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EXSOLUTION TEXTURES IN MAJORITIC GARNETS FROM THE MIR KIMBERLITE PIPE (YAKUTIA, RUSSIA)

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INTRODUCTION

Majoritic garnets were originally discovered as inclusions in diamonds from the Monastery kimberlitic pipe (South Africa) (Moore, Gurney, 1985), and this find demonstrated that diamonds could contain the matter of asthenosphere and transition zone. Later such garnets were registered in diamonds (Stachel, 2001), mantle xenoliths (Haggerty, Sautter, 1990; Sautter et al., 1991), and rocks of metamorphic complexes (Van Roermund, Drury, 1998) worldwide including Yakutia, Canada, Brazil, China, and Himalaya. They are characterized by the high silicon concentration controlled by incorporation of majoritic component ($Mg_4Si_4O_{12}$) in the mineral structure being stable at a pressure of >5 GPa. With increasing pressure, mantle garnet becomes Al^{3+}-deficient and the content of Si increases gradually in the octahedral site (Akaogi and Akimoto, 1977). During decompression, majoritic garnet breaks down according to the reaction like: Majoritic garnet = garnet+ exsolved pyroxene (Dobrzhinetskaya et al, 2004). The conditions of primary crystallization of majoritic garnets may be reconstructed by calculation of the concentration of pyroxene lamellae and their composition.

We studied three garnet nodules (Samples 317, 559, and 563) with sizes of >5 mm containing numerous oriented lamellae of pyroxene and olivine from the Mir kimberlitic pipe. Parallel polished sections with a thickness of 0.5-0.8 mm were prepared from garnets, in which relationships between the minerals and their contents were estimated under the microscope in transmitted light. Five-axis universal stage was applied to establish orientations of lamellae and measure the angles between the lamella-rich planes. The phase compositions were analyzed on an electrom microscope Jeol JSM-6480LV equipped with an energy-dispersive microanalyzer INCA in the Laboratory of local methods of matter investigation (Geological Faculty, Moscow State University). We applied the method of X-ray tomography for precise measurement of the pyroxene and olivine contents in the garnet volume for the first time. This study was performed on a scanner Skyscan1172 (Geological Faculty, Moscow State University) at a voltage of 59 kV and a current of 167 μA. The obtained patterns of X-ray density were processed in the programs CT-An and CTvol to obtain 3D-images and quantitative estimations.

RESULTS AND DISCUSSION

The studied garnets from the Mir pipe have a pink color with orange hue and contain numerous needles of monoclinic pyroxene and olivine regularly distributed in garnet volume (Fig. 1). The thickness of needles ranges from 0.n to 100 μm, whereas their length varies from $4*10^{-3}$ to 0.5 cm. Acicular inclusions are strictly oriented in garnet by four directions (Fig. 2a). Angles between the pairs of crossing needles measured on a five-axis universal stage are 70-71^o, which corresponds to the angles between the three-fold axes in the cubic garnet structure. Needles are characterized by polygonal sections and sometimes flattened. Flattening of needles and tables is consistent with rhombododecahedral planes (the angle between closing tables is 60^o). Regular orientation of inclusionsand their typical shape allow us to conclude that these needles are the exsolution textures in majoritic garnet. The scheme of lamellae orientation in garnet crystals is illustrated by Fig. 2b. Sample 563 contains only pyroxene lamellae, whereas pyroxene and olivine are observed in Samples 317 and 559 with the strong prevalence of the first mineral.

Microprobe analyses of garnet, clinopyroxene, and olivine are given in Table 1. *Garnets* of all three samples are homogeneous and enriched in pyrope (75-80 mol %). They are characterized by the moderate concentrations of calcium (4.5-5.8 wt % CaO) and relatively low chromium concentrations (up to 0.59 wt % Cr_2O_3), which corresponds to garnet of the lherzolitic paragenesis (Garanin et al., 1991). The concentrations of Na_2O in garnets are very low (0.06–0.07 wt %). The composition of *clinopyroxenes* corresponds to diopside with small admixtures of hedenbergite and jadeite. Mg# in lamellae practically does not change within the individual sample ranging from 0.90 до 0.94. Pyroxenes are characterized by small admixtures of NiO (0.2-0.3 wt %) and Cr_2O_3 (0.11-0.16 wt %). The composition of *olivines* from Samples 317 and 559 corresponds to forsterite with Mg# of 0.95 in both samples. Olivines are characterized by extremely high nickel concentration (from 1.6 wt % (Sample 559) to 2.79 wt % (Sample 317) NiO). We should note that such high nickel concentrations in olivine were not reported before in any rock types.

