OROGENIC HIGH-PRESSURE PERIDOTITES OF KAN TERRANE - POSSIBLE SOURCE OF DIAMONDS FOR ALLUVIUM OF THE SOUTH PART OF THE SIBERIAN PLATFORM (RUSSIA)

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ABSTRACT High-pressure garnet lherzolites were found recently in the Igil massif of the Early Precambrian Kan terrane, Siberian platform basement. Peridotites reveal multistage evolution and had high-temperature spinel protolith (1040-1123, <20 kb). At the first stage of the evolution these rocks were moved isobarically to the garnet stability field (860°C – 20 kb). At the second stage garnet-spinel peridotite sank to a deeper and hotter mantle level (933-977°C – 25 kb). The main deformation accompanied the latest progressive metamorphism was in the garnet stability field. Garnet peridotites underwent regressive metamorphism and were exhumed afterwards. Stages of the evolution reflect definite plate-tectonic events, which were caused by continental collision and subduction. At the first stage mantle wedge spinel peridotites were thrust to the sinking cold continental block as a consequence of collision and subduction. These rocks sank together with continental crust to the deeper level of upper mantle. Next stages were connected with regressive metamorphic events during the exhumation of Kan terrane. Presence of HP garnet ultramafites suggest the Kan Precambrian block to be a source of diamonds and pyropes in the alluvium of the Siberian platform south part.

Keywords: garnet peridotite, orogenic peridotite, high-pressure metamorphism, geothermobarometry; high-pressure terrane.

INTRODUCTION High-pressure orogenic mantle ultramafites are common attribute of high-pressure – ultra-high pressure (HP-UHP) terranes. Such terranes have been described in Europe (Western Gneiss Region of Norway, Bohemian Massif of Czech Republic etc.) and China (Su-Lu and Dabie). These rocks are a key to understanding upper mantle composition and processes. They are of the keen and constant interest of petrologists not only due to their unclear origin, but also their possible diamond potential, which was identified after the discovery of graphite pseudomorphs replacing diamond in the Beni Bouchera Massif, Morocco (Slodkevich 1982, Dobrzhinetskaya *et al.* 1995). According to the latest research orogenic garnet-bearing peridotites might be exhumed from mantle depth of diamond stability field. Ultra-deep origin (>6Gpa) for Otroy peridotites (WGR) was assumed (Van Roermund *et al.* 2000). Occurrences of high-pressure ultramafites were recently found in the Kan Early Precambrian terrane, which is considered as a basement of the Siberian platform (Tsypukov & Kostrovitski 1999). Over an area of about 600 sq.km, a total number of 400 ultramafic bodies are present. Moreover the presence of diamonds and pyropes in alluvium of the southern Siberian platform has been known for decades. This fact suggests that the Kan HP orogenic peridotites are a possible source of the high-pressure minerals in the neighboring alluvium.

GEOLOGICAL SETTING The Kan terrane is supposed to be a collisional orogen (Tsypukov 2001). There are three main metamorphic units of different composition distinguished inside the area. Paragneisses after graywackles, metapelites and quartzites are dominant in the eastern part of terrane.

Metamorphosed leucocratic basalt-andesite-rhyodacite series and melanocratic picrite-basalt series prevail in the central and western part of terrane. Plutonic complexes composed of pyroxenite, anorthosite, and gabbro intrude these amphibolite-gneisses suites. All of the lithological and magmatic units have experienced multiple phases of intense deformation. Mineral assemblages are indicative of amphibolite and epidote-amphibolite facies metamorphism at moderate to elevated pressures. K/Ar and Rb/Sr ages clearly indicate a Late Archean age (2.8-2.7 Ga) for metavolcanic units and 3260 ± 50 Ma for the basement complex (Romanov & Gerasimov 1987). Various granitoids from the Kan terrane have reported Pb/Pb zircon and allanite ages of 1900 ± 65 , 1830 ± 25 and 1750 ± 340 Ma (Volobuev *et al.* 1980).

