Polychrome olivines in coarse grained lherzolites from the Udachnaya pipe - possible fine indicators of reduced metasomatism

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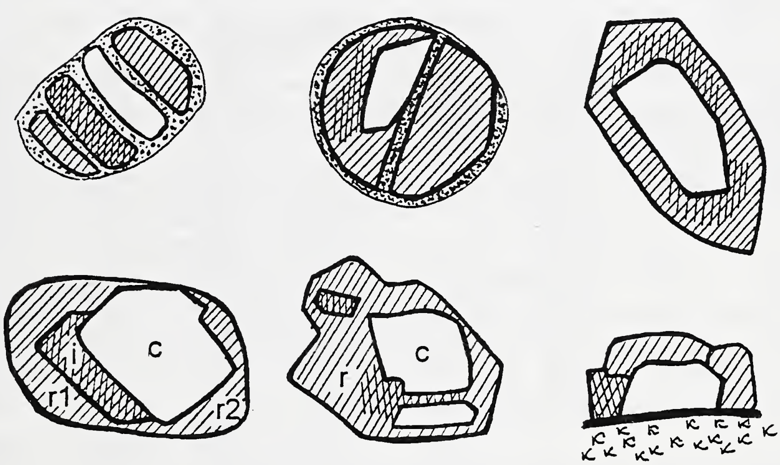
The phenomena of polychrome character of olivine in deep-seated xenoliths of grained peridotites has not been described. It is more likely due to olivine serpentinization, shading this effect. The polychrome olivines are found in approximately 20-25% of xenoliths of grained spinel, spinel-garnet and garnet lherzolites from the Udachnaya pipe. Olivines show the zonation of the following type: central grain parts, having a shape of one or two-three regular blocks, are coloured pale orange, brownish-yellow, while the marginal parts are light green, colourless (Fig.1). The transitional yellow-green blocks are observed between these zones. The change of one colour into another is evident and frequently goes along the boundary of blocks. The ratio of different colour olivines in different xenoliths widely vary - from the predominant orange olivine (~ 90%) with narrow green zones (~ 10-15%) to the rocks with uniformly coloured light green or colorless olivine.



a b c

Fig. 1. Zone and block character of polychrome olivine in common granular lherzolites from Udachnaya pipe. White – pale orange, brownish-yellow, cross-hatching – yellow-green, green, hatching – pale green, colourless olivine. In upper left part it showed the serpentinization of olivine on block boundaris (points). a – sample 345/87 (spinel lherzolite): c, i, r1, r2 – points of microanalyses in table 1. b - sample 325/87 (garnet lherzolite): c and r - points of microanalyses in

table 1. c – kimberlite (k) contact cut different coloured blocks of olivine grain. Size of grains is 2 – 5 mm. The sketchs from samples.

Table 1.Mineral compositions in xenoliths with polychrome olivine

Sample	345/87 – Spinel lherzolite								
Oxide wt%	Ol_c	Ol_i	Ol_{r1}	Ol_{r2}	Opx_1	Opx_c	Opx_r	Cpx	Sp
SiO_2	41.1	40.8	40.8	40.9	55.4	57.0	57.1	54.4	0.03
TiO_2	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.03	<0.003
Al_2O_3	<0.003	<0.003	<0.003	<0.003	3.00	2.63	2.14	3.66	40.4
Cr_2O_3	<0.003	<0.003	0.01	<0.003	0.48	0.40	0.28	1.18	28.6
Fe_2O_3									1.59
FeO	7.25	7.53	7.45	7.35	5.14	4.90	4.95	1.51	11.7
MnO	0.08	0.07	0.08	0.07	0.07	0.10	0.13	0.05	0.40
MgO	51.3	51.4	51.3	51.4	35.2	34.9	35.0	15.7	17.0
CaO	0.02	0.03	0.01	0.02	0.52	0.41	0.30	22.3	n.a.
Na_2O	n.a.	n.a.	n.a.	n.a.	n.a.	0.01	0.02	1.14	n.a.
K_2O	n.a.	n.a.	n.a.	n.a.	n.a.	<0.003	<0.003	<0.003	n.a.
CoO	<0.003	<0.003	0.02	0.05	<0.003	<0.003	<0.003	0.01	0.05
NiO	0.41	0.35	0.34	0.40	0.07	0.02	0.02	0.04	0.13
Total	100.16	100.18	100.01	100.19	99.88	100.37	99.94	100.02	99.90
mg	93	92	92	93	92	93	92	95	72

Table 1 (continued)

Oxide	325/87 – Garnet lherzolite								
wt%	Ol_c	Ol_r	Gnt_{1c}	Gnt_{1r}	Gnt_{2c}	Gnt_{2r}	Opx_c	Opx_r	Cpx
SiO_2	40.5	40.7	41.4	41.6	42.0	41.6	56.7	57.1	53.7
TiO_2	<0.003	<0.003	<0.003	<0.003	0.01	<0.003	<0.003	<0.003	0.003
Al_2O_3	<0.003	<0.003	21.1	21.3	21.5	20.9	1.43	1.06	2.58
Cr_2O_3	<0.003	<0.003	3.90	3.63	3.30	3.78	0.51	0.26	1.52
Fe_2O_3			0.03		0.14	0.32	1.40	0.65	2.53
FeO	7.65	7.60	8.33	8.00	7.23	7.80	3.58	4.35	
MnO	0.03	0.03	0.45	0.42	0.34	0.40	0.05	0.10	0.02
MgO	51.2	51.1	19.4	19.7	20.0	19.5	35.4	36.0	16.1
CaO	0.03	0.05	5.56	5.40	5.46	5.55	0.44	0.24	21.2
Na_2O	n.a.	n.a.	0.01	<0.003	0.02	0.01	0.10	0.05	1.80
K_2O	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	<0.003	<0.003	0.02
CoO	<0.003	0.03	<0.003	<0.003	0.01	0.01	<0.003	<0.003	0.003
NiO	0.40	0.37	<0.003	<0.003	<0.003	<0.003	0.05	0.02	0.003
Total	99.81	99.88	100.18	100.05	100.01	99.87	99.66	99.83	99.47
Mg	92	92	81	81	83	82	95	96	