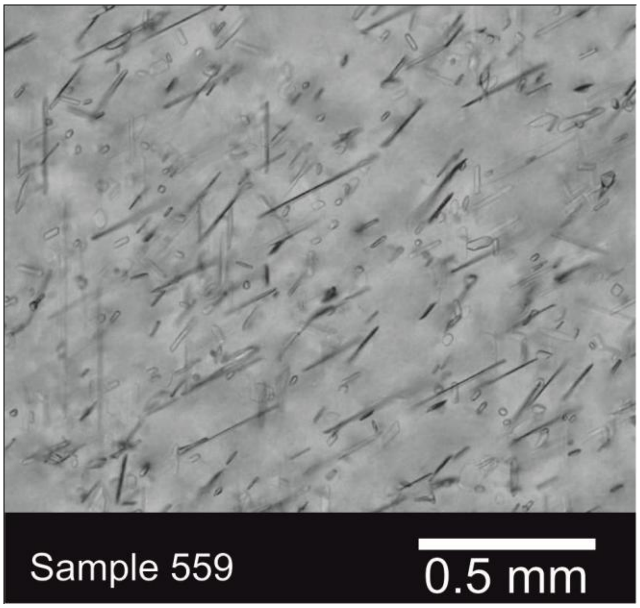

Fig. 1. Exsolution textures in majoritic garnet (Sample 559). Microphotograph is taken in transmitted light.

To reconstruct the primary composition of majoritic garnet, we performed the estimation of quantitative content of pyroxene and olivine inclusions in garnet volume using the CT-An software. We used the histogram reflecting the brightness in order to distinguish mineral intergrowths on a set of photographs of parallel sections of majoritic garnet. The detailed 3D analysis of Sample 317 allowed us to establish that garnet contained 9.5 vol % pyroxene and 0.5 vol % olivine. It is necessary to mention that the values obtained characterize the minimal volume concentrations of pyroxene and olivine due to the application of maximally "strict" regime of background removal, as well as impossibility of account for the smallest lamellae. The calculated primary compositions of garnet demonstrate that the concentrations of Si exceed 3 f.u. (Table 1). According to the diagram (Fig. 3), the formation of such garnets occurred at pressures of >7.5 GPa, and subsequently the decrease of pressure resulted in the formation of exsolution textures in them. As this took place, extremely high concentrations of nickel in olivine and nickel admixture in pyroxene provide evidence for the presence of nickel in primary majoritic garnet and high-temperature (~1500°C) crystallization of this mineral (Canil, 1999).