The Kan terrane is a province of high-pressure ultramafites of mantle origin. Usually these rocks occur concordant as boudins and lenses (0.5-20 m in thickness) in para- and ortho-metamorphic suites. Peridotites of small massifs usually comprise serpentinites after dunites, harzburgites and lherzolites. The latter contain spinel-cpx-chlorite intergrowths, pseudomorph after garnet. The largest of the ultramafic massifs is the Igil massif. This lenticular ultramafic body is 1.8 km long and 400 m wide. The observed layering and schistosity dip gently to the east and steeply to southwest respectively. The massif is mainly composed of spinel facies dunite, harzburgite and lherzolite. The lherzolite consists of olivine (50-70 vol. %), clinopyroxene (12-15 %), orthopyroxene (10-12 %), spinel (0-7%), garnet (0-20%), amphibole (<3%) and serpentine (0-10 %). Garnet peridotites are scarce and observed only in small exposures, a few meters in width. The serpentinization of ultramafics is extensively developed.

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The serpentine commonly inherits the ocellar-banded structure of the lherzolites. The rocks typically exhibit deformation and recrystallization structures. The porphyroclastic textures are especially typical of harzburgite and lherzolite. In garnet lherzolites of Igil massif the porphyroblasts and neoblasts of olivine and pyroxene, as well as the garnet porphyroblasts are incorporated into a fine-grained neoblastic groundmass of crushed and subsequently recrystallized olivine.

MINERAL CHEMISTRY The garnet lherzolites are characterized by an anomalously high proportion of chemically unequilibrated samples. They demonstrate variable mineral compositions and, hence, a wide range of calculated thermodynamic crystallization conditions. Six generations of cpx, four of opx and two of garnet were recognized in garnet lherzolites according to petrographical data. Different generations slightly differ chemically mostly in Al, Cr, Ca (pyroxenes) or Cr, Fe (garnets) as a consequence of forming conditions. The olivine is characterized by low Cr and Ca contents (<0.1 wt %) and a high NiO (0.4-0.5 wt %). Mg# varies from 88 to 95 (average 90.67), and is proportional to the Mg# of the host rock. Mg# in orthopyroxene (enstatite) varies within the same limits. The Al_2O_3 content of orthopyroxene ranges from 1.5 to 6.5 wt %, Cr_2O_3 0.1-0.7 wt %, CaO 0.15-1.8 wt %. The clinopyroxene (diopside) is close to Cr-diopside (0.4-1.3 wt % Cr_2O_3), its Fe index is 5.9-9.5%. The relative amount of the high-pressure jadeite component is rather high (4.9-12.5 mol %). The Al_2O_3 contents in cpx vary from 5.2 to 8.8 wt %, Na_2O 0.5-2.1 wt %. Both Cpx and Opx have a regressive diffusion zoning in the rim of grains. Sharp decreasing of Al, Na, Cr and increasing of Mg and Si could be seen in margins. Both pyroxenes have pyroxene or pyroxene-spinel exsolution lamellae.

The pyrope garnet contains up to 76 mol % of pyrope. The regressive diffusive zoning in garnet grains is expressed in the increase of Fe and Mn contents in the margins of grains. Simultaneously, the pyrope component is depleted to 63-67

mol %. Based on all parameters, except the low Cr_2O_3 content (0.1-1.5 wt %), the garnet compositions are consistent with equilibration with a lherzolite assemblage. Garnet has opx or opx-rutile, or opx-amph-rutile exsolution lamellae and isometric mineral inclusions of cpx and spn (Al_2O_3 49-53 wt %).

ROCK CHEMISTRY Orogenic peridotites and dunites have clear chemical evidence of formation from the mantle as residues after basalt melt removal. The degree of melting is calculated to vary from 7 to 17 % (Gornova *et al.* 2001). In comparison with primitive mantle (PM) these peridotites have lower contents of highly and moderately incompatible elements (Fig. 1). Lherzolites, the most fertile rocks observed in the terrane, demonstrate slight depletion of high incompatible elements (fig1), that could indicate a smaller degree of melting. Peridotites have high abundances of Al, Sr, Ba, Rb, which may be related to substantial amounts of phlogopite being introduced as a consequence of metasomatism or granitization.

GEOTHERMOBAROMETRY AND P-T PATH OF GARNET LHERZOLITES

There are few lines of mineralogical evidence constraining the major processes responsible for the formation and PT evolution of these rocks. The P-T estimates based on the geothermobarometry yield a substantial scatter due to the complex evolution of the rock, the lack of a common equilibrium mineral assemblage. The following geothermobarometers were used for the PT calculation: two-pyroxene and Ca-in-opx (Brey & Kohler 1990), garnet-clinopyroxene (Krogh 1988) geothermometers, garnet-orthopyroxene (McGregor 1974) geobarometer.

