

Exsolution textures in majoritic garnets from the Mir kimberlitic pipe (Yakutia)

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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. In the course of rock uplift to the upper horizons of the Earth, pyroxene lamellae are often exsolved from majoritic garnet. 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 electromicroscope 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 μ A. The obtained patterns of X-ray density were processed in the programs CT-An and CTvol to obtain 3D-images and quantitative estimations.

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. The thickness of needles ranges from 0.1 to 100 μ m, whereas their length varies from $4 \cdot 10^{-3}$ to 0.5 cm. Acicular inclusions are strictly oriented in garnet by four directions (fig. 1). Angles between the pairs of crossing needles measured on a five-axis universal stage are 70–71°, 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°). Regular orientation of inclusions and their typical shape allow us to conclude that these needles are the exsolution textures in majoritic garnet. 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 to 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 are extremely rare.

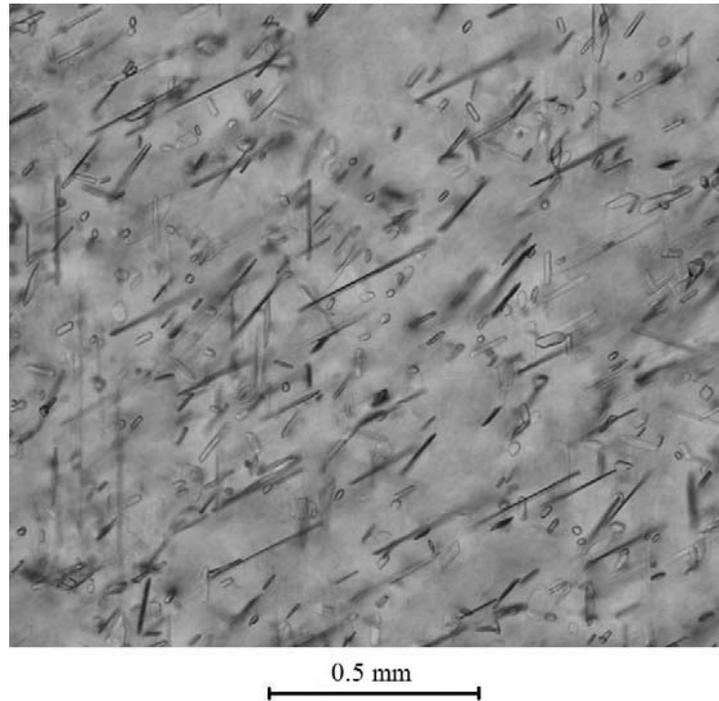


Fig. 1. Exsolution textures in majoritic garnet (Sample 559). Microphotograph is taken in transmitted light

Table 1. Composition of garnet nodules and intergrowths of pyroxene and olivine from the Mir kimberlitic pipe