Notes. c – centre of grain, r – rime of grain. Fe_2O_3 calculated from stochiometry. n.a. – not analysed. Analyses were obtained using standard electron microprobe techniques with a CAMEBAX – MICRO microprobe.

Table 2. The values of $Fe^{3+}/\sum Fe$ from Mössbauer data for olivines

Sample	345/87 – Sp lherzolite	325/87 – Gnt lherzolite	343/87G l	545/80 G l	34/83SpG

Ol colour	c - orange	r – green	c – orange	r – green	c – brown	c – orange	t - green
$Fe^{+3}/\sum Fe$	0.025	0.019	0.020	0.008	0.025	0.034	0.008

Notes. c–centres of grains, r–rimes of grains, t–total grains. G l and SpG l– Gnt and Sp-Gnt lherzolites.

The distribution of polychrome olivines in xenoliths does not show any dependence on the distance to the boundary with the kimberlite. Sometimes, olivine blocks of different color are cut by this boundary (Fig.1c). An evident correlation between polychrome character of olivines and intensity of mineral serpentinization as well as occurrence of late metasomatism products in xenoliths (complex kelyphitic rims on the garnet and micro-grained fringes of needle amphibole, Al- clinopyroxene, Al-spinel, Cr-magnetite on pyroxenes) is not available.

Table 1 gives the composition of minerals from two xenoliths with polychrome olivine. Spinel lherzolite 345/87 (~ 3% Sp, 5-7% Cpx, ~ 30% Opx, ~ 60% Ol) contains nearly 30-35% of pale orange olivine (central grain parts), 40-50% of yellow-green olivine (transitional zones) and 10-15% of light green olivine (grain margins). In composition the central block of the analyzed grain (Fig. 1a, Ol_c- table 1) is homogenous. Insignificant increase of FeO and decrease of NiO are observed in the transitional and marginal zones (Ol_i and Ol_{r1}). The marginal light green zone Ol_{r2} is compositionally similar to the orange olivine of the central block Ol_c. Different orthopyroxene grains (Opx_1 and Opx_c) are various in terms of Al, Cr, Fe, Ca and Ni oxide compositions. There is a significant decrease of Al, Cr, Ca oxide contents in the marginal zone of the grain (Opx_r) as compared to the central (Opx_c) part. Clinopyroxene and spinel have not been studied for the chemical heterogeneity.

Garnet lherzolite 325/87 (5-7% Gnt, 5-7% Cpx, 3-5% Opx, 80-85% Ol) contains 35-40% of pale orange olivine of central blocks, wide marginal zones are represented by green, light green variety. Both colour olivine types, analyzed in one grain, are similar by composition (Fig.1b, Ol_c and Ol_r - table 1). An opposite zonation type by Cr, Fe, Ca oxide contents are found in two garnet grains from the centre to the margins. The concentrations of Al, Cr, Ca, Fe^{3+} oxides decrease in the marginal part of orthopyroxene grain. Different clinopyroxene grains show different concentrations of Al, Cr, Fe oxides.

The heterogeneity and zonation of mineral composition in lherzolites with the polychrome olivine indicate the metosamatic transformation of rocks . At the same time the absence or weak change of main oxide contents in different colour olivine zones suggest that polychrome character of olivine is not related to the change of its chemical composition.

The Mössbauer spectroscopy investigations were done to reveal a possible influence of iron oxidation on the olivine colour. Olivines of different colour were selected by hand under the binocular from < 0.25 and < 0.5 mm fractions. The survey was done on gas-resonance spectrometer (AI-4096-3M) with a multi-channel device under a room temperature. The source was ^{57}Co in chrome matrix with the activity in 23 Ci.

The results of these investigations suggest that orange, yellow olivines from the central grain blocks have higher Fe^{+3} concentrations as opposed to green and colorless olivines from the marginal zones and from separate samples (Table 2). It may be believed that green and colorless marginal zones in polychrome olivines resulted from the influence of the reduced fluids. The pattern of block zonation in mineral indicates that this process took place after the superimposed deformations. The latter dismembered the olivine grains into regular crystallographic domens, blocks. The boundaries between them prevented the fluid diffusion. It is likely that polychrome olivines are fine indicators of metasomatism of a reduced type, which occurred on the early stage of kimberlite-forming tectonic-magmatic cycle and is possibly associated with diamond formation [Solovjeva et.al. 1997].

1. Solovjeva L.V., Egorov K.N., Markova M.E.et al. // Mantle metasomatism and melting in deep-seated xenoliths from the Udachnaya pipe and their possible relationship with diamond and kimberlite formation // Russian Geology and Geophisics.– 1997.–V. 38, 1.