaO (4.18-6.70 wt. %), moderate Cr_2O_3 (1.78-6.08 wt. %) and classified as pyrope.

Concentration of TiO_2 in garnet ranges from 0.05 to 0.28 wt. % for plogopite-garnet peridotites and from 0.04 to 0.18 wt. % for garnet peridotites. The pyrope compositions define a lherzolitic trend (Sobolev et al., 1973).

Clinopyroxene

Clinopyroxene in lherzolites has high-Cr content (0.22-2.81 wt. %) and classified as Cr-diopside. Clinopyroxene from phlogopite-garnet lherzolites has lower Mg# (89.7-94.6), Cr_2O_3 (0.22-2.43 wt. %) and higher TiO_2 (0.05-0.66 wt. %), Al_2O_3 (0.71-4.07 wt. %) и Na_2O (1.09-3.09 wt. %) in comparison with garnet lherzolites (Mg# 93.9-95.5; Cr_2O_3 1.15-2.81 wt.%; TiO_2 0.01-0.25 wt.%; Al_2O_3 (2.08-3.05 wt. %), Na_2O (1.44 – 2.94 wt. %).

Ortopyroxene

Ortopyroxene (classified as enstatite) from phlogopite-garnet peridotites has lower Mg# (90.1-90.3) and higher TiO_2 (0.02-0.24 wt. %), Cr_2O_3 (0.09-1.7 wt.%), Al_2O_3 (0.35-1.97 wt.%), CaO (0.16-1.18 wt.%) and Na_2O (0.02-0.29 wt.%) compared to garnet peridotites (Mg# 92.1-94.0; TiO_2 0-0.11 wt.%; Cr_2O_3 0.08-0.98 wt.%; Al_2O_3 0.57-0.79; CaO 0.13-0.85 wt.%; Na_2O 0.01-0.1 wt.%).

Phlogopite

Phlogopite is observed in 12 samples and divided into 3 types: large tabular grains, rims around garnet grains and smaller, irregular in shape grains. All three types can be within one sample. The concentrations of TiO_2 and Cr_2O_3 in three types are different.

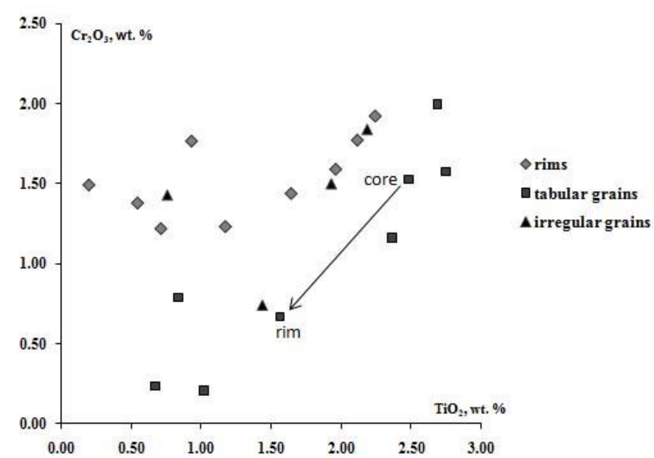

Fig.3. Correlation between concentration of Cr_2O_3 and TiO_2 in phlogopites from phlogopite-garnet peridotites of V. Grib kimberlite pipe.

Tabular grains contain 0.67-2.75 wt. % of TiO_2 and 0.24-2.00 wt. % of Cr_2O_3; phlogopite in rims contain 0.16-2.24 wt. % of TiO_2 and 1.22-2.92 wt. % of Cr_2O_3 and irregular, small grains contain 1.44-2.38 wt. % of TiO_2 and 0.75-1.84 wt. % of Cr_2O_3. In one sample (89-305) significant zonation in contents of TiO_2 and Cr_2O_3 was identified (Fig.3).