	Sample 317				Sample 559				Sample 563		
	Grt	Cpx	Ol	Grt*	Grt	Cpx	Ol	Grt*	Grt	Cpx	Grt*
SiO ₂	42.23	54.64	41.40	42.53	42.29	54.32	40.85	42.58	42.66	54.68	43.15
TiO ₂	0.02	0.09	0.00	0.03	0.01	0.00	0.00	0.009	0.00	0.04	0.002
Al ₂ O ₃	23.30	1.01	0.12	22.29	23.35	1.80	0.18	22.37	23.61	1.87	22.74
FeO	5.68	1.07	4.42	5.47	5.48	1.09	4.54	5.27	5.45	1.09	5.27
MnO	0.21	0.00	0.00	0.20	0.18	0.00	0.00	0.17	0.24	0.03	0.23
MgO	21.34	17.90	51.20	21.12	22.33	17.26	51.57	22.04	22.21	17.20	22.01
CaO	5.72	24.51	0.05	6.44	4.55	23.35	0.00	5.28	4.96	23.46	5.70
Na ₂ O	0.06	0.47	0.00	0.08	0.06	0.93	0.00	0.09	0.07	1.01	0.11
K ₂ O	0.00	0.02	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NiO	0.00	0.29	2.79	0.013	0.00	0.21	1.64	0.01	0.00	0.20	0.008
Cr ₂ O ₃	0.59	0.11	0.00	0.57	0.43	0.16	0.00	0.42	0.39	0.15	0.38
Total	99.18	100.14	99.98	98.77	98.68	99.15	98.79	98.26	99.59	99.77	99.60
Si	2.993	1.978	1.001	3.018	2.997	1.979	0.996	3.022	2.998	1.980	3.037
Ti	0.001	0.002	0.000	0.001	0.0005	0.000	0.000	0.0005	0.000	0.001	0.000
Al	1.946	0.043	0.003	1.862	1.950	0.077	0.005	1.869	1.955	0.079	1.883
Fe	0.336	0.032	0.089	0.324	0.324	0.033	0.092	0.313	0.320	0.033	0.310
Mn	0.013	0.00	0.000	0.012	0.011	0.000	0.000	0.011	0.014	0.001	0.014
Mg	2.253	0.965	1.846	2.232	2.358	0.937	1.874	2.329	2.325	0.928	2.306
Ca	0.434	0.950	0.001	0.491	0.345	0.911	0.000	0.403	0.373	0.910	0.431
Na	0.008	0.033	0.000	0.011	0.009	0.066	0.000	0.014	0.009	0.071	0.015
K	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	0.000	0.004	0.054	0.001	0.000	0.003	0.032	0.001	0.000	0.003	0.000
Cr	0.034	0.003	0.000	0.032	0.024	0.005	0.000	0.024	0.022	0.004	0.021
Сумма	8.019	4.013	2.996	7.985	8.020	4.012	3.000	7.984	8.018	4.012	8.018

Note. Each analysis is the average of 8-10 analyses in different points. Grt, garnet; Cpx, clinopyroxene; Ol, olivine; Grt*, majoritic garnet, the composition of which is recalculated on the base ox X-ray tomography (95.5% Grt + 4% Cpx + 0.5% Ol).

To reconstruct the primary composition of majoritic garnet, we performed the estimation of quantitative content of pyroxene and olivine 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. 2), 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].

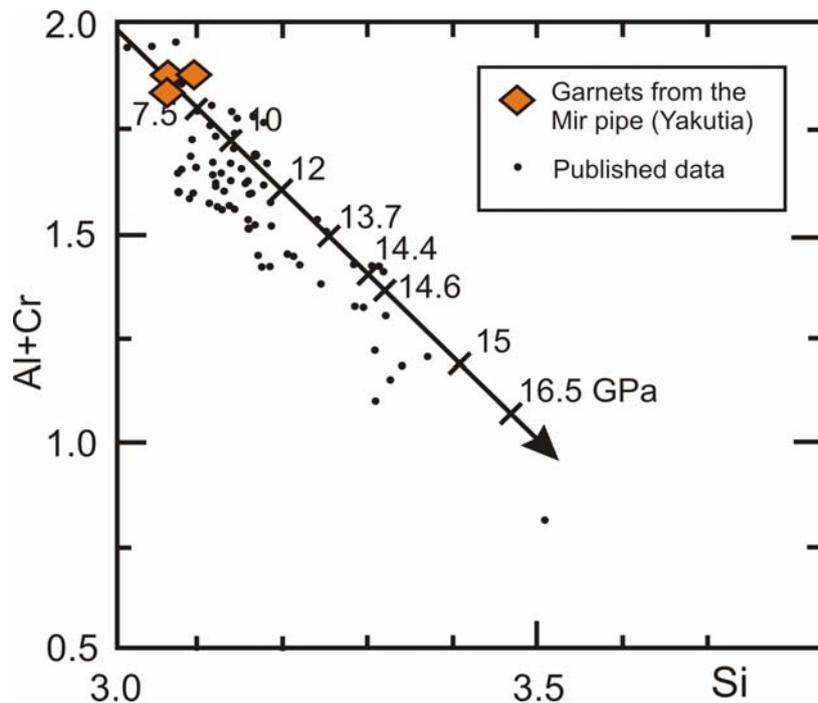


Fig. 2. Compositions of majoritic garnets depending on pressures of their formation, after [Stachel, 2001]

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