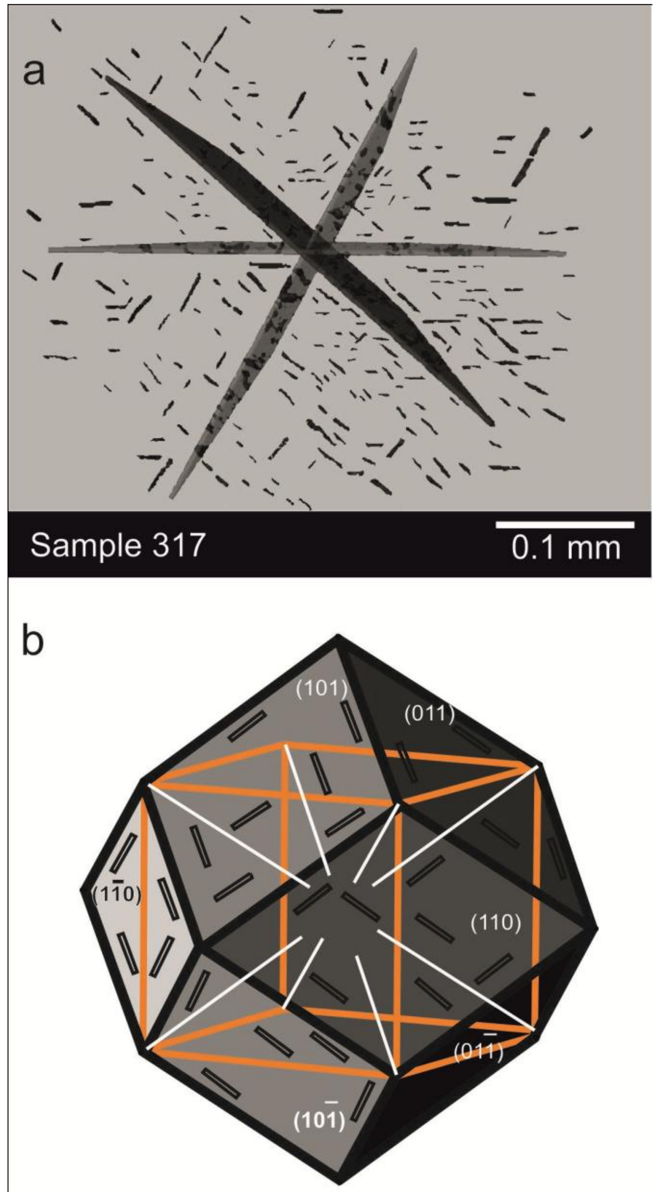

Fig.2. 3D images of pyroxene and olivine lamellae orientation from the Mir kimberlitic pipe. (a) 3D X-ray tomography image; (b) suggested scheme of lamellae orientation in garnet.

Table 1. Reconstructed compositions of majoritic garnet

	Grt*317	Grt*559	Grt*563
SiO_2	43.72	43.98	43.56
TiO_2	0.03	0.01	0.00
Al_2O_3	21.23	21.46	22.39
FeO	5.27	5.12	5.21
MnO	0.19	0.17	0.23
MgO	21.32	22.28	22.00
CaO	7.53	6.40	6.09
Na_2O	0.10	0.15	0.13
NiO	0.04	0.03	0.01
Cr_2O_3	0.55	0.41	0.38
Total	100.00	100.00	100.00
Si	3.084	3.088	3.054

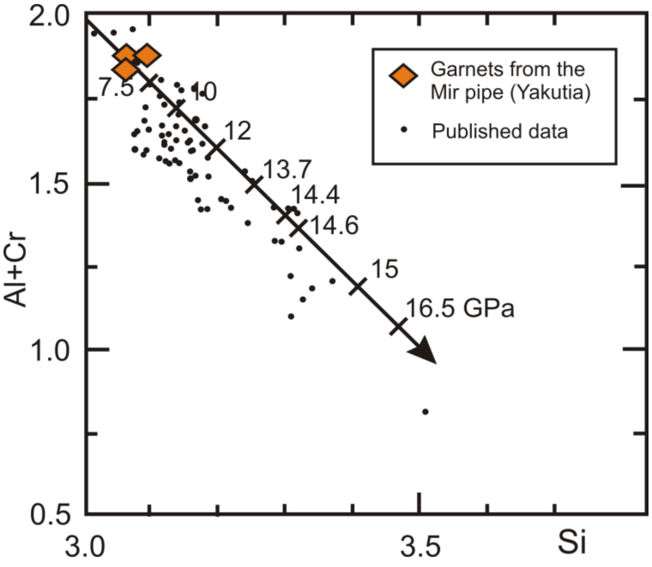

Fig.3. Compositions of majoritic garnets depending on pressures of their formation, after (Stachel, 2001). Pressure estimations are given after (Akaogi, Akimoto, 1977; Irifune, 1987).

CONCLUSIONS

(1) Megacrysts of majoritic garnets from the Mir kimberlitic pipe were initially formed at a pressure of ~7.5 GPa, which corresponds to depths of ~250 km.

(2) Subsequent decrease of PT-parameters to 3.0-3.1 GPa and 950-1000°C resulted in pyroxene and Ni-olivine exsolution in former majoritic garnet.

(3) Extremely high concentration of Ni in olivine indicated the presence of Ni in original majoritic garnet and the high-temperature crystallization of this mineral.

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