There are evidence of local equilibrium in these rocks, like exsolution lamellae and mineral inclusions. Spinel inclusions in garnet infer the spinel facies prograde. Opx porphyroclasts correspond to the early spinel stage and were formed in high-temperature (1040-1123°C) conditions because of high CaO

Figure 1 - PM normalized (after McDonough, Sun 1995) contents of major and minor elements in mantle orogenic peridotites of Kan terrane.

Table 1 - Stages of metamorphic evolution of garnet lherzolites of the Kan terrane.

	Stage	T (°C)	P (kb)
1	High-temperature spinel facies protolith	1040-1123	20
2	Isobaric Transition to the garnet stability field	857-877	20
3	Deformation stage	933-977	24-25
4	Regression stage I	863-818	24.2-17.5
5	Granulitic stage	722-781	14
6	Regression stage II	657	< 14

contents (up to 1.8 wt %). According to Al-in-opx geobarometer spinel facie pressure was about 20 kb (Table 1). The next imprinted stage, is an isobaric transition from spinel to garnet stability field because of T decrease. Garnet I ($\text{Cr}_2\text{O}_3 = 1.08$ wt %, $\text{FeO}_{\text{tot}} = 11.95$ wt %) has no zoning and was captured in to the cpx crystal as poikilocrystal and keep early garnet stage conditions of 857-877 °C. The big porphyroblastic garnet (garnet II) have more Cr and less Fe contents ($\text{Cr}_2\text{O}_3 = 1.56$ wt %, and $\text{FeO}_{\text{tot}} = 9.65$ wt %) that may point to the higher pressure of formation (23-25 kb), than the garnet I. Deformation was developed in lherzolites mostly in garnet stability field and were connected with peak pressure of 25 kb and $T = 933-977$ °C. Opx exsolution lamellae in garnet II shows drop of P from 25 to 17 kb and T down to 818 °C what reflect the exhumation of the terrane.

DISCUSSION AND CONCLUSION Modeling of the compositions of the Kan peridotites suggests that these originated as residues of melting of the Primitive Mantle. Two models were checked to explain their origin - fractional and incremental (0.1% increments) melting models. The latter displays better correlation with the real data. According to these data, the peridotites were formed as a result of 3-15% melting of PM not in garnet, but in spinel facies. The complementary melt would be of basaltic composition (E-MORB) and may correspond to the amphibolites of the north-east part of Kan terrain. In spinel facies, peridotites melt according the equation

This is observed in the Kan peridotites, where increasing MgO is accompanied by increasing Mg# in Ol and Cr# in spinel. Spinel compositions fall within the field of abyssal peridotites, which were formed under mid-ocean ridges.

The presence of mantle garnet lherzolites and spinel lherzolites and harzburgites in an amphibolite-gneiss complex

indicates that the Kan metamorphic block is a high-pressure terrane, which was subducted to a mantle depth of 100 km or more. Geological evidence shows such massifs to be the fragments of thin mantle lenses generated as a consequence of underthrusting. The high extent of alteration of the ultramafites indicates that they represent the mantle wedge above the subducted slab.

PT path of garnet lherzolites may be explained from the positions of plate tectonics. High-temperature spinel protholith in the form of lenses or plates was thrust to the cold subducted continental block and sank to the deeper levels of the mantle. During the peak metamorphism (25 kb, 933-977 °C) rocks were deformed and acquired sheared fabrics. The opx exsolution in garnet, garnet Fe-Mg retrograde diffusive zonation pattern and pyroxene and spinel exsolution structures in pyroxenes retained information on the reduction of pressure (25-13 kb) and temperature (980-670 °C) through this retrograde stage. There are differences in chemical composition of minerals of garnet lherzolite as well. Pyroxenes which were formed in garnet facies have more Cr and less Al contents, than minerals formed in spinel facies. Garnet of the earliest stages is more ferric and have less Cr, than the one, formed in high-pressure conditions. There is no evidence of HP-UHP metamorphism in the Kan terrane besides the presence of garnet peridotites. However, these provide every reason to believe that other high-pressure assemblages were present in the Kan terrane as well, but were obliterated by retrograde metamorphism. The presence of diamonds in alluvium in the southern part of the Siberian platform has been known for decades and the source of diamonds remains unclear. In this respect, the HP peridotites of Kan terrane could be considered as a potential source.

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