THERMOBAROMETRY

Estimates of the P-T parameters of equilibrium between minerals are based on composition of unaltered, homogeneous grains of olivine, clinopyroxene, ortopyroxene and garnet. P-T parameters were estimated using the following combinations: $BKN_{Ca\text{-}in\text{-}opx}$ + NG85, FB84 + MG74, $BKN_{Ca\text{-}in\text{-}opx}$ + MG74, TA98 + NG85 for lherzolites as well as $BKN_{Ca\text{-}in\text{-}opx}$+ NG85, $BKN_{Ca\text{-}in\text{-}opx}$+ MG74 for harzburgites (Brey et al.,1990; Finnerty & Boyd, 1984; Nickel & Green, 1985; Taylor, 1998; MacGregor, 1974). Generally, there is a good correlation between all combinations. However among 4 combinations, $BKN_{Ca\text{-}in\text{-}opx}$+ NG85 method gave the best result. According to $BKN_{Ca\text{-}in\text{-}opx}$+ NG85 method temperature and pressures vary within the following ranges: 804-1250 C° and 33.6-75.5 kbar for phlogopite-garnet lherzolites; 772-868 C° and 30.9-38.9 kbar for garnet lherzolites; 787-906 C° and 31.1-43.3 kbar for phlogopite-garnet harzburgites; 788-869 C° and 33.2-39.4 kbar for garnet harzburgites. These P-T estimates define a cool continental geotherm and lie near 37 mW/m^2 conductive model geotherm of Pollac & Chapman (Fig. 4). The estimated depth (calculated according to Lehtonen et al., 2008) for examined samples varies within the following ranges: 122-235 km for phlogopite-garnet lherzolites; 99-124 km for garnet lherzolites; 100-137 km for phlogopite-garnet harzburgites; 106-125 km for garnet harzburgites.

CONCLUSIONS

Thus, V.Grib pipe kimberlite contains large variety of rock types of upper-mantle (peridotites, pyroxenetes, and eclogites) and lower-crust (eclogites, granulites) xenoliths. Upper-mantle peridotites can be devided into two groups: phlogopite-bearing and phlogopite-free garnet peridotites (lherzolithes and harzburgites). The chemical composition of minerals from phlogopite-garnet peridotites and garnet peridotites is differs.

Within the global context, the thermal state of upper-mantle beneath V. Grib kimberlite pipe is cooler than cratonic upper-mantle beneath Kaapvaal (Finnerty and Boyd, 1987) and Siberian cratons (Griffin et al., 1996, Boyd et al., 1997) and is closer to Slave craton (Kopylova et al., 1999). The most deep samples are 62-75.5 kbar , that can indicate that

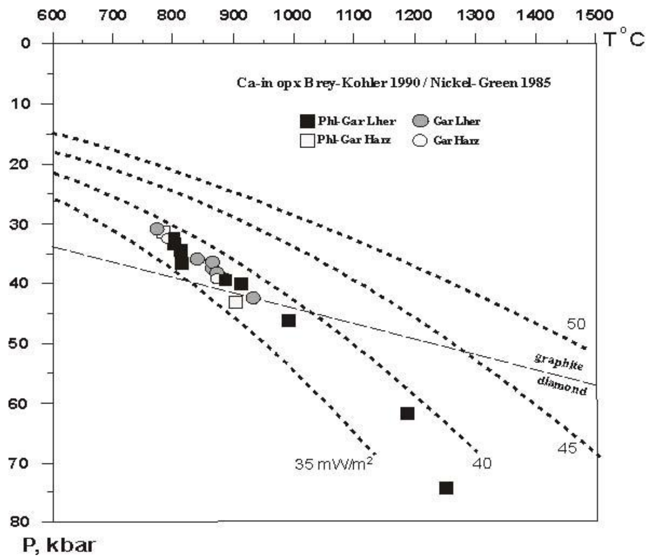

Fig.4. P-T estimates ($BKN_{Ca\text{-}in\text{-}opx}$+ NG85) for garnet peridotites of V. Grib kimberlite pipe.

minimal lower boundary of lithospheric mantle beneath V. Grib kimberlite pipe is 194-235 km.

The occurrence of phlogopite in many samples can be a result from the infiltration of fluid or melt into solid mantle rock.

Undoubtedly some of mantle peridotites from V.Grib kimberlite pipe were exposed to modal metasomatism. It can be considered as a reason for the difference in chemical composition of minerals from phlogopite-garnet peridotites and garnet peridotites. Based on P-T estimates for xenoliths, modal metasomatic processes operated through all sections of lithospheric mantle. It can indicate that metasomatic processes had a local manifestation in the upper mantle and possibly developed in the form of veins